MODALITY SHIFT IN DESIGN PROCESS:

UNDERSTANDING THE RATIONALE BEHIND MODALITY SHIFT AND ITS EFFECT ON ARCHITECTURAL DESIGN

A Dissertation

Presented to

the Faculty of the Graduate School

at the University of Missouri

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

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by

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MAY 2015

The undersigned, appointed by the dean of the Graduate School,

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MODALITY SHIFT IN DESIGN PROCESS:
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Presented by AKM Zahidul Islam

A candidate for the degree of Doctor of Philosophy

And hereby certify that, in their opinion, it is worthy of acceptance.

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ACKNOWLEDGEMENTS

First of all, I would like to thank Dr. Benyamin Schwarz and Dr. Newton D'Souza for their guidance and patience along the way. I was very fortunate to have them as advisors: they made this a valuable and enjoyable learning experience. I sincerely appreciate both of my mentors moral support and advice.

I also want to thank the members of my dissertation committee, Dr. Ruth Brent Tofle for her endless help and support and Dr. Deanna Sharpe for taking time to read the manuscript and for being willing to join the committee at the end.

I gratefully acknowledge the support of my colleagues in the Department of Architectural Studies and my family and friends. Their encouragement and understanding meant so much to me.

And last but not least, I want to thank two of the most important person in my life- my wife, Shahnaz Talukder and my son Abrar Zahid for their continuous encouragement without which perhaps it would never be possible.

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ABSTRACT

Architectural design is a deliberate act of creativity without any definite starting point which is often described as a nonlinear, multimodal approach of problem solving. Critical analysis of any design process reveals its basic stages, as ideation, evaluation, development, communication and production. It is obvious that these stages are not necessarily linear but can be examined as such. Designers use a number of design and drafting tools as well as their media (modality) to perform these processes. Designer's focus of attention shifts between different aspects of design problem during the design process. In search of effective solution designers often tends to switch between modalities which is the method of communicating design ideas. This study considered three types of design modalities as manual, digital and mixed where a combination of various traditional and computer mediated design and drafting tools were used by design students to research, develop and communicate optimal design solutions.

The purpose of this study is to understand- how design students rationalize their selection of modalities and factors causing modality shifts during design process as well as the impact of these shifts on design outcome.

This study, first of all- examined different form of externalization of design ideas; second, identified any deviation from initial design ideas during development and evaluation phase that occurred due to modality shift; third, it analyzed final design outcome by comparing with initial ideas and its follow through on the basis of their

visualization and representation, and finally looked into correlations between the modality shift and design outcome.

Observation and analysis of several design studios revealed the fact that students tend to shift between modalities not necessarily for facilitating problem solving only. Individual style, studio instructions, project requirements, context, culture, competency, ambiguity and cognitive aspects also play a significant role. It was also evident that the amplitude of shift has a positive correlation with designers' experience and accordingly impact final design outcome.

The result of this study would help us to identify reasons and effects of modality shift in design process thus benefit design pedagogy and practice. By identifying and developing effective design method and process through meaningful incorporation of traditional and technologically advanced design and drafting tools and its media students of the digital age would benefit and enhance their design perception and decision-making.

CHAPTER ONE: INTRODUCTION

1.1 Background

Architectural design is a deliberate act of creativity without any definite starting point which is often described as a highly subjective, nonlinear, multimodal approach of problem-solving. Many cognitive psychologists defined design as a problem solving activity that produces artifacts and solutions to satisfy specific functions and requirements. This act of design requires various modes of ideation, internalization and externalization of thoughts both in abstract and concrete manner. But often the distance between the imagination of a design and its representation, communication and realization appears as an obstacle. Designers use a wide range of tools to bridge this gap (Pérez-Gómez*, et al.*, 2000).

Communicating design ideas in form of externalization is considered as 'reflective conversation' with the design problem that happens through creation or modification of external representation. Design professionals and students use a wide range of media and tools for informal, construction, presentation and other types of drawings and documents. These vivid lists of externalizing media are more often than not used to engage in a dialogue with the design problem.

Externalization is an essential part of this complex process (design activity) that establishes the foundation for reasoning, exploring, criticizing, manipulating design ideas with designer him/ herself as well as communicating with others. Designers use more

than one type of tool to express his/ her thoughts depending on the nature and complexity of the project or experience and competency of the designers. Influenced by numerous factors, this process may follow established proceedings and traditions or a designer may choose to explore freely without considering any unorthodox convention. In all instances, the medium in which the exploration takes place will affect the act of designing to some degree (Pérez-Gómez et al., 2000).

When different tools regardless of their manual, digital or combined classification are used as a tool set to achieve desired expression of designer's thought- can be considered as a design modality. Designers use variety of modalities to bridge the gap that exists between the imagination and its representation, communication and realization (Pérez-Gómez et al., 2000). Design modalities, used for communicating perceived design ideas can affect the externalization process (H. Casakin & Kreitler, 2005), therefore it may also influence final design outcome.

Two types of tool sets are widely used and analyzed by designers and researchers in general, namely- a) traditional, conventional or manual and b) CAD, CAAD, CG drawings or digital. A meaningful design representation often uses more than one of these tool sets at the same time. In this study it was observed that various combinations of digital, manual modalities are being used to develop design representations by the architectural studies students at a mid-western university. It is natural in design that different stages of design necessitate different design representation (Do, 1995; Herbert, 1993) and due to various constraints designers select, shift, and combine one or more drawings tools. These constraints simply can be the limitation of designer's knowledge,

accessibility of instruments, nature of design or a combination of some cognitive features that can motivate designers to select a modality over another one for proper externalization of their concepts and proposed solutions. In other word, designers' continuous effort to involve reasoning with problem solving activities is one of the primary reasons of shifting modalities. Drawings act as a vehicle for not only design reasoning but also decision making, expressing ideas, verifying and evaluating proposals as well as taking action.

Due to the nature of complexity the act of design is considered greatly complex which can be influenced by numerous factors. Designers often follow rules or established proceedings and traditions however, they also explore spontaneously without following any conventions. In both cases, the modality with which the exploration takes place tends to influence the act of designing to some degree (Pérez-Gómez et al., 2000). Due to this reason Davidson &Campbell (1996) argued that the distinctive nature of different modalities allow designers to be creative by using of the properties of some that other tools do not offer.

1.2 Statement of the Problem

Most of the studies in design research and cognition are comparatively isolated projects that tried to experiment methods and explore the design universe. Some other researches took a special focus on various aspects of the design process. In design thinking, research conducted on diversified context. For instance- internal and external

representation (Omer Akin, 1978), design development (Cuomo, 1988; Darke, 1979; McDermott, 1982), knowledgebase of design thinking (Omer Akin, 1986b), generating design problems (Omer Akin, *et al.*, 1992), design pedagogy (Donald A Schön, 1985), design process (Chan, 1990; Eckersley, 1988), analyzing design activity(Nigel Cross, *et al.*, 1996), design protocol & mental operations (Bryan Lawson, 2004), design events (M Suwa, *et al.*, 1998), design ideas (Goel, 1995), drawing conversation (Donald A Schön, 1985); however, a little research had been done to investigate the use of drawing in the graphic design process.

Thus, this research aims to understand the causes and effects of switching modalities or design and drawings tools and their media during design process. To get an in depth and with a holistic view two design studio was observed. A detailed analysis and review of literature is conducted in this study with focus on identifying and reinterpreting the relation between different design drawings, creation media, and reasoning behind adopting and switching one or more of these modalities.

1.3 Purpose and Objective of the Study

The purpose of this research was to discover why designers use and switch between different design modalities during various stages of design process and whether any of these phenomena affect their final design Process. The specific aim of this study were 1) to analyze design process to acquire in depth understanding on selection of specific design modality or another 2) to identify the triggering factors or causes that

leads designers to switch modalities, 3) to establish a rational behind this modality shift based on cognitive, context and constraints matrix and finally, 4) to measure the degrees of deviation between final design outcome and initial concept.

1.4 Questions to be answered

Designers use a wide variety of media to express his or her ideas. Throughout the course of a project, different representations are used at different times to explore different issues (Lawson, 1994, p. 90). The differences between manual and digital modalities as well as their cognitive involvement in designers' mind are significant and undeniable. There is a lack of information about consequences of changing modalities during early design phases; therefore, this study focuses on identifying reasons behind changing/ switching design tools and media as well as whether this shift plays any significant role on final design outcome.

The main questions are:

- What are the critical reasoning behind modality shift?
- What are the factors that force or encourage designers to switch between modalities?
- How does it affect design process and its outcome (compare to initial design ideas)?

1.5 Significance of the Study

The objective of this study is to identify reasons of modality shift and its effect on design. By understanding how designers engage, communicate and develop ideas using various design modalities and their constraints this study would be able to identify reasoning behind switching between design modalities. By examining how the exploration of volume, void, space, shape and form in '*gestalt'* (Arnheim, 1969) can be enriched by using various design tools, the influences of modalities on the design process can be unveiled.

This understanding will help to realize how switching design tools can empower designers to bridge the gap between imagination and reinterpretation of architectural design and how adopting and experimenting a new tool allows designers to explore and express their ideas and creativity in a way that benefits the resulting design.

1.6 Limitations

Architectural design is influenced by numerous factors. It is difficult to isolate all discrete sources to determine a direct 'chain of cause-and-effect'. Designers made significant formal decisions in the initial stage of design. These decisions include but not limited to massing and form, volume, space, circulation, orientation and their relationships etc.

In order to limit and focus the scope of this research, investigation was narrowed down to two design studios. Since the design process is not linear and not limited to a particular method, this study is subjected to interpreting the outcomes relating to the design methods and modalities students have employed in those studio courses. Besides the type of projects, diversity among students with various levels of expertise and didactic method has significant influence on the overall result.

A further development with various designs projects conducted by all level of design students without restricting modalities may result in diverse outcomes to the findings of the different design stages.

The results of this research depend profoundly on the available technologies, the computing equipment and applications, designers' knowledge and competency over multiple design modalities, instruction method and final evaluation criteria. Furthermore, studio students and their background, individual skills, methods and understandings of architectural design inevitably influence the outcome of this study, especially in the context of a creative design process and strength of perceiving design attributes. Yet, this thesis tries to establish general trends and connections within the specified framework of a qualitative research that allow an interpretation independent of influencing factors causing modality shift during design.

1.7 Theoretical Framework

Explanatory sequential design approach was used as overall procedure with an emphasis on grounded theory as a theoretical framework for this study. Because of the lack of previous research regarding theories and effects of modality interaction and its effect on design an explanation or identification of rational is required to understand the underlying relationship between modality shift and its corresponding effects on design process and outcome.

In the realm of architectural design modality theory is relatively new. Available investigation on this field mostly addressed attributes related to computational user interfaces, its design for web based programs and various aspects related to human computer interaction (HCI) for graphic and other software packages. Here a complex mix of spatial and abstract information is entered by the users when operating a graphic design application (Andre, 2004). By investigating theories on general problem of mapping task domain information into interactive multimodal interfaces (Bernsen, 1993) in this field with intent to relate those with architectural design paradigm, a new theory was expected to emerge related to modality shift. When a particular set of information (design problem) is given that need to be exchanged between its user (designer) and system (manual or digital) for constructing a solution, modality shift is often appears inevitable. Based on Bernsen's (1993) understanding of modality theory where explicit emphasis is given on task performance in context requiring identification of input/ output modalities offering optimal representational solution and exchange of information is considered as theoretical framework in this study.

With proper understanding of modality theory and rational behind its shift during design, useful support to contemporary designers can be provided. By taking the study drawings (in multimodal and unimodal form) as an instrument, designer's (student) thoughts can be analyzed while keeping focus on each shift between modalities. Some external variables as the nature of the project (exhibition space/ designer product display) and studio instructions may have explicit effect on the overall design solution and quality of the project.

The main purpose of using the sequential explanatory study is to use quantitative results to develop qualitative study and then to use qualitative data to explain, interpret and validate the findings. In a mixed methods approach, the researchers build the knowledge on pragmatic grounds (Creswell, 2003; Maxcy, 2003). Gathering and stating truth is something "what works" (Howe, 1988) where approaches, variables and units of analysis are selected based on what appears to be most appropriate for finding an answer to the research question (Tashakkori & Teddlie, 1998).

By identifying themes and patterns (Bloomberg & Volpe, 2012), data in qualitative research is analyzed through "an intensive, open-ended, and iterative processes that simultaneously involves data collection, coding (data analysis), and memo-writing (theory building)" (Groat & Wang, 2002, p. 181). A mixed method with qualitative emphasis was implemented where grounded theory method was used throughout the majority of the process. According to Creswell (2009, p. 14) – when conducting grounding theory researcher "attempts to derive a general, abstract theory of a process, action, or interaction grounded in the views of participants in a study".

For inductively develop a theory embedded within the activities in context (design studio) instead of protocol analysis, I observed and collect data in the field as it happened without any interference and motivation. Figure 1 shows the theoretical framework if this study.

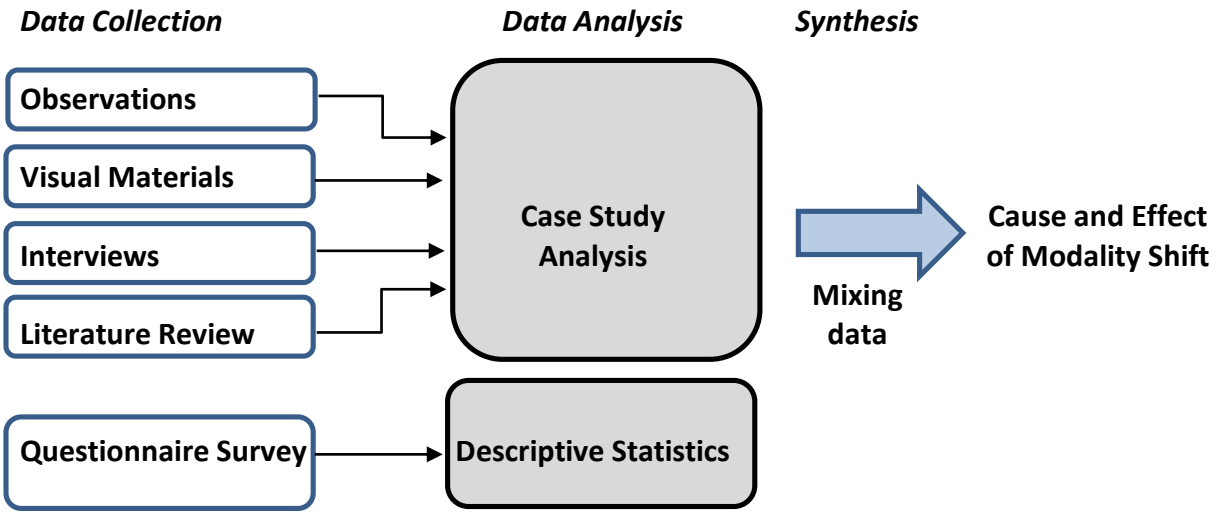

Figure 1: Theoretical framework of the research.

1.8 Organization of the Study

This first chapter has given a general background about the design process, modalities and importance of this study. The second chapter involves a literature review regarding design, design process, tools, media, drawings, design perception, constraints and theories currently known regarding act of designing, design drawings, designers' knowledge, and analysis of design activities. A detailed explanation of the research methodology is found in the third chapter. Within the framework of qualitative study, participant observation and protocol analysis methodologies are applied to the research

and to data analysis. Chapter Four details the findings. Finally, Chapter Five and six provides discussion about the findings and revealed new insights and concluding remarks.

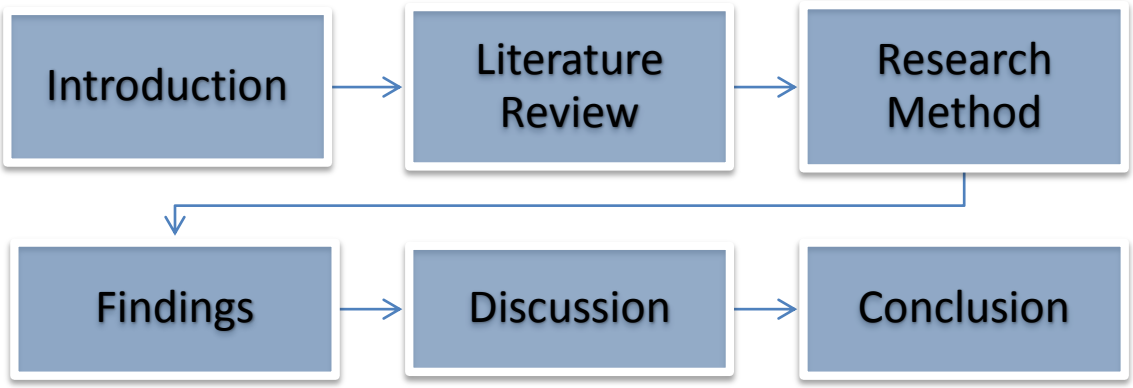

Figure 2: Overview of the dissertation

1.9 Definition of Terms

Design, design process, drawings tools and types, traditional and computational design modalities, design cognition and representation, externalization and design communication, various theories and its practice in design; conceptualization, abstraction and transformation of design ideas are among many relevant issues discussed in this study.

The definition of terms used in this thesis set out a preliminary map of literature review, experience and influences. Most of these terms are regularly addressed through available literature, however sometimes they are arguably quite ambiguous. Such as the term ‘digital tool’ and ‘digital media’ are often considered synonymous while at the same

time these two terms can suggest different methods or attributes in use as argued by Glanville(1992) and Fischer (2011). Only through a thorough review of terms a significant contribution to the clarification can be achieved. This chapter also indicates a history and some results of the different aspects of my evaluation.

Architecture:

Architecture refers to the practice of designing and constructing buildings. The term can also refer to the style that of a building's design and construction ("Oxford Dictionary," 2001). Architecture embraces two distinguished but not separated aspects - aesthetics and utilitarian or functional. the relative weight of either aspect can vary from project to project and firm to firm ("Encyclopaedia Britannica," 2002).

Architectural Design

Discussed in greater detail later in this study, an architectural design according to "Oxford Dictionary" 2001) is the actions involved in generating the form of a building and producing drawings and diagrams that demonstrates the appearance and functionality of the building before it is constructed. It also refers to the actual construction and architectural drawings produced following various rules of mathematical, geometric and drawing conventions ("Oxford Dictionary," 2001).

Architectural Designer

As stated in Oxford dictionary (2001) architectural designer is the person who performs the architectural design.

Conceptual stage and design ideation

The activity of architectural concept stage involves forming abstract ideas to seek solutions for design problems in hand ("Oxford Dictionary," 2001). This is the earliest phase when the design of a building is conceived in some abstract form. It is particularly important since various creative aspects of design start brewing in designers mind. Sketch, note and diagrams are among some of the internalization and externalization medium that designers use to converse with the ambiguous concept.

Concept

The term concept is difficult to define. Researchers in design education, cognitive psychology, professionals in practice perceived it in different ways. However, one aspect of concept is unanimously agreed on fact that it is an 'abstract idea'. Concept is defined in philosophy as an idea or mental picture of a group or class of objects formed by combining their aspects. Concept and idea are closely related.

CAAD

CAAD stands for Computer Aided Architectural Drafting. It refers to computer-based applications used for drafting, visualizing and testing various aspects of design process. CAAD is more focused on digital applications available for architectural design,

as opposed to CAD, which defines Computer Aided Drafting available for other industries such as engineering and manufacturing. CAAD used in architectural designing started by following the same steps a conventional tasks and skills would perform. Due to the advancement of computational industry CAAD has grown from a marginal movement used by a 'few academics to a multi-billion dollar international industry' (Maver, 1995). Digital tools are widely used to facilitate the 'solve the discrete mathematical or data manipulation problems'(Kvan, 2000).

Conventional Media

Conventional media refers to the design medium being used in architectural practices and education form the beginning of its formulation as a structural and methodical mean of practicing, learning and communicating the knowledge of architecture. This includes but not limited to drawing, physical modeling, photography, crafts, drafting, typology and page layout. Arguably, some digital media can be included in this category as it has become typical to architectural design, for instance computer aided architectural drafting (CAAD). CAAD has already been employed by the majority of architectural firms to develop and document design. It is now safe to say that various former generation digital media are well adopted in the curriculum of almost all of the design institution around the world. Media used in design can be considered as a living element like language that adopt new items and drop some over the period of time. Once considered as a cutting edge, superior media in design industry and education, CAAD has become such an obvious and primary tool that it safely falls in the category of conventional design media in present era. Most firms were generally using CAAD for

plans, elevations, sections in media such as AutoCAD™, computer rendering and simulation for three dimensional spaces using programs such as 3D Studio Max™, Form-Z™ and Maya™, computer animation and finally multimedia presentations using Adobe Premiere™, After Effects and similar applications.

It is noteworthy to mention one of the most important arguments over the use of this digital media as the typical view of architectural practices was that these digital media were 'good for design presentation but not for design'(Y.-T. Liu, 2004).

Design

Design is a multifaceted comprehensive term. Bryan Lawson (2005) saw it as a term used in everyday conversation that holds different meanings by particular groups. More often than not refers an end product and a process(Bryan Lawson, 2004, 2005). As per Oxford Dictionary (2001)- design defines a plan or drawing produced as well as the action involved in making the plan or drawing. It is a highly complex activity that requires sophisticated skills (Bryan Lawson, 2005) and is subjective in nature. It will be discussed in greater detail further in literature review.

Design Practice

Design practice is considered idiosyncratic depending on the way that a designer thinks and performs designs. Generally it refers to the action of undertaking design.

Digital Media

‘Digital’ is a theme or a concept when implied with media it acts as a collective noun that covers a group of medium (Oxford Dictionary, 2001) developed within digital platform. Media is the plural form of Latin word medium, means- by which ‘something’ is communicated or achieved. This thesis refers the term ‘digital media’ as a collection of digital software and hardware that designers use in practice and education. Designers usually engage more than one type of digital media during their design process. Media is considered as an ‘extension’ of some human faculty, physical or psychic can creatively alter the way we think and perceive the world (Mitchell, 1977).

Digital media can be used to reach beyond the conventional methods of design communication and development. For instance, architectural practices explored new perspectives, opportunities, liberation of form and space, parametric modeling intelligence, and unorthodox mean of physical and virtual collaboration. According to Y.-T. Liu (2004) architecture in general have started utilizing the advantages of above mentioned features as well as benefiting from integrating simulation, animation and rapid proto-typing into design practice and education since 2004.

Digital Architecture

'Digital Architecture' was inexistent before 2000 (Y.-T. Liu, 2004). Digital architecture refers to the practice of designing and constructing buildings primarily within and through digital media. In research, practice and education of architectural design various extreme perspectives of digital architecture, and the impact of computing

media in design exist (Brady, 2003; Coyne, 1990; John S Gero, 1977) which will be discussed later in this study.

Digital Design

Digital design can be defined as an act of producing design proposals with various digital media. Design often may involve a variety of media, both conventional and digital. According to Y.-T. Liu (2004) the terms ‘digital design’ or ‘digital architecture’ have emerged in the design industry and education since 2000. Since then it thrived and evolve to respond to new design practices.

Digital Designing and Visualization

The action of producing design proposals, generating form, solving functional requirements, producing drawings within digital media is considered as digital architectural designing.

Whereas digital visualization can be categorized in to a variety of drawings, images, montages, models, simulations and animations generated digitally and used in the different stages of design. From the production point of view this type of communication medium is fundamentally different from conventional architectural illustrations as hand drawn perspectives and sketches.

Digital Architectural Rendering

Digital rendering is a specific type of visualization generated digitally and often called as a photo realistic visualization. Computer generated photo realistic rendering is

increasingly replacing conventional architectural illustrations. The process of producing such renderings requires the creation of proportional and scaled three-dimensional models of the built environment. Designers then add real life textures, material, colors, map, and lights to their CG (Computer Generated) models. They are typically used for presentation, marketing and design analysis purposes (Y.-T. Liu, 2004).

Digital Simulation and Animation

A digital architectural simulation is a model that imitates accurately and realistically the appearance and nature of a proposed building. A digital animation is a specific type of architectural visualization that requires the creation of a three-dimensional model of a proposed building with its context which presents the internal or external spaces of the proposed building.

Distortions

Designing, developing and analyzing digitally created model and built environment can often be misleading. Digital media is not physical; hence, aspects of aesthetics, scale and proportion can be distorted. Experiencing a digitally modeled object on computer screen rather than viewing the physical three dimensionality of the object, can lead to confusion and misinterpretation. By using multiple views of computer generated model, simulation, nonlinear multimedia, animation and creating physical models of the digital object can help to rectify this issue.

Digital image file

Made out of numerous single square called ‘pixel’ (for picture element) digital images are data files that explain variations of light intensity across a visual field which when interpreted by the appropriate software plot an approximation of an image. In bitmaps, these are stored as an array of integers where each integer specifies intensity. When arranged together in a raster grid (or single line) is called a raster image (Pérez-Gómez et al., 2000).

Contemporary image processing and editing applications are advanced enough to let designers avoid dealing with the raw integer. Resolution, conversion or translation through media can reduce sharpness or add distortion that can alter appearance and reduce depth cues of an image. Digital images have their limitations when they are just numerical equivalents of scanned photographs or paintings (Pérez-Gómez et al., 2000).

Digital Model

Unlike digitally drafted file (CAD drawings) that contains only two-dimensional information, a digital model contains information regarding a three-dimensional object. Several digital model files can be linked to produce large and complex design. The linked files accommodate collaboration between professionals, groups or various stake holders; at the same time maximizing use of computing resources.

Hybrid Digital

Hybrid mode of representation can be defined as a technique of making digital visualizations that includes combination of digital images, drawings, renderings(prepared

in CAD and/or manually), etc. ("Oxford Dictionary," 2001). Instead of following one particular media designer typically use realistically simulated image, CAD print outs, freehand sketching, and scaled or non-scaled drawings. These drawings could be montaged, overlapped or supplemental. Designers may move through different applications as CAAD, 3D modeling, parametric to image and graphic editing. Designer also may draw on rendered or printed CAD drawings, which provide a greater manual control over the quality, analysis, synthesis and communication.

Digital tool

According to "Oxford Dictionary" 2001) digital tool is usually a digital device or an application that is used performing a particular function. It is important to understand the distinction between digital media and digital tool. Glanville (1992) distinguishes two types of computer supports as 1) ‘tool’, that does not require a computer to obey commands, participate or offer information feedback; and 2) ‘media’- that is out of user’s control, computing is participating and informing without obeying. Most of the researchers used the term digital media to identify a generative use of digital technologies where as digital tool defines the uses of digital technologies in a restrictive manner that does not supply information feedback.

The term digital visualization media covers the range of media available that creates still or moving digital files that illustrate a digitally modeled object (Oxford Dictionary 2001).

Digitally derived architectural variable

When a variety of potential solutions are produced using digital media to facilitate complicated computation algorithms or complicated programming(Mitchell, 1977) Contemporary digital architects and the use of digitally supportive media in architectural design is a mindset of mathematics and other computational ideas as drivers of architectural design. A proto-computing (a differential analyzer that considered to be an early mechanical analogue computer) paradigm existed prior to the notion of 'Digital Architecture' that included Antoni Gaudí and Frei Otto (Scriver 2006). These proto-computing paradigm architectural designers are commonly used as precedence for contemporary digital architectures (Scriver 2006).

A digitally derived architectural variable is a subset of digital architecture design. The term defines an aspect of the design which is likely to change, or is able to be changed, is obtained from, arises or originates from either the use of digital media or generated from computation (Oxford Dictionary 2001). Another subset of architectural design namely, digitally conveyed architectural solution defines the communication of the proposed design via the use of digital media.

Design Ideation

Idea is defined in Oxford dictionary (2001) as an aim or purpose, a thought or suggestion about a possible course of action. During design in early stages it is often known as a concept. During early design phase- design ideas may not primarily be driven to produce commodity, rather the term 'idea' is used to refer designer's style of design

practice, influenced primarily by site, story and program. In psychology, ideate or ideation means imagine, to conceive and/or form ideas. The term derives from the Latin term *ideare* meaning 'form an idea'. In architectural design, ideation occurs in the design process however; it is not often marked or recorded. Ideation is the very earliest steps in designing when designers communicate with themselves, or with their teams, to put together ideas and begin to find a form for an architectural design.

Ideation is considered as a process of identifying and conveying concepts as a diagram of an idea. An abstract concept is conveyed thorough ideation by association, or metaphor, to transmit and register the essential elements of the thing described(Brady, 2003). She also referred it as a poetic device for linking concepts or words to the basic elements of visual form. Designers used this term to highlight a specific approach to the typical process of conceptualization that often is driven by ideas, over pragmatics or utilitarian uses.

Practice in architecture

It refers a place of work or business where the action of doing something, rather than the theories about it is more focused (Oxford Dictionary 2001). More often than not usual way of doing something (repeatedly) to improve skill is called ‘practice’ (Oxford Dictionary 2001). The term practice could refer to a design culture, specific style of a group as well as their business that follows a set of accepted protocols and behaviors within a group of creative practitioners and a means of identifying idiosyncrasies and rituals within a group.

Computer applications

Computer application, software or program is the executable programs and databases (a set of instructions) that encode the computer hardware. Relevant software contains CAAD knowledge in digitally process-able form. There was a distinct division 'between those that create the software and those that use it (designers)' (W. Mitchell & M. McCullough, 1991) since designers do not create software and those who does do not design. Mitchell and McCullough argue that software is often created by naïve or unskilled producers (in the context of architectural design paradigm) unfamiliar in the skills and art of the architectural profession (W. Mitchell & M. McCullough, 1991). This distinction results in an inconvenience to the architect and an increase in attempts of producing innovative software or using existing software in ways that would have been far beyond the capacity of the past.

Developers and executives have adopted a pragmatic usage by producing software with some particular interests in mind, where most of the focus on digital media has been relegated to delivering efficient later stages of design development and documentation process (Coyne, 1990).

Despite the tremendous improvement of computing hardware and software John S Gero (1977) noted that- it would be 'virtually impossible to describe in detail every application in architecture' due to their 'limited transferability of from one user to another'. It is evidential in this study

It was experienced in this study that some applications (software) can both impede and advance the design of a project. Depending mostly on designer's competency and knowledge, these issues with software, its limitations and impact upon implementation plays a crucial role over final design.

CHAPTER TWO: REVIEW OF LITERATURE

2.1 Previous and Related Research

Most of the studies in design research and cognition are comparatively isolated projects that tried to experiment methods and explore the design universe. Some other researches took a special focus on various aspects of the design process. In design thinking, research conducted on diversified context. For instance- internal and external representation (Omer Akin, 1978), design development (Cuomo, 1988; Darke, 1979; McDermott, 1982), knowledgebase of design thinking (Omer Akin, 1986b), generating design problems (Omer Akin et al., 1992), design pedagogy (Donald A Schön, 1985), design process (Chan, 1990; Eckersley, 1988), analyzing design activity(Nigel Cross et al., 1996), design protocol & mental operations (Bryan Lawson, 2004), design events (M Suwa et al., 1998), design ideas (Goel, 1995), drawing conversation (Donald A Schön, 1985).

Research conducted by architects and industrial designers as Lockard (1982); Laseau (2001); and Lawson (2005), had made significant contributions to characterizing the role of drawing in creative thinking; however, a little research had been done to investigate the use of drawing in the graphic design process. Subsequently, notable contributions have been made to the role of drawing in creative processes by researchers like Tovey (1989), Garner (1990) and Temple (1994), and to the understanding of the

creative behavior of designers, including the role of drawing, as characterized in the work of Cross(1982), Goel (1995), and Archer (1997). Schenk's (2005) 'search for helpful computer tools for sketching in the early phases of design' has also supported through extensive contributions by researchers like Verstijen and Hennessey(1998). An invaluable review of this literature is given by Garner (1992) on role of drawings in design. However, a more detailed analysis and review of literature is conducted in this study with focus on identifying and reinterpreting the relation between different design drawings, creation media, and reasoning behind adopting and switching one or more of these modalities.

Associating diverse design tools and media has been widely used as a method of design simulation and presentation. Educational and professional settings employ using design tools successfully to study, communicate and present architectural design. The brisk improvement of digital tools during the past decades had profound impacts on the architectural education and the way how designers create, converse or appreciate the use of digital spatial environments (Davidson & Campbell, 1996). Numerous studies demonstrate the impact of digital media on design studios and education as well as propose solutions for the multi-modal design approach and how to make efficient use of externalizing media (Arnheim, 1969). Yip (2001) explored distributed design studio, Mizell, et al. (1995) investigated collaborative design within remote collaboration, while Gao &Kvan (2004) analyzed pattern of communication within digital design studios. Virtual Environment (VE) and Virtual Reality (VR) can be used as a presentation tool only to assess design alternatives and final design solutions (Bryan Lawson, 1994).

In the early nineties a new concept of design studio emerged which investigated various possibilities of the learning and the exploring of architectural design. Named as Virtual Design Studios (VDS); this new approach defined ‘virtuality as acting while physically distant or as acting by employing digital tools’(Bridges & Charitos, 1997).

In another initial literature search conducted in the mid 1980's it was found that while research by architects and industrial designers had made significant contributions to characterizing the role of drawing in creative thinking (for example, Lockard, 1973; Laseau, 1980; and Lawson, 1980), little research had been done to investigate the use of drawing in the graphic design process. Subsequently, notable contributions have been made to the role of drawing in creative processes by researchers like Tovey (1989), Garner (1990) and Temple (1994), and to the understanding of the creative behavior of designers, including the role of drawing, as characterized in the work of Cross (1990), Goel (1995), and Archer (1997). The 'search for helpful computer tools for sketching in the early phases of design' has also led to extensive contributions by researchers like Verstijen and Hennessey (1998). An invaluable review of this literature is given by Garner (1999).

2.2 Modality and Modality Shift:

Modality is “a particular mode in which something exists or is experienced or expressed” *(Oxford Dictionary of English, 2003)*. It is a way or mode of performing and experiencing something. Widely used in the field of medical science as ‘diagnostic

modality' which refers to ways in which doctors perform diagnosis of diseases. In psychology, 'sensory modalities' means the way of sensing as vision, hearing, tasting, feeling etc. In the field of human computer interaction 'modalities' are commonly known as means or mode of communicating between computer and its users for both data input and output.

Table 1: Modality, Drawing type piecemeal and their relationship within and with Design Phases

Drawing Category	Drawing Type	View development and Rendering		Purpose	Mode	Modality Output	Design Phase
Representational drawings	Sketch	Contour, Stroke, Marker, Travel sketch,	Free hand	Study, Note taking, Reference keeping,	Manual	Thumbnail drawing, Conceptual drawing, Study sketch,	Ideation
	Conceptual sketch			Formal, Spatial, Environmental control, Plan,		Analytical, Diagram 2D, 3D, Relationship, Schematic,	Development
	Study drawing						
Scaled drawing	Orthographic projection	Plan, elevation, section (architectural drawing conventions)	Conventional drafting tools with or without CAD applications	Documentation Communication Instruction		Presentation document Construction document	
	Paraline projection	Isometric, Dimetric, Axonometric,					
	Multiview Projection			Contextual presentation	Hybrid / Mixed	Generic 3D view	Externalization
	Oblique projections	Plan oblique, Elevation Oblique, Paraline Oblique,		Information rich Realistic Representation, Academic, Research, Business, Promotional, Information modeling, collaboration,		2d/3d Manual drawing with enhanced depth cue	
	Perspective	One point, two point, Three point cut-away, Expended/ Exploded,				Mixed media presentation, Manual touch up over CAD Printouts	
Composite drawings	Linier perspective, Fold out, Multi panel					Building Information modeling, 3d Printed model, Linier/ non linier multimedia simulation, Augmented reality presentation, Various VR representation,	
	Manual		Photorealistic rendering/ view				
	Hybrid						
	Digital	Computer generated model and 3d rendering					
		Augmented Reality, Virtual Reality	Simulation	Immersive presentation	Digital		

In this research modality is considered as mean of communication both internally (designer with him/herself as a process of design thinking) and externally (in form of construction documentation and presentation). Hovy and Arens (1990) defined modality as a mechanism to express information as chart, table, form, map, diagram, verbal or written natural language. Whereas medium is a hardware or tool that modality utilize to create and realize the expression of the information. For instance, tracing paper or computer monitor is a medium to display some modalities or information about a design project. Table 1 demonstrates various modality end products in relation to drawing categories, types, intended purposes and when those are generally used during different design phases.

2.2.1 Modality shift

Multimodal environment enriches design process by encouraging multiple iteration between and among manual and /or digital design and drafting tools. This shift or transition of media and their re-interpretation is very important. Because shifting modality may enhance design process by aiding to cognitive, qualitative and productive aspects of design development or it may hinder the process through loss of information, adding further constraints and relocating focus from the design problem (Bermudez, 1997b; N.Y. Cheng, 1995; Herbert, 1995; Kellett & Ronald, 1996; Matthews & Temple, 1998; Parsons, 1994; Smulevich, 1997).

While performing design task, to constitute optimal solutions designers need to identify and exchange abstract information (ideas, thoughts); externalize, represent and prepare tangible documentation through some interfaces which are considered as

modalities in this research regardless of their manual or computational attributes. Modalities, in other word – design, drafting tools and their mode of utilization which can be completely computational, manual or a combination of both.

Contemporary designers use increasing number of different, and often alternative input/output modalities for the expression and exchange of information between abstract thoughts its tangible documentation. Designers often than not convers with their design thinking (Schon and Wiggins, 1992) through the cycle of externalization (drawing-inspect- revise). As they inspect and verify their own sketches, various visual cues are discovered suggesting means to refine and revise design ideas.

Form modality perspective designer's task can be illustrated roughly as follows: (1) Identify the abstract thoughts to be expressed or concretized (2) perform good match in terms of functionality, competency, efficiency, experience, constraints etc. between that information and the available input/output modalities; (3) execution and verification. Designers gradually acquire skills and cultivate a media 'repertoire' - a palette of tools and techniques (Kellett, 1990a) to perform these steps (sequentially or non-sequentially) in combination with numbers of design and drawings tools.

Features of each modality are assumed to have profound implications and specific capacity of representing information hence the choice of medium strongly influences the effectiveness of the representation so as considered a choice between different modalities. Depending on designers experience, aptitude and intention modalities are often swapped and tested for developing optimal and intended representation, thus shift of modality

happens. Depending on needs, situations, and opportunities experienced designers seamlessly 'switch' back and forth among and between several techniques and media.

An extensive discussion on design modalities are presented in section 2.8: design modalities.

2.2.2 Working definition of Modality and Modality Shift:

While performing design task, to constitute optimal solutions designers need to identify and exchange abstract information (ideas, thoughts); externalize, represent and prepare tangible documentation through some interfaces which are considered as modalities in this research regardless of their manual or computational attributes. Modality, in other word – design, drafting tools and their mode of utilization can be completely computational, manual or a combination of both. For instance, designers can use various computational applications as SketchUp, Autodesk Alias, Sketchbook, Project Vasari and such to research, analyze and conceptualization with digitizer as input or drawing tool. They may also take occasional printouts and use it as underlay for further design development; when satisfied those new features can be edited on existing digital drawings. Or, this whole process could happen using traditional medium and tools. This wide array of arrangement can cycle through every design stages like design ideation phase. When designers represent their thoughts using traditional design and drawing tools as their major mode of communication it is considered as manual modality. Likewise, when computational means become major communication mode it is denoted as digital modality. And, when designers use both with equal importance it is considered as hybrid or combined modality.

Modality is a more comprehensive term that comprises of not only digital and analogue ‘tools’ which designers use to externalize their thoughts but it equally involves ‘media’ where our mind interacts with design issues (DeLaura, 1997; Herbert, 1994). Design tools, its media and their interactions are directly associated with design process and method. Interaction between media provides fluid thinking and multiple viewpoints instead of particular specifics of the final design product. Thus this relationship encourages the process of design development and has deep impact on how design is conceived, developed and communicated (D. Herbert, 1994).

2.3 Design

Different definitions of design agreed on this point that it is a deliberate act of creativity which often described as a nonlinear problem solving, impulsive in nature without any definite starting point. Aspelund (2006) argued that the design process is definable regardless to what is being designed that follows a well delineated path in its creation. Critical analysis of any design process in design studio settings reveals its basic stages, each of which contains its own set of goals. These stages can be described as inspiration, identification, conceptualization, exploration/refinement, definition / modeling, communication and production. It is obvious that these stages are not necessarily linear but can be examined as such. Designer’s focus of attention shifts between different aspects of design problem during the design process. For instance, a design process must begin by examining and identifying the nature of the problem and determining the possible solutions, and most important, illustrating and explaining them

so that they can be realized (Aspelund K, 2006). Some designers argue on the fact that design cannot be defined as a systematic scientific process. Further discussion can be found later in this chapter.

Great designers from Le Courbusier to Eisenman went through the same kinds of activities: schematic plans and variations, fragments of elevations or perspectives, hypothetical details, experimental sections, adjustments to previous decisions, abstract spatial diagrams: all draw with the same familiar graphic conventions and draw in about the same unpretentious fashion (Herbert, 1993).

Arguably, design is not necessarily the only part of the protracted process of any building's existence. According to Hillier (1996) the 'building process' involves many other essential phases besides designing an explicit form. These phases of design are- 1) formulation of necessity to build, 2) conceptualizing the look, 3) initiate resourcing, 4) negotiate and organize, 5) processing representation(s), 6) refining representation(s), 7) constructing and fitting, 8) operationalising, 9) occupying the building. Aspelund (2006) on the other hand defined design process in seven basic stages as: inspiration, identification, conceptualization, exploration/ refinement, definition/ modeling, communication and production. His argument extended in the line of Hillier's understanding of 'design function' when mentioned- this process of design may not be linear "but can be examined as such" (p. 1). Various scholars, researchers and design theorists have described and seen these phases vividly and spoken in different language but the underlie theme remained the same.

Design is also considered as an individualistic creative method that evolves diversely in each designer's mind. Vitruvius in his book of architecture credited Terentius's understanding of design individualism – "*Duo cum Facinunt idem, non est idem*"(when two do the same, it is not the same)(Vitruvius & Morgan, 1960). Unlike mathematics, issues in design are not always clearly stated at the outset, nether those are examined, identified, illustrated and explained by designer in similar fashion. As it is undoubtedly a cyclic process, it can be argued that the act of designing should not be mistaken as an independent function apart from this process.

The act of searching, conceptualizing, surrogating, representing and building is author independent but the existence of some kind of control on this process is desirable according to Hillier (1996). He also argued that design function embraces two fundamental phases as 1) creative and 2) predictive which essentially subsist in all design process to a varied extent (see table 2).

Table 2: *Design process piecemeal.*

	PHASE	***OBJECTIVE***	***PROCESS***	***GOAL***
Design Process	Creative	To create design proposal	Searching and creating	Solution of design problems
	Predictive	To refine and foresee	Testing against the objectives	To satisfy- Beauty, price, style, idea, investment, function, sustainability, etc.

The first phase of this design process can be thought as the formative phase while the later as production phase. Design, throughout most of the duration, exists, evolves and continuously changes s its form as an abstract idea or representation. Thus it becomes

more of an individualistic approach. Like theory, design process is an evolving mechanism that changes, gets modified, shuffles within and surrogating the design. The evolution started with traditional two dimensional design processes to systematic (design by reason), heuristic (design by discovery) to conceptualization (design by ideas) (Hyde, 1989). It has been documented in few other researches that the latest developed model of design process through conceptualization is being used widely in teaching design because of its normative aspects of focusing on designer's attention on ideas rather than the process of design. Nonetheless, I think, design is a fact based investigation that requires a subjective study which should be authenticated or validated by the 'real world factors', which can be assisted by well-developed theories. It is evident that theory developed from a well conducted research as it involves investigations and theory involves prediction in both implicit and explicit manner.

Design with technologies on the other hand are enabling a direct correlation between what can be designed and what can be built, thus bringing to the forefront the issue of the significance of information, i.e. the issue of production, communication, application and control of information in the building industry.

Design often seems to be frustrating, superbly challenging, and comprehensively rewarding activity at the same time. Since designers are initially uncertain of the goals design problems are seldom explicit. However the attempts are continuously being undertaken to bring an increased understanding of how designers think, and for that alone it should be encouraged and the process must be studied as the design process immensely influence the products.

Unlike science, art, law, medicine, politics and other fields of human endeavors design problem has a unique set of qualities. Design can be taught but the process must be adopted and each of us must find our own methodology and learn how to adapt it. Depending on the nature and uniqueness of design problem it encompasses researchers from so many backgrounds as -cognitive, psychology, information science, philosophy, sociology, linguistic, art and of course design itself.

2.3.1 Evaluation of architectural design

By abdicating the technical utilitarianism of Gothic architecture over humanitarian aesthetic principles, Leon Battista Alberti- an Italian nobleman adopted a system of rules based on the vocabulary and the syntax of the ancient Greek orders to form the structure of professional practice in the 1450s which is known as architectural design exercised today. Since then, architects and designers are experimenting and inventing design methods to facilitate the process. This hundreds of years old process was only formalized in the 1960s (Edwards, 1979) with four major interlaced phases; as – (problem) *Analysis*, (solution) *Synthesis, Evaluation* and *Communication.*

In the phase of problem or feasibility analysis designers attempt to determine the elements of problem then set target(s) to achieve, comply with the constraints and evaluate the solutions' possible side effect and after effects. During solution synthesis phase ideation of possible solutions to address goals, constraints, opportunities and such are established which necessarily may not be a rational process. Results of a synthesis often could be incomplete with internal conflicts; hence obtained solutions need further rational evaluation. Though evaluation is a rational process many elements as aesthetics,

human behavior and other such qualitative aspects may challenge the rational measurement and quantifications.

To generate solutions and its evaluation design process must be communicated. Modern architecture and building industry so much diverted that it requires several specialization that an architect alone cannot master it. Designers keep record of thoughts, internalize, evaluate as well as externalize design solutions via wide range of representational means as drawings, specifications, renderings, models, notes etc. Communication acts as a stimulus, binder and recorder of different phases of design. Communication is a process of encoding and decoding information.

Khun (1962) argued that due to the open ended nature, problem solving should consider as a paradigm rather than a theory or method which allow design process to oscillate within two cognitive modalities—problem solving and puzzle making. Within this paradigm alternative solutions are generated and tested against the goals and constraints until a satisfactory conclusion arrives because of the fact that the goals and solutions are not interdependent or individualistic in nature.

2.3.2 Design Methods

Design method is different from its process since process is the way of designing something through the act of designing whereas; designers adopt a method to accomplish a design task. Many design methods established a notion that design is a solution searching process until it satisfies a given set of goals and constraints. Evidently the intent of instituting these methods is to make this search more effective. Due to the

difficulty and unreliability of the design process when transiting from setting goals and the constraints to devising potential solutions architects tried to establish reliable methods to overcome this unpredictability without compromising the "delight of discovery". Thus various form of methods evolved from trial and error searches, constraints satisfaction methods, rule based design, precedent based design and so on. (Kalay, 2004).

Search

By finding, developing, potential solutions and evaluating those against the goals and constraints designers engage themselves in the action of search. Generally this process repeats itself within generating possible or potential solutions and selecting the appropriate one for further development until a reasonable solution arrives.

Constraints satisfaction

When the number of potential solutions increases it become challenging for the designers to find a right candidate to satisfy the design goal(s) that essentially will comply with individuals' conceptual and technical difficulties, designer tends to follow a different method by looking for a solution of the problem instead of searching for the solution space for the solution of a problem (M. D. Gross, *et al.*, 1987).

Rule Based Design

Marcus Vitruvius in his drawing-less, narrative style treatise *Ten Books on Architecture* provided specific rules for all aspects of Roman design that influenced Renaissance architects to develop or adopt new design methods for professional intervention. This rule based methods are one of the most commonly practiced and effective way to complete a task, because rule can be used to capture any well-known

process, and thus it becomes the method of choice. However, many researchers argued that the set of rules established necessarily portrays its author's views biases and condemnations(Kalay, 2004).

Case-Based Design

Most disciplines of knowledge as architecture, law, medicine, business, engineering and so on depend largely on past experience to acquire rich, empirical, valid and reliable solution for intricate problems. In architectural education and practice references often are drawn from the work of the masters as Mies van der Rohe, Louis I. Khan, Le Corbusier and Frank Lloyd Wright. Architects interpret these precedents and prototypes then adopt the attributes that resembles the problem on hand. This provides a starting point to develop new design. Though different methods uses different approaches its major purpose is to bridge gap between phases of design process.

Design event

Some researchers referred design events as 'moves' other called it as 'segments'(M Suwa et al., 1998). These design events are usually- drawings, physical actions, modeling, gesturing, verbalization or internalizing mental operations(Bryan Lawson, 2005). These 'moves' are apparently repeated within a wide variety of design protocol and hard to breakdown or distinguish as a separate, individual action. More often than not to move a project forward some of the relatively close events are performed together in a group. Some writers noted these cluster of events as 'chunks', 'dependency chunks' or 'modules'.

Externalizations

Designers are inextricably associated with drawings; however they don't always design by drawing. One of the major means designers use to externalize their thoughts is drawing. Many recent cognitive science theorists recognized drawings' specialty in design. Modern cognitive science stressed upon understanding design as a core method to demystify design ideas. Vinod Goel (1995) in this book Sketches of thoughts raised a very sophisticated argument by identifying and mentioning it as deep rooted phenomenon in modern cognitive science that is often inaccessible to those who are not fully conversant with this field.

Design representation

In design process drawing possesses such a significant role that practically almost every design curriculum place substantial emphasis on teaching and developing various drawing skillset. Exploring designer's drawing is an excellent way to expand understanding on what designers know and what message they want to convey. Tom Porter and Sue Goodman (1991) claimed that – "in the wake of rapidly advancing computer graphics technology, drawing by hand remains undisturbed as the central activity in the process of design" (Brawne, 2003 in Lawson, 2004). It is widely believed by many modern cognitive science theorists that the obscure relationship between designers' thoughts and its representation is made through drawing as it reflects what is going on in designers' mind and consequently designers' knowledge and method of mental representation.

Constraints

To develop a theoretical framework and didactic principles for digital design process and education it is important to analyze constraints as adaptability, inertia etc. that traditional design process is experiencing. Oxman (2008) noted these constraints as various classes of influence- such as: 'the influence of design medium', 'the influence of knowledge and theory' and the 'influence of models and methodologies'.

Designers seem to have control and greater degree of freedom and choice over internal constraints. On the contrary, external constraints are much complex yet plays a significant role in design.

Knowledge

Design is a process that implies how the world might be based on uncertain but predictive knowledge instead of describing how it is now. This process is extremely selective or individual that relies on designer's own interpretation of problem.

With same starting point of any given design problem each designer is more likely to end up with diverse solutions. This make analyzing and generalizing design process a very difficult task. Thus design problems and its solution significantly depends on the extent of knowledge of a designer (Lawson). Zeisel 1984 argues about the properties depends on two types of information—'heuristic catalyst' for imaging and 'body of knowledge' for testing. They use knowledge to decide on how things might be and to see how well things might work. These notions are however perspective, not descriptive.

There are evidences of enough debate on identifying and describing sequences of activities in design process. Vinod Goel (1995) suggested that 'design development occurs in distinct phases'. Arguably these distinct phases he mentioned can be simplified as 'activities' that designers perform. Goel's distinct phases are 'problem structuring' and 'problem solving' which has three sub categories as 'preliminary design', 'refinement' and 'detailing'.

Early researchers were more inclined toward a progression model that starts from 'briefing' through 'analysis' and 'synthesis' to 'evaluation' and finally 'communication'. Researcher as Lawson 1978 declined to accept this chain of processes due to lack of evidential support even though this model looks allegedly logical to many others.

2.4 Design Process

Design problem can be identified as "ill-structured"(Rittle & Webber, 1973) and "wicked" (Bijl, *et al.*, 1971) that initially do not offer enough information a rational solution. Problem analysis, often considered as a major effort taken during the process of design- is a rational behavior that tries to unveil the cause and develop successful solution by deduction, induction and abduction of formal and logical methods supported by experience and heuristic reasoning. Unlike most form of art where artist's self-imposed objective, vision and constraints play a major role, in architectural design internally imposed confinements and inspiration as well as external constraints like site, climate, function, cost, legislations, client etc. are considered with equal importance. The design

process requires both rational and creative ability to produce solutions which is often impossible to solve with one particular facility (Minsky, 1968).

Kalay (2004) defined design as a process of transforming current situation to a desired solution. This makes design a purposeful activity focused on accomplishing some well-defined objectives through analysis to reveal the constraints on accomplishing those objectives. At the same time designers also need to identify means to predict and evaluate all possible potentials of each action.

Cognitive psychology research on design mainly involves the study of:

a) Knowledge involved in designing and processing (using) this knowledge; and

b) The organization of the actual activity and the strategies implemented by designers.

These aspects have been studied in various design domains; even if most empirical studies have been conducted in the domain of software design (see Hoc, Green, Samurçay & Gilmore, 1990). Other domains in which design has been examined through empirical studies are: architectural design: Eastman (1970); errand planning: Hayes-Roth & Hayes-Roth (1979); text composition: Hayes & Flower (1980); computational geometry algorithm design: Kant (1985); mechanical design: Whitefield (1986) and Ullman, Staufer & Dietterich (1987); traffic-signal setting: Bisseret, Figeac-Létang & Falzon (1988); computer network design: Darses (1990).

Design studies have mainly concerned solution development by knowledge evocation. One of our studies has examined, next to this important approach, the other

main solution development mode, i.e., solution elaboration. A final characteristic, valid of all three studies presented in this paper, is the focus on dynamic -rather than static- aspects of problem solving, i.e., planning of the design activity, strategies implemented and problem-solving processes used in order to execute the design task.

One of the most influential doctrines Beaux Arts School of design considered about the set of factors which associated with final design outcome, more specifically end products. Traditionally designers are judged and differentiated by the final design outcome. Design is highly individualistic and each designer need to acquire his/her own process hence design process must be learnt rather than taught. Design is a process with no definite natural end point because there is no way to determine beyond doubt when a design problem has been solved. Factors that force designers to stop designing are often time constraints, money, information or insufficient progression. Unlike mathematical problems design problems are seldom apparent and must be identified by the designers. According to Bryan Lawson (2005), it is hard to identify a definite end of the design process because design problems tend to challenge comprehensive description and offer an inexhaustible number of solutions. He also argued in contrast with some early design methodology that there is no infallibly good way of designing, since there is no sequence of operations that will assure a result. However, many modern design researchers believe that in design problem and solutions emerges side by side in a less linear manner rather than following each other logically.

Though many literatures on design methodology identified the process of design as an activity closely related to scientific method; Bryan Lawson (2005) again argued by

stating—“the most obvious and fundamental difference is that design is essentially perspective whereas science is predominantly descriptive.”

2.4.1 Ideation / Conceptualization

Once design problem is identified (in case of design studios design problem is often supplied to the students in form of design program) possible solutions are generated via examining various methods. Though this process we (designers) conceptualize our ideas into less abstract form by using different metaphor and symbols that results in a coherent presentation.

Idea is a form of mental image formulates in designer’s mind during the period of (design) problem identification by the elements required to achieve a design solution. At this stage of conceptualization or internalization of ideas and information, abstraction of designer’s vision begin to transform into more tangible form. Depending upon whether the idea is grounded in a practical orientation or driven by the fantasy designer tends to work in different manner with different modalities to establish a solution that works for the practical world.

Aspelund (2006) suggested brainstorming with holistic methods of thinking and analysis derived from the parts we assemble form our mental images. He identified in this regard that there are four tasks required to conceptualize initial ideas into more concrete form of designer’s vision as: 1. Filling the gaps, 2. Ground/ convert concept into a systematic logical reality, 3. Externalize concept with effective communication methods

and 4. Comprehensive understanding of primary thoughts for further modification, rework and refinement of detail without altering the core of the concept.

Early 20th century psychologist and theorists, Kurt Koffka, Max Wertheimer, and Wolfgang Köhler Koffka, *et al.* (1934) identified that human tends to see objects as a global constructs where all the attributes are perceived within a holistic environment. They referred this as 'Gestalt', a German word means 'whole shape, pattern or form' that determines and defines the principles of perception, guide the way in which objects were perceived. The phrase "The whole is greater than the sum of the parts" is often used when explaining Gestalt theory (Hothersall, 2004). According to Sternberg and Robert (2003), Max Wertheimer considered thinking formulates in two ways: productive and reproductive: where productive thinking is solving a problem with insight which is a quick insightful unplanned response to situations and environmental interaction. On the other hand reproductive thinking is solving a problem with previous experiences and what is already known. The gestalt approaches to form perception tried to explain human perception about groups of objects and how we perceive parts of objects and form whole objects on the basis of these. This phenomenon mostly is cited in the HCI (Human Computer Interaction) or interaction design community that can equally be identified within the proximity of architectural design.

2.4.2 Exploration/ Refinement

Using sketch and illustration:

Initial design ideas are generally consists of many unexplored, incomplete probabilities that must be examined regardless of their outcome. Different methods are often required for both internalization and externalization of effective and clear communication of design ideas. The methods and media are undeniably influential over the development and production of a concept.

Arguably the most important phase among all stages is design development when designer brainstorm to arrive in to a more focused and solution orientated state. Design tools and exploration methods used during this time become more dominating toward creating a specific result such as sketches or a technical diagram. Designers can develop a visual language by using sketches and illustrations in most efficient, clear and consistent way. The most perceptible method to investigate a design problem is to visualize it through sketching and modeling as the stereotypical image of a designer is his/her own sketches not computers or other traditional media.

Using CAD (Computer aided design):

> *"This technology (a specific CAD program) provides a way for me to get closer to the craft. In the past, there were many layers between my rough sketch and the final building, and the feeling of the design could get lost before it reached the craftsman. It feels like I've been speaking a foreign*

language, and now, all of a sudden, the craftsman understands me. In this case, the computer is not dehumanizing; it's an interpreter."

-- Frank Gehry (www.dte.co.uk/).

Computer aided design is undeniably an effective tool for developing design ideas. It offers much more control over the vision of a designer with its availability, greater speed and detail as well as quick and direct interpretive ability from rough sketches to three dimensional models. Increased control and versatility of this media has its own inherit dangers as many researchers criticized. A good rendering is almost interchangeable with photographs which influence the perception of reality and the relationship with design. Especially during early design stages these realism can freeze the development of the idea. Often the tendency of manipulating overboard is observed among design students which are beyond necessity or even reasonable boundary.

Other noteworthy disadvantage of computation media is the physical sense of scale on computer screen that contributes to confusion. However, the speed and flexibility of computer is a great strength it is important to be working in different media and not focus too heavily on one discipline.

2.4.3 Definition/ Modeling

Level of perfection of any design decreases as it moves from conceptual phase to the next stage. This phenomenon often can be controlled to a certain level if adequate attention is paid to its details and needs of design that determined by definite hierarchy. Modeling is a method to convey the effect and intent of any design mostly concluded by

the methods and materials used. In modeling phase of design, concept tends to turn in to an object – a more decisive incarnation in respect to the physical world. The words '*exactly'*, '*precisely'* and such get more emphasis while describing and analyzing a project. Some researchers argued that this decision making process is the designer's primary function (Aspelund, 2006). One drawback often noticed during this phase is to conclude into a baseline that forces a designer to choose from the perfection and completion. More often than not, the adequate accomplishment of a project becomes a question of establishing a boundary on what good enough is in terms of the overall concept and purpose of the design.

Abraham Maslow (1970) first introduced his concept of a hierarchy of needs model in "A Theory of Human Motivation" that remains valid today for understanding human motivation, management training, and personal development. The act of design also has its own hierarchical needs. Examining these needs can reveal if any change is required in concept to satisfy these needs in succession.

Researchers and advocates of learning by doing theory took effort to translate Maslow's hierarchy to design (Figure 3), where the hierarchy from low to high is categorized as- functionality, reliability, usability, proficiency and creativity (Lidwell, *et al.*, 2010). However, arguments can be drawn over a few aspects as whether a not a design have to be reliable before it can be usable or if both of these can be satisfied at the same time; or over the choice between a design satisfying proficiency for advance user while not being usable to beginners.

Maslow's Hierarchy of Needs	The Hierarchy of Design Needs
Self-actualization **Peace, knowledge, self-fulfilment, personal growth, realization of personal potential**	Creativity Aesthetic, innovative solutions, design perceived to be of the highest level
Esteem needs **Self-esteem, achievement, status, confidence, prestige, recognition, mastery, independence**	Proficiency Synergistic approach to maximize users' experience through efficient design that perceived to be of high level
Belongingness and Love needs **Friendship, love, intimacy, family, community, belonging, relationship**	Usability Functional design solutions, accessibility, ease of use, versatility
Safety needs **Personal and finical security, health, order, law, protection from elements**	Reliability Constant, sustainable, safe design practice and consistent performance
Biological and Physiological needs **Breathing, food, water, shelter, sex, clothing, sleep, comfort**	Functionality Satisfying basic functional requirements of design program

Figure 3: Comparison between Maslow's theory of hierarchy and hierarchy of design needs (Bradley, 2010)

First and foremost requirement of any design is to function adequately. However, design that meets only the basic functionality is usually considered to be of lesser value without any special achievement. Reliability can be measured by the consistency and performance. Once the basic functionality is met consistency of its performance need to be secured. Next the usability need to be assessed even though ease of use is a relative factor; predictive nature of a project is desirable so that user can get the same experience every time without re-learning the operating procedure. Proficiency allows things to perform better, improve experience in ways that was not possible before. The incorporation of new technology, materials and methods can significantly improve the performance of a design. Finally, once all the lower tire design needs are accomplished creative needs to be taken in to consideration to change perceptions and experiences that often may cross between disciplines. Ralph Caplan (2005) noted while describing design in his book *By Design*--

> *"… design at its best is a process of making things right. That is, designers, at their best, create things and places that work. But things often do not work. And making things right is not just a generative but a corrective process – a way of righting things, of straitening them out and holding them together coherently."*

Creating model is one of the best ways to examine the possibilities of design content in regard to its textures, functionality and manufacturing techniques. Designer is expected to conceive all aspects of design in him/her but to effectively convey the message an effective communication method need to be established. More often than not a model can bring the audiences inside the process. However, issues like individual elements, details or methods (of construction) get more focus than the sum of its parts.

One common constraint is that sometime ideas converted in to model work well in smaller scale may not work at all when scaled up. Aspelund (2006) identified this problem into two categories as *forces* and *interaction*. A rather self-imposed and very common phenomenon is becoming completely preoccupied with modeling in such intense that the actual design issues diminish behind the technical and practical aspects of the modeling. Method of presentation gives is the framework to work inside with a clear endpoint for the modeling depending on the functionality of the project.

2.4.4 Communication

Much of a successful design depends of how it is communicated throughout the entire process both externally (to share with others) and internally (to communicate with the designer him/herself). It is a designer's responsibility to choose from the array of design and communication modalities based on to whom, how and why the message is being communicated as methods, media and presentation style has a significant impact over the message.

The act of design can be treated as a process of communicating concepts or ideas through a set of verbal or imagery code which essentially breaks up the abstraction of designer's thought into a more conceivable format for its audience. A building, a sculpture, a painting, a book and such are all various form of the same intent of its designer, communicating thoughts. Therefore, it is safe to assume, communication is a key issue throughout the whole design process. However, it is important to identify which methods and media are more suitable for each design stages to convey the intended information across.

The process of communicating a design generally consists of four incremental levels based on its depth of clarity, pragmatism and sense of purpose. These are- *statement, concept, detail,* and *planning*. During the first level the aim of the designer is to elaborate the statement of the design and to share the large issues and general definition about the project. By creating a concept board and starting sketches designer examine and flesh out their ideas.

2.5 Theory in Design and Design Process

Architecture is an intellectual and creative process that is reflective and imaginative at the same time. Design not necessarily a simple task but can be assumed as a relatively simple set of operations performed on a highly complex structures where 'theories' and various mode of representations simplify these complexity (Hillier & Leaman, 1974). It is assumed that theory would render a non-discursive and general principle which is applicable to versatile cases. Theory is essential in architecture as it "supports the creative act by proposing a generalized understanding of spatial and formal organization of buildings than available within the limits of a single culture" (Hillier, 1996, p. 39).

On the other hand, the design process traditionally is considered consisting of five distinct parts: fact finding, analysis, synthesis, verification and communication. This cyclic process could be categorized in two broader phases as creative and predictive phases. Once this creative-predictive process is understood through formulation of structural reasoning, s/he can predict how that particular design will work and be experienced. We can apprehend theory as one mean of structuring the design process that essentially gives us a bigger picture which is more generalized. Through its lens of theory, the analytical and normative aspects that contribute the design process can easily be understood. Theory does not essentially establish any solution or define a path to follow rather it points toward how the path(s) should be (followed).

From the essence of Hillier's (1996) seminal treatise, diversified theoretical viewpoints in connection with design process was examined in this study. To investigate how theories are implemented and followed in architectural design process, I will review definitions, application and importance with arguments and examples from literature and experience. Later I will present my own perspective on this issue.

For a critical review, it is important to have a clear understanding on general definitions of theory, architectural theory, architectural design, design methods, design process and rationale. The reason because all these interrelated facets of design thinking and development has theorized with different terminologies by different theorists. These differences are created by varied degrees of abstraction and scale as well.

2.5.1 Theory

The word theory has a number of distinct meanings in different fields of knowledge, depending on their methodologies and the context of discussion. The elementary semantics of *Theory* could be found in its literary defined as "1) Supposition or a system of ideas intended to explain something, especially one based on general principles independent of the thing to be explained, 2) an idea accounting for or justifying something, 3) a set of principles on which an activity is based"(Oxford Dictionary of English, 2003). Theory usually reflects the general or abstract principles of a body of fact, belief, policy or procedure derived from context, situation based past experience, knowledge, professional experience and followed as the basis of action. The derivation of theory through research is a common phenomenon in most of the discipline of science and humanities. "In science, this means objective, empirical studies grounded in hard

facts; in the humanities, this means interpretation of phenomena."(Tarbox, 2006, p.73). The realm of design has carefully encompassed the both with systematic, self-conscious discussion and analysis where interpretation and intuition of designer's thought plays a key role. That's why some researchers argued that traditional theories and instincts may no longer be adequate and thus quest for new approach has evolved. One example is this approach however is the use of activity theory for design research, where social constructivist theory plays a critical role in providing groundwork (Tarbox, 2006).

Architectural theories are juxtaposition of analytic-normative complexes as Hillier (1996) described in his book *Space is the Machine*, which should not be mistaken as separate percepts. In essence of this theme, a theory can be specified in connection with design process. It is important however to examine the design process from its analytic-normative landscape to collate a more generalize, comprehensive view.

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Philosophers, aestheticians, theorists and researchers interpreted and referred architecture as both an activity and a thing where 'systematic intent' is evident. Architectural theory aims to explain architectural phenomena as well as to guide design. Being one of the most influential advocates of this statement, Hillier (1993) raised a question on this regard as, "are architectural theories, in short, theories applied to architecture or are there also theories of architecture?"(p. 9). Critical analysis of this intriguing aspect of architecture links it back to history as concept on architectural theory can be produced objectively, "…. but it would run the risk of turning out to be unhistorical, since it would assume a constancy of meaning that the term may not

have”(Kruft, 1994, p.12). Two major aspects that we should consider while studying architectural theories are, the time when that particular theory has its foundation on and the procedure of its evolution. With a deep root in to precedents or vernacular traditions new theme emerges and if verified and adopted the concept eventually produces a theory so that mass application becomes possible.

The perspectives and definitions of theories are viewed and documented diversely by researchers. Some, for instance Roger Scruton, a well-known critic of architectural theories noted in The Aesthetic of Architecture that “…there is not and cannot be a theory of architecture” (Hillier, 1996, p.40), whereas others as Lang (1987), Hillier (1996), and Groat and Wang (2002) argued that architecture is intrinsically theoretical act which provides an important source of perspectives that guides architects and urban designers to decide upon organizing principles and constraints in the realm of theoretical discourses. Hillier defined it succinctly as “theories are forms of knowing that summarize experience into abstract principles, and thus transform the meanings we assign to experience and the way we act on the world.”(Hillier, 1993, p.9).

Based on the enormous amount of published essays on architecture many researchers pigeonholed theories related to design process to a few clusters as 1) descriptive 2) explanatory and 3) normative. Lang(1987) comprehended two kinds of architectural theories: positive theory and normative theory where he explained three ways to incorporate theory: as a model for world view, as a prediction to foresee and generate hypothesis, finally as a prescription to execute (p. 13). Hillier on the other hand distinguished architectural theories as analytic or scientific and normative but argued at

the same time that: “Although presented normatively, then, architectural theories must have a great deal of analytic content, whether this is explicit or implicit”(Hillier, 1996, p.42).

Though the role of theory is to demystify the non-discursive aspects of space and form for rational analysis but to define architectural theory itself is complicated. A critical analysis of Le Corbusier’s literary work can be called design theory where he attempted to set rules and goals for design using new concepts in order. Theory is an effective tool for analyze and criticize design with concepts in designers mind or writing or for comparing designs done by others.

Finally, this study finds theory as an indispensable element of architectural study, research as well as practice. Many scholarly literatures from the time of Vitruvius to present day discussed, argued and raised issues on design theory, criticism, and the philosophy of architecture(Kruft, 1994). And thus provided us with a broader picture and in depth perspective on how theories can be adopted, implemented in building to sustain with a workable design. To apprehend how design theories can be formulated and implemented in and for design process an investigation on design process essential. The following discussion will examine the design process and how theory is related to this process.

Design Process

From the discussion above it is clear that the necessity of theory is undeniable in practice and pedagogy. Theory becomes essential when architecture become true to itself, free from copy of another building. Theory constructs from a

combination of ideas about how the world should be (theoretically) and how it is believed to be (designed). It was observed that design is simultaneously a creative and predictive process. With proper understanding of this creative- predictive nature of design one can make connection with normative and analytic aspects of theories so that they can be associated in the design process (Hillier, 1996). As it was discussed earlier, theory is not the only way to structure design process and achieve solution. But it can help designer searching for a possible design solution from vast and unstructured world of information. Cross (1984) proposed a separation between two crucial components of designing as logical analysis and creative thinking. The analytical activities as, data collection, problem identification, solution evaluation and such performed in more explicit fashion that results in providing specification required for creative phase. Tovey (1986) describe this as 'solution-led' approach. 'Specification driven' strategy is another process that uses specification as an initiator to develop solution proposal and criteria to evaluate proposed solution. Like Hillier's (1996, 1993) understanding of creative- predictive aspects of design process, both specification driven and solution-led approach emphasize the interaction of analytic-evaluative or normative process where the only difference exists in the sequence as the former starts with analysis and latter begin with synthesis (B Lawson, 1980; Tovey, 1986).

From a cognitive perspective, what designers perceive and think can be classified again in to four categories based on information acquired. These are: elementary details, spatial relations, function, and knowledge (M Suwa & Tversky, 1997). As the process of designing involves representation and re-interpretation in a

cyclic process cognition plays a major role. Among the four categories Suwa suggested, the first two offers visual information in form of 'form creation' and non-visual information is presented in last two as 'conceptual articulation'(M Suwa et al., 1998). In design process conceptualization interacts with the form creation where application of design theory often directs the protocol of design methodology.

With the example of one of his students Wang (2002) identified the possible factors those contributed student's decision and influenced his design process. These factors include: personal history or emotion, knowledge of precedents and experience, studio instructions, evaluation through sketches (foreseeing) and the 'light bulb'. Wang's understanding of this 'light bulb' resulted from the relationship between design and research as he noted-

> *"... by design we mean what architects do every day: conceiving of built form by responding to clients, programs, budgets, and other "real-world" factors. These are intermingled with the designers' conception and visions, and ultimately translated into graphic representations that increase in detail until they become the guideline images used to construct the actual project"(Groat & Wang, 2002, p. 101).*

In both phases of creation and prediction designer's effort and research continues for the search of a suitable solution of the problem which s/he validates through a set of objectives. Designer's knowledge of real world and context acts as a stage to perform this procedure. Wang's 'light bulb' only triggers when designer finds a connection with his or her 'creative proposal' and 'real-world' context by refining and foreseeing the design

problem. Theory acts as a key performer here which is based on knowledge and precedents but greatly depends on interpretation as it tells how the world should be rather than how it is. We use theory in our design knowingly or unknowingly because "much use of theoretical ideas in architecture is tacit rather than explicit"(Hillier, 1996, p. 62) but not necessarily means that we design strictly under theoretical influences (Hillier, 1993, 1996; Hillier & Leaman, 1974).

In studios, often it was observe that proposed solutions expected to come at later stages of design, formulates in the early phases. without following any inductive or deductive process this early hypothesis directly influences subsequent refinement of design problem (Hillier et al.1972). Design reasoning however, does not follow inductive or deductive procedure in any simplified way. It is rather an implied phenomenon embedded in the design process and explored by theory. But some researchers argued that "explanation sometime occurs by proposing reasonable hypothesis that can be tested deductively"(Zimring & Craig, 2001, p. 131). In design literatures many theorist and researcher's attempted to characterize design within logical reasoning process to ties it with science. I think design should not be treated only as a simple combination of general logical reasoning as: deduction or induction. March (1976) has identified this as an 'adductive' process because design reasoning does not follow logical reasoning in a simplified way. To understand hypothesis generation in science the term abduction is generally used. Much similar to this trend of thought Hillier (1996) in his book *Space is the machine*, tried to establish a relation with science and theory. He found theory as a deductive process that simultaneously implicit and explicit in nature as it occurred in

design process. A pure scientific theory however, is generally free from tacit elements whereas “much use of theoretical ideas in architecture is tacit rather than explicit” (Hillier, 1996, p. 62). This paradoxical position of design makes it a unique field of study concerning experiment and investigation from both fields of science and humanities.

Design is undoubtedly a research process that emerges from a creative analysis. Designer use induction, deduction and/or reduction method to formulate a predictive view of building through objective satisfaction and thus design process can be overlapped with any scientific process. At the same a closer look at design reveals two possibilities to incorporate logical reasoning in to design problem solving as analysis and synthesis. This helps designers to describe design from a general and abstract concept to a more concrete and specific idea. Based on various literature on design methodology according to Salama (1995), originally based on the concept /analysis that was developed by Hillier et al. (1972) the concepts that have a direct relation to different approaches of designing are:

-Induction- Deduction- Abduction.

Induction :

Induction generally indicates that ‘there something actually is’. It is a process of reasoning and finding a unifying pattern. Designer’s main concern is to establish and explain the rules (design) by which facts are connected. S/he can do so by finding connection with other general facts (world view) and uniting those facts with design problems or given facts. Salama (1995) identified induction process

having three steps as: a) observation of facts, b) formulating theories to establish these facts and c) testing the theories by experimentation.

Deduction:

Deduction however proves that ‘there something must be’. This is also a method of reasoning by inferring or making presumption from general rule (world view derived from multiple theories) to a specific solution.

Abduction:

“Abduction is a process of productive reasoning” (Salama, 1995, p. 84). This offers possible solutions by telling ‘there something may be’. Abduction is a process when designer finds strong resemblance between facts in certain given respects and infer to other respects that they may strongly resemble one another.

In their study Hillier et al.(1972) formulated the concept of ‘conjecture-analysis’ and supported by their proponents as Akin (1979), Cross (1984). They argued real knowledge cannot be acquired by just simply observing what designers do when they design.

Hillier (1996) asserted that theory aids creative process when design arrives and analytic process to predict whether that particular design will work and be experienced. The covertness nature of this connection often misguide designer to identify how normative aspects of theory directs where to search for design solutions and how analytical aspects forecast of workability of the solution. Abstraction and concretion are

two processes fused together in design and thus it entails both normative and analytic theories as he claims while introducing theory and design,

> *" The word 'theory' is used not in the common architectural sense of seeking some set of rules which, if followed, will guarantee architectural success, but in the philosophical and scientific sense that theories are the abstractions through which we understand the world. An architectural theory, as we see it, should deepen our grasp of architectural phenomena, and only subsequently and with great modesty, suggest possible principles on which to base speculation and innovation in design. Such a theory is analytic before it is normative"(Hillier, 1996, p. 3)*

Several aspects as prediction or foreseeing require experience and logical reasoning based on knowledge, intuition and experience. The problem with the prediction is – designer needs to know and understand some 'non-discursive' factors as form and space and how they will be experienced once build that usually remain unknown at the creative phase. Hillier (1996) suggested two logical ways of this prediction, 1) from known precedent, 2) theoretical principles. The problem with following the precedents persists within the definition of design as building to be created should free from the idea of exact copy of one which exists; precedent therefore only be used for parts of the building and "parts will not work differently in the context of new whole."(p. 62). Precedent is necessary with only proper interpretation if we want concrete evidence in support of prediction. Prediction based on theoretical principles however requires knowledge on theoretical discoursers. To gain advantage, architect needs to work within

a particular theory that contains the solution in it. Both means of solution of prediction are based on experience where the former is specific and the latter is general.

In architecture, as in any organized human endeavor, after the principles have been established with scientific precession, the application of those principles to the solution of specific problems become a subject of art. Designers are always involved in a process of defining problems, and developing solutions as well as making inferences, establishing and finding rules in order to connect the facts. By testing theories they interpret those facts. It is believed that a good and working theory will contribute by aiding creativity.

By observing the relationship among CAAD and architectural design this study tried to establish a well-defined theoretical platform that would help digital designers with providing references and views. The basis of this theories can be architectural theories and methods accompanied by computational theory. It is very important to have a theoretical framework upon which we can depend in case of seeking for directions while lost in search for ideal design solutions. Hertzberger (1995) noted on this regard as

> *"The architect's design process, as such, should be viewed more as a method of research. It should then be possible to make explicit the steps of the process, so that the designer is better able realize what he is actually doing and what reasons are guiding him…… We work according to strategies to achieve specific aims, preferably with as limited means as possible" (as cited in Hill, 2002, p. 409).*

However, perhaps the most significant field of study at the moment involves the impact of new technologies in education, practice and construction. Architects usually engaged themselves in theoretical debates about styles, principles etc. Hillier (1993, 1996; Hillier & Hanson, 1984; Hillier & Leaman, 1974; Hillier et al., 1972) argued in several literature that theory is indispensable component of design and it exists in practice itself not only in a bookish appendage to practice. In search of architectural theory Hillier(1993) noted its importance and obviousness as:

> *"Architects use theories in design, knowingly or unknowingly, not only because the creation of forms must reflect how the designer understands the world, but also because architecture, unlike everyday building, seeks as yet unknown forms, whose nature cannot, by definition, be predicted from experience."(p. 9)*

Among many diverse perspective of theory and its association in design process, I find the process of design as nonlinear and non-discursive that evolves through both creative and predictive phases. Designer has to go through theses phases until s/he finds a solution. Certain capabilities of generative and performative processes have been enhanced by incorporation of digital methodologies in the design process. As a result of this it is changing the theoretical processes and sequences of conventional design as well as redefining theory itself. More implication of different methods based on digital media need to be involved in various phases of design to strengthen theoretical frame work that designer may arm themselves with. A few arena where as a researcher and designer can implement theories are: a) Research method: for searching problem and data collection

via web database management and mapping techniques, b) Qualitative and quantitative method: for analyzing and interpreting a design problem with various applications as GIS, Space Syntax etc. c) Design method: to reinvestigate conventional approach and search for new options and perspective of design thinking. d) Graphical representation method and e) Construction method: though it is not considered as an important factor in education most of the research has been conducted in this category.

Theories of Design Thinking

Drawings, models, sketches, doodles, notes, interviews etc. act as a storage device to freeze the memory for later evaluation and manipulation as they depict the intuitions and thought process associated with design. Among many contrasting theories related to the phenomenon of human thoughts, the great behaviorist Thorndike argued that the only basic process that human intelligence comprises is the formulation of associations(Thorndike, 1932). Advocates of this line of thoughts explained thinking as a direct association between stimuli and response(Bryan Lawson, 2005). Gestalt schools of thoughts theorize thinking as a process and organization rather than mechanism. Markus identified designer's own experience, others' experience, existing research and new research as the basic sources of information that contributes to the design decision making(Markus, 1969). These cognitive theorists' arguments on exploring design process elaborate our understanding by drawing many parallels between thought and perception. The most well recognized division of 'thinking' adopted by psychologists are "reasoning" and "imagining". Reasoning directs towards a particular conclusion by using logic, problem- solving, concept formulation and other purposive methods. Imagining on

the other hand, derived from individual experience, relatively unstructured, creative and artistic thoughts. Unlike design that is focused to solve real world problem, art is mainly self-motivated expression of one's inner thoughts.

2.5.2 Digital Design Theory

Ideational impact of digital technology in design is one of the influential factors that many theoreticians considered while attempting defining any paradigmatic approaches in architecture (Kwinter, *et al.*, 2004; Lynn, 1999, 1998). With the new knowledge base and skill set design discipline has become rich with diverted ideas, methodologies (Y. T. Liu, 2006; Oxman, 2006) and conceptual contents(Lasch, 2006; Reiser & Umemoto, 2006 in Oxman, 2008). Introduction and --continuous addition of new design modalities presents with new digital methodologies that enhances certain capabilities of generative and performative process that were never before available in conventional methods.

Thus it creates demand of a unique set of design logic through formulation of the symbiosis between the product of design and the way it is now conceived, generated and materialized in digital media. Researchers (Knight, 1999; Knight & Stiny, 2001; Oxman, 2006, 2008; Oxman & Oxman, 1994) along this line of enquiry claimed that- digital design and design computation has evolved a unique educational framework by influencing theory, computing and cognition associated with design; its education and pedagogy.

Most of the design theories are deep rooted in to paper-based culture of design that raises such questions as- can those be adapted to the new situations of digital models and arbitrated design process or is it reasonable to assume that we can now theorize the forms of 'digital design thinking'? How do we conceptualize the 'paperless studio'; what is its knowledge content and what is its expected educational contribution (H. Hertzberger & Rike, 2005)?

It appears to be important to reconsider certain existing theories of design and education. Concepts and theories such as 'design thinking'(Rowe, 1991) introduced a dominant cognitive model of design. Around the same time to presents the idea of knowledge in design and what this might imply with respect to new approaches of digital design education- new term as 'designerly ways of knowing' (N. Cross, 1982; N Cross, 2007) has been coined.

Up until today theories derived from studies and design research related to conceptual and exploratory practice of traditional paper & sketches -based design process often emphasized on designer's interaction with its process of reception (perception), reflection (interpretation), and reaction (transformation)(N Cross, 2007; Bryan Lawson, 2005 in Oxman, 2008).

'Dialogue with the materials of the problem' and the process of 'backtalk' from visual images are some of the most common models characterized by Schön (D A Schön & Wiggins, 1988) to explicit thoughts and reasoning that is being practiced in design studios. It is still considered to be a dominant model to explicate thought and reasoning which is evidently associated with paper-based media. It is hard to identify if any or some

specific theories of design are derived from Schön's model of cognitive theories of designing but its general characterization of design as reflection supported by representational process shows a comprehensive authority on architectural design and its education.

If the characterization of design as reasoning through the exploration and manipulation of graphical symbols has become less relevant as a description of design with digital media, how can we characterize digital models of design? Today, it has become important to re-consider the significance of digital media and what they might imply with respect to a different characterization of the design processes.

Contemporary practices of digital media are different form traditional design media in terms of their cognitive phenomena, pedagogy, process, practice, and epistemology. Researchers and educator Rivka Oxman (2008) raised questions on method of characterizing and establishing a generic model of digital design by stating-

> *"Are we encountering the same cognitive phenomena of known processes of design in the new digital media? Or are we encountering new forms of knowledge, new scientific foundations, and new models of design? A basic assumption presented here is that we are, in fact, facing new terrain in design thinking and that there is a need to formulate a rationale for digital design didactics. We describe below how it is possible to explore the role of digital media in relation to the way knowledge, concepts, design models, digital processes and methodologies are related in digital design"* (Oxman, 2008, p. 102).

Architectural Design in Digital Environments

Design is experienced performed and explained diversely. For instance Lawson (1994; Bryan Lawson, 2005) defines architectural design as an act of creation, when Dorst and Cross(1996) focused on more customary definition of design related to any action involving artistic intention. Many contemporary researchers have considered differentiating design based on the platform (traditional/ physical and digital/ virtual) it is performed (Bridges & Charitos, 1997). To establish a framework as basis for this thesis this study will not identify or concentrate on a specific definition of design, but provide a background of different interpretations.

Designers use a wide variety of media to express his or her ideas. Throughout the course of a project, different representations are used at different times to explore different issues (Lawson, 1994, p. 90). Theoretically an architect can generate drawings using any kind of modality, such as all types of paper, pencils, ink and paint and all sorts of CAD applications. Lines and shapes in a drawing can be soft edged or hard lined, vague or precise. Mass or detailed, physical models can be created using a vast array of materials, such as metal, cardboard, clay, and plastic which represent an abstract form or the real appearance.

As designers start to gather all these representation s/he begins to identify constraints, prospects, and references which are important for developing solution. Using representations such as perspectives, plans, elevations, sections or models designers articulate sketches of their thoughts in order to understand and communicate the design. The differences between manual and digital modalities as well as their cognitive

involvement with designers' mind are significant and undeniable. Since the introduction of CAAD by Sutherland's Sketchpad (Sutherland, 1964), extensive research has been undertaken to explore possibilities and potentials of different modality and its implication in design and often specifically during early design phases (Goel, 1995; Goldschmidt, 1991; Bryan Lawson & Loke, 1997; Edward Robbins & Cullinan, 1994; Schon & Wiggins, 1992; M Suwa & Tversky, 1997; Verstijnen et al., 1998). However, it is important to perceive and comprehend the fundamental differences of different modalities by looking at their purpose and effectiveness of resolving externalization need of a designer at a specific moment. As they illustrate the diverse nature and expressions of the drawing techniques which has a powerful influence on how designer sees and perceives a design.

Paper-based or manual design process and thinking as a base of design education is globally accepted as well theories regarding its attributes. Researchers in design education started encompassing cognitive aspects around early 1980s. Schön (1985; 1992)and his advocates, one among them concentrated on designers where Oxman (1994) focused on knowledge and design thinking. Many other theoreticians took initiative to identify and explain digital paradigmatic approaches and its ideational impact in design (Lynn, 1999, 1998).

Most of the researches conducted during early eighties recurrently reported restraining effects of CAAD systems. However, it was also claimed that – despite high expenditure of hardware and software it was relatively user friendly (W. Abdelhameed, *et al.*, 2002; Rauhala, 2003). Perhaps the reason was the introduction of a groundbreaking

technology in the realm of design that emulated the drawing process followed in conventional work process in the later phase of the design. Research and developments on this regards is still an undergoing process with the emphasis on deploying a system or a series of systems that will work as an effective digital sketching device that will offer sufficient creative aid to the designer. The process of developing a generic solution to this issue is immensely complicated due to the nature of design as well as the subjective attributes of the designer. Brown and Horton (1991a) as well as many other design researchers agreed on the fact that different stages of design is associated with different kind of drawings and showed how contemporary computer applications could be modified to accomplish the need of pictorial representation more efficiently.

Like many other researchers and educators Dura (1991b) claimed- "Sketching lays a manifold role in design and design education now as much as it did in computerless days. Design sketching is indispensable during the early design process". Sketches and other forms of manual modalities are often considered as reflective conversation with the act of design and understanding this conversation is the key to develop a sustainable design solution (Schon & Wiggins, 1992).

2.6 Drawings and Types of Drawings

Design researchers experimented and established several form of classification of drawings. Iain Fraser and Rod Henmi (2000) analyzed specifically architectural drawings and suggested five types of drawings. These drawings are: a) Referential

drawing, b) Diagrams, c) Design drawing, d) Presentation drawing and e) Visionary drawing. This taxonomy is largely based on the characteristics of drawings. Each type of these drawings has its own set of rules which are largely implicit and depends on designer's knowledge. Some of these drawings are prepared for public communication whereas others are to internalize or interact with designers him/herself.

Diagram usually refers to a drawing or expression of externalization that uses geometric elements to abstractly represent natural and artificial phenomena such as sound, light; building components as wall, windows; human behavior as sight, circulation and other such attributes. Often considered non-pictorial, this type of drawings is also known as charts or graphs which include various forms of 'diagrammatic representations' with minimum to none physical or visual qualities. The focus of these exploration or thinking drawings in form of bubble diagram or other form of archetypal design diagram is on problem or solution. It shows important relations between elements through brief graphical representation.

Diagrams often developed into proposition drawing. Designers tend to refer back to it without remembering and this incident creates an unconscious over constraining of a problem. This happens mainly because of a major characteristic of diagrammatic drawing which should remain as fixed authoritative representations of knowledge rather than speculation (Herbert, 1993).

Media of communication between designer and their audiences are generally known as *presentation drawing*. These types of drawings are prepared only to convey current status of design or final design. Often than not theses drawings are exaggerated

with intention to impress the jury. With the advancement of CAD system designers are increasingly adopting and utilizing computer techniques to produce these crisp, intense images of their design drawings.

A less ambiguous linear mode of communication from the designer to builder is conducted by *instruction drawings*. These kinds of drawings are often prepared after a significant amount of design issues are resolved and ready to be described. Often deliberately created and selective in nature, instruction drawings reveals a little about the thinking process implemented in design.

A special category of presentation drawings primarily created to communicate with clients, stake holders and other participants in the design process to collaborate and assist the process itself in known as *consultation drawings*.

An *Experimental drawing* unveils designer's natural and habitual tendency of drawing more often than only when it's needed during design development. It is an excellent lesson for the design students(Porter & Goodman, 1988). This process of drawings is one of the most efficient way to absorb design idea because of the transformations on an idea through collaboration and integration of mind, eye hand and media result in a level of understanding not necessarily achieved via simply looking at or observing, photographing, computer modeling (Bryan Lawson, 2005) and such.

In this regard Mark Gross (1994 in Lawson, 2004) quoted while describe the impact of Louis I. Khan use of vary thick charcoal sketch as-

" ... he cheated a lot. That charcoal line was very thick ...he would make everything work and then he'd go away. You wouldn't see him for maybe the next day, and you were left with these very thick lines that when reduced to realistic wall thicknesses and spaces – you couldn't put this functional stuff back in."

Using thick vague tools on the early design process makes it easy, quick, less precise which later turns in to a finer detailed drawing using CAD system left the transformation more complicated as Mark D. Gross (1994) mentioned.

Proposition drawing often considered as a design drawing(Von Wodtke, 2000) since it is the heart of design process where designers process possible design outcome. When a designer 'have a conversation with the drawing' (Donald A Schön, 1985) they work with proposition drawing (Bryan Lawson, 2004). Some researchers argued that these drawings changes and reforms as the design process moves from a vague and sketchy to more precise and concrete from. Goel (1995) describes this as –'there is an increase in the degree of expectation and detailing'.

Some literature distinguished another highly speculative drawing that often shows many of the characteristics of both proposition and presentation drawings are called 'visionary drawing' (Fraser & Henmi, 1994), or 'fabulous drawings' (Bryan Lawson, 2004). Generally used by designers in an artistic form and not used to test an idea but rather to let it flourish and develop so they are usually 'uncritical'. It often represents something that yet does not exist and offers a suspension of disbelief, criticism and realism. The suspension of disbelief and criticism are some actions practiced in creative

thinking procedures as developing design drawings through synaptic (Gordon, 1961) or brainstorming (de Bono, 1970).

Calculation Drawings often considered as a special case of propositional drawing where calculations are effectively altered or substituted through fairly rough but quite precisely constructed drawings using formal drafting methods or CAD (Herbert, 1993). These kinds of drawings illustrate how some aspects of the proposition will turn out. Seldom is this kind of drawings prepared for the purpose of visual effects or to communicate with others rather than for understanding and confirming the implications of some state of a design proposition.

2.6.1 Importance of Drawings

The importance of drawings and visual thinking in design has been stressed in many research studies since it is considered as the 'reference' that transforms and initiates the later composition (Graves, 1977) and conversation with drawings (Bryan. Lawson, 1994); record the sequence of design moves (Goldschmidt, 1991), formulates a graphical conversation with material of design (Schon & Wiggins, 1992). Drawings also support the design process by "directing, order, clarify and record ideas" (Edward. Robbins, 1994) since research on design thinking argues that it is a "principal mean of thinking" (Herbert, 1993) that let designers inquire about shapes and ideas of buildings and spaces(Rowe, 1991).

In summary some of the major significance of drawings are:

- Designers make extensive use of drawings and they are often central to the thought process employed in the design.
- Designers use drawings not just inside a project but as a way of sorting knowledge and linking ideas from one project to another.
- Designers are usually very visual people and drawing is the primary media of visualization.
- The visual world which designers seem to understand and appreciate is actually one which they manipulate directly through conventional language.
- Designers are able in some way to think visually. Through drawings they represent their thoughts physically.

2.6.2 Exploration with Study Drawings

The methods of classical science research of breaking down problems to get in to solutions do not work for design problems as it do not juxtapose predictably or theoretically describable way with each other. The ambiguity of the informal drawings enables a designer to read more out of a drawing than it initially intended for and thus it often generates new meanings and feed designer's thoughts.

Unlike completed presentation drawings, study drawings are often incomplete and contingent. These are also intrinsically problematic which is neither neutral nor transparent. Herbert (1993) sought in his book Architectural Study drawings that study

drawings or design process and their associated drawings should focus on active participation in formulating the design rather than passive recording of the process itself. He suggested five epistemological properties of study drawings required to understand to comply with the interactive design process.

1. Pre-existing parent culture and architectural sub culture is often embedded as an imposed order and tacitly determines the design.

2. Designers continuously reinterpret the marks developed from the graphic process to generate information which constitute the drawings.

3. The ambiguity of the design task and its process is often than not introduced by the nature of study drawings that embody graphic and cognitive process.

4. Graphic conventions impose certain order on our perception, creation, storage, retrieval etc. which allow designers to move from personal drawings and remarks to more public and formal communication.

5. Continuity and change in dynamic design process can be observed through the use of two different types of drawings: context drawings that includes the evolving design decision in a presumed order and the ambiguous exploration drawings to investigate selected design issues abstracted from the context drawings.

While establishing a theory of symbols, Goodman (1976) in his influential book-Language of Art, considered three kinds of documents: specifications, rendering and construction drawings. Among these types architectural renderings are more complex in nature as it constitutes of sketches which is according to Goodman “do not define a

work… but rather is one”(Goodman, 1976, p. 193). However, early design drawings lack a strong theoretical basis in comparison to other form of drawing. Graphic theory for making presentation drawings and construction drawings is well inscribed as well as its application has been codified into rules through education and practice.

The inward focus or internalization purpose of the initial drawings makes it more personal and informal in appearance where graphic conventions are usually less complex. In contrary, formal drawings are targeted toward external and often anonymous audiences. Frequently misjudged study drawings are not strictly confined to early conceptual phases rather often may be used in later phases of the work to experiment and evaluate a solution of a problem or a detail that emerges at the time of preparation of construction drawings or even during construction.

2.6.2 Drawings and the Design Process

Interest in design process has increased in the past few years so as related architectural researches and publications. This contemporary new area of research have confirmed the importance of graphics as a field of study and means of design thinking which explored specific techniques for effective drawings in design.

All extents of design processes disclose its one major attribute- the use of various kind of drawings. The processes of design involve the use of relatively abstract illustrations as functional diagrams, plans and sections as well as more unstructured form of pictorial representation such as sketch. These are frequently employed in collaboration with more realistic visual demonstration like perspectives and orthographic or paraline

projections rendered in color. As the design process gets closer to the solutions highly structured and detailed representation of their preliminary ideas formulates in more articulated manner. Enough empirical studies has undertaken to advocate the importance of these seemingly unorthodox and more personalized type of drawings developed during the idealization and development phase of design (Herbert, 1993). Gero and Purcell (1998) scripted in a study that – designers spend a considerable amount of time looking at representations of previous designs that act as precedents in the design process and has significant effects on the cognitive process involved on synthesizing design solutions. In another study Gross *et al.* (1988) argue that drawings prepared in the early phase of design process are particularly important as it embody abstract and high level design ideas that allow a degree of uncertainty about physical attributes and enforce constraints.

Herbert (1993) in his book- Architectural Study Drawings, identified the aptitude of architectural sketch drawings as a provider of graphic means to transform facts from cognitive experience. This conceptual knowledge is then recalled and manipulated into visual representations relevant to the solution of design problems. A small number of recent empirical studies have however been focused indirectly on yielded information about the role of drawing in design (J S Gero & Purcell, 1998).

More often than not these different types of drawings are allied with different phases of design. During the early phase of the design process relatively unstructured and ambiguous drawings as quick sketches, diagrams, notes are typically used by designers. These drawings are considered to be closely associated with innovation and creativity and play a vital role on shaping the design solution.

As design develops and moves to the next phase more structured forms of representation, such as plans, sections, elevations and such scaled drawings become essential parts of the design and its development process. Unstructured form of illustrations or pictorial representations are considered more closely related to creativity and innovation (Herbert, 1992). However, empirical evidences regarding these thoughts are relatively sparse. To address this issue many recent researchers in the field of design slanted toward relating their research in cognitive psychology and science to better understand the significance of design drawings and its final outcome (J S Gero & Purcell, 1998). At the same time to provide possible insights on cognitive process associated with the use of drawings in problem solving in design researchers in cognitive psychology stressed on relating working memory, imagery, mental synthesis and such.

By analyzing design protocol Goldschmidt (1989, 1991, 1992) developed a model of the design process. Based on the role of drawings and psychological process she divides the design process into 'moves' and 'arguments'. A series of design activities are distributed into smaller units or chunks of design reasoning are denoted as 'moves', which is '... a coherent proposition pertaining to an entity that is being designed' (Goldschmidt, 1991, p. 125) . Whereas any particular design move or statements about the design are related with 'Arguments'.

Schön (1992) described design as an investigation that involves reflective 'conversation' with the material of the design circumstances. He inferred designers 'sees', 'moves' and 'sees' again through visual medium as drawings. Through this process designers visually register information as well as construct its meaning by

identifying patterns and developing meanings beyond their visual attributes (Schon & Wiggins, 1992). Designers use various modalities and draw on a medium to literally see the evolving products of their work.

As design moves from preliminary phase to refinement and reaches further developed stage level of detail increases so as the explicitness of drawing and notes. This transformation can be of two types – as Goel (1995) identified. One is 'lateral transformations' that refers to the movement of a particular idea to a different one and in most cases this occurs in the preliminary design phases. Association of various forms of unstructured drawings is a major characteristic of this phenomenon. Designers tend to shift their modalities to benefit the process of externalizing the information generated during ideation phase into a more explicit from.

Second , 'vertical transformations' where a single idea is transformed into a more detailed form and occur during the refinement and toward more mature stages of design development phase which mostly is associated with considerably detailed and precise drawings.

By examining and comparing design protocols in both traditional and computer based drawing system it becomes evident that digital means are not as rich and often unambiguous thus it makes lateral transformation difficult which essentially is an important aspect of the design process.

Design knowledge on various information domains that designers use during sketching can be differentiated in two levels. First level consists the emergent properties

of drawings which according to Suwa and Tversky (1997) includes elements depicted in the sketches as well as elements that are emerged from inspection of the sketches. Which they subdivided in to spaces, items, shapes and sizes, spatial relations (both local and global), functional relations (views, lights, circulation, and other functional relations) and conceptual or background knowledge. If the protocol is now segregated into similar categories or segments based on the above mentioned attributes as spaces, items, shape, spatial relation and qualities then segments those are conceptually related can be grouped to develop dependency chunks. Designers often shift their focus during the first segment of a dependency chunk while remaining segments are observed as continuing segments.

2.7 Digital Media in Design

Since the ancient time as a practical form of art, architecture needed computation and computational aids. Renaissance's contemporary interpretation on Vitruvian ideal of reflecting the proportion of the human figure in every temple required computational aid. Computers unarguably excel in keeping track of all the goals and constraints that a design solution must accomplish as well as group the information into related issues based on the precedent analysis and even offering alternative standard solutions that better fit the problem. Once this superb analytical engine satisfies its user with logical conclusion then it could help represent the solution graphically and numerically. Designer's familiarity with the communicative language is crucial here as it often appears easy to communicate from computers to humans with some degree of intelligence on textual, numerical,

graphical and auditory modalities. On the contrary, communicating with computers are relatively complex and aggravating especially who lack the ability to interpret. In last fifty years the majority of computer aided design researches have been conducted on developing computational systems that would help designers during design process. Designers today use computers as a drafting and modeling system that support human designers in drawing lines and other geometrical entities which has a little to no meaning to the computer's analytical system.

The attempt of incorporating computer use in design studios is still ongoing. The worry was the negative effects as undue constraints imposed by the new possibilities of digital design studios. There were constant comparisons with traditional, manual techniques. Digital design is no longer questioned. The current interest is in how to most effectively conduct digital design studios. There is a healthy interest in developing new design techniques and even new software for studios of future.

Surprisingly a few researches related to digital design studio describe design studio analogous to conventional studios, where a primary emphasis is on design quality on addressing all phases of a building design as – talking a building design form initial concepts and program to design development and presentation. Most of the researches took a special focus on some aspects of the design process. This perhaps because computing still involves so much overhead that the focus must be reduces from a conventional studios or studios either resisted computing or accommodated students using them without explicit recognition or revised pedagogies.

So the questions remains.. “Do computers make differences on digital design studios?”

If the use of computers in design studios makes a difference, should it be just allowed to just happen or should the momentum be guided by studio teachers skilled in computing.

Does the use of computers in design studios demand a special pedagogy that goes beyond teaching the user of hardware and software?

Are there design approaches that should be taught best advantages the strength of computers in design rather than make computers follow the paths trodden by manual design techniques?

The importance of the design studio in the current curriculum of architecture school cannot be overestimated. Students reinforce the studio-centric culture through academic scheduling and social structures. Thus, by definition, examining the role of computing in this educational context is crucially important. In the intervening years, the number of studios that focus on the use of the computer as a design aid has continued to grow.

In the process of creating and developing architectural design ideas computer aided drawings play a major role if not entirely conclusive. Designers use drawings for exploring their concepts of built form free from the constraints of construction. Computing media integration in design studios is basically a negotiation between year old analog design and considerably new digital production system. Digital tools are

immensely evolved and sophisticated than it was even a decade earlier but the disposition of architecture require some direct reference to the analog world. The ontological character of architecture as grounded, defined, developed on materiality, tectonics, embodiment and presence are evident and cannot be completely supplemented by electronic simulation in virtuality (Bermudez & King, 2000b).

The competitive interaction between the two media is not the extinction of the analog in the hands of the digital but rather a coordinated and collaborative coexistence of both representational systems; each one highly evolved to do what it does best. Digital will not displace/ replace the representational power of analog but instead will help clarify its different strengths, force specialization and complementation which often among others stated by researchers as Bermudez(1997b),Cheng(1997), Herbert(D. M. Herbert, 1994; 1995), Smulevich(1997). Even though technological advancement resulted in an increased abandonment of analog tools in preference of the new fashionable digital system of production, "it is more likely that the outcome of the competitive interaction between the two major set of modalities is not the extinction of the analog in the hands of the digital but rather a coordinated and collaborative coexistence of both representational system, each one highly evolved to do what it does best" (Bermudez & King, 2000b, p. 8).

This is however important and challenging to develop a productive method to allow representational media interaction instead of rushing to digitize all architectural work. Because the currently, this challenge is methodological and paradigmatic rather that technical as to support this kind of work most of necessary equipment are available

in most of the schools and offices. Although there is a territorial line between these two broad modality categories, a necessary outline need to be drawn to investigate it systematically to develop an approach or methods and theory to bridge the gap between them.

Academia is the perfect place to perform this job. Having grown up surrounded by computers and pressed by the real need to develop marketable skills for jobs, architecture students slowly began bringing their own computers to studio; resulting schools find themselves having a hybrid productive environment with little or no elaborated pedagogy and theory to deal with it. This is why there are a little or no instructional procedures or concepts about how to negotiate the interface between digital and analog media. Students are left alone to figure out these connections. This often produce superficial, wasteful and frustrating use and understanding of what otherwise could be a powerful productive environment.

2.7.1 The History of Computer Aided Design

Computers were first evidently used in building industry for various engineering analysis though the design process was usually manual except for feeding the data retrieved from the drawings for quantitative assumptions. Experiments in using computers for architectural design first emerged in academic circles in 1963 and by inventing implementation tools and incorporating modern concept of CAD Ivan Sutherland and S.A. Coons developed a mean to integrate evolving design and analysis program. Computing systems strongly announced its appearance in architectural practice

during 1970s when CAD divided its attention into two different directions: geometric modeling and building specific modeling.

Due to the introduction of relatively cheap personal computers, display systems, graphic input devices to the market CAD system became affordable to large design society. As a result, demand for more useful program started to appear. Specially, the introduction of the Macintosh in January 1984 made the drafting on a personal computer both practical and operable to non researcher designers which eventually encouraged companies like AutoDesk, VersaCad, Summagraphics, Micostation and others to marketed software explicitly to support the drafting aspect of architectural design. To capture this thriving market other companies as Auto-Des-Sys, Kinnetix, Graphisoft, Revit and such started developing various modeling and rendering software for the architects and digital movie industries.

As a result of this overwhelming data processing, efficient drafting and rendering power architects seemed to lost their analytic capabilities that was initially the foundation of the introduction and development of computing initiation into this industry (Kalay, 2004).

2.7.2 Role of computing in architectural design

The way built environment is conceived, constructed and used has changed significantly in last few decades where technology acted as a driving force. In architectural design computers empowered the process by efficient execution of some specific tasks much precisely or effortlessly more than any other tools even though it is

assumed as an Instrument with no artificial intelligence of their own that can mimic or augment the abilities of an experienced designer. It just replaced the traditional paper and ink with binary digits and electronic implements

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With varying degrees of impacts and numerous roles, computation in architecture as a tool stretches from augmenting certain traditional activities to more extensive impacts on design environment itself.

2.8 Design Modality

Different discipline of knowledge has its own established concepts for analyzing and studying supporting materials. These concepts can be incorporated or applied in study of architectural drawings with appropriate adaptations. For example, arts and

literature focuses on interpreting already completed works as performance, pictures, texts, products, artistic process and such for a critical analysis. Critical analysis focuses on design process and its associated graphics; however they are more often accomplished for the final products. Herbert (1993) concepts from disciplines in humanities and science show that any representation is inherently problematic, that any medium introduces substantial new issues into its own discourse, and that all thought is inseparable from its medium of formulation and expression. The medium does not hold the content, as our ordinary terminology suggests; medium and content fused, or perhaps it may be said that the content is function of the medium.

Such ideas raises fundamental questions about graphic media and design content, especially about study drawings as the designer's principal means of thought.

2.8.1 Interaction between Modalities

To understand media interaction between digital and analog during design process it is as vitally important to collect information objectively as relating and testing acquired data. The need for systematic study reflected in other researches indicated that this cross referencing of work possess the ability to move architectural thought, production and education to a higher level of competence.

Literature review of existing researches reveals that not until mid-80's when digital media began to be really employed with some degree of success in design process. Around that time the dialectic between analog and digital systems begins to be directly and indirectly addressed. Developments remain steady until after 1994, and there is

literally an explosion in research work in this area. It is believed to have a direct impact of Herbert's seminal paper "A Critical Analysis of Design Processes and Media: Applications for Computer- Aided Design"(D. M. Herbert, 1994) and few other reactionary books by McCullough (1996c) and W. J. Mitchell &M. McCullough (1991). The importance of cyberspace communication and production is certainly undeniable as it has the ability to revolutionize the way of thinking and making architecture.

Even though the list does not appear to be complete, nineteen assumptions were made in support of a relevant yet diverse lines of inquiry by comparing and summarizing documented experiences over the past decade.

A substantial number of hypotheses present fundamental premises and concepts of the media interaction process though these could be versatile regarding all media iterations. This study is proponent of this fact that- the shift between digital and analog increases the design impact of media well beyond traditional iterations within the analog.

Some other directs to the essential characteristics found in analog, digital and hybrid media; some offers interfacial issues surrounding the media interaction process. Whereas few others apprehended findings in the area of architectural representation and dealt with the relationship between the media interaction process and architectural theory. Reminder hypotheses presented pedagogic implications and issues that seems to be needing more experimentation.

2.8.2 Modality Shift in Design Process

Media and design process are highly interrelated. Media and design process/methods associated with media have direct impact on its development process as the way it conceived, developed and communicated (Osman Ataman & Bruce Lonnman, 1996). Herbert (1994, p. 136) mentioned in his writing: rather than being "neutral, transparent and timeless" media and processes are more "intentional, substantial and timely ". Analog and digital media representations should not be considered as mare "tools" for externalization of design thought and making. These are "matrix" or media that is, environments where designers get fully involved kinetically and mentally with the issue of architecture (Bermudez & King, 2000b; DeLaura, 1997; D. M. Herbert, 1994; McCullough, 1996a).

Modality shifts, multiple iterations and interactions of digital analog media improve the design process(Bermudez & King, 2000b). One of the most undeniable stages of design development is transition and re-interpretation of ideas which could be either smooth or problematic. Modality shifts offer great chance of improvement and it enhances the design process in cognitive, qualitative and productive terms. (Bermudez, 1997b; Chang & Y, 1995; Herbert, 1995; Kellett & Ronald, 1996; Matthews & Temple, 1998; Parsons, 1994).

Interaction and alteration of modality encourages doing as an extension of thinking, not just to prepare a product of thinking. In other word it prefers idea and practice of process over product, doing over thinking. It is observed that designers with attachment of final products often demonstrate restrictions to non-stereotype and creative

thinking. Whereas multiple modality interactions offer such fluidity in movement of design process that designers could easily overcome this stagnant situation. Researcher as Ataman(1996), McCullough(1996b), Neiman(1997) and many others identified the paradigm of a considerably new trend in pedagogy of experimentalism, play and constructivism which follow the rule of "learning by doing".

Different modalities offer diverse features and perform distinctively in different stages of design; they however, immensely dependent on accessibility, user's aptitude, competency and such. During early design stages effective and quick development of ideas are important. Analog representations proved to be much competent than its digital counterpart due to its fluid nature. Researchers as Cheng(1995), DeLaura(1997), Kellett (1996), Novitski, Solomon, Steigh, Goldman and others as cited in Bermudez (2000b) referred to various influential characteristics of manual modalities as -- its fluidity and appropriateness for initial and fast development of ideas, externalization (simulation) of imagination, free inquiry, intentional and random cross reference of diverse source, the communication and evaluation of tectonic/ light studies, the manipulation and visualization of scale, the expression of emotional states etc.

As design process steps into the next phase (design development); digital modalities are more likely to play effective part as this phase generally requires higher degree of geometrical definition and abstraction, elaboration and coordination of complex detail, evaluation, articulation and generation of visualizations (multiple view points), manipulation of information (imagery), sorting and resources (models and images), immersive and photo realistic rendering, 3d simulation. Researchers as Barreneche

(1996), Bermudez, DeLaura (1997), Goldman(1987), Kaiser (1993), Smulevich (1997), Solomon(1995) and many others has agreed that most of the above mentioned characteristics of digital modalities are more often than not results in a modality shift, since effective implementation of these actions require some degrees of competency.

2.8.3 Selecting and Switching design modalities

Selection of and switching between design modality roots deep into the mechanics of drawing and drawing preference as well as various other individual factors influencing degree of conveying semantic information. Van Sommers (1984) studied "drawing and cognition" to identify how people use speed, pressure, and line weight; Goel (1995) argued that- design cognition is supported by sketching in such a way that is impossible with more finite and precise representation. Larkin and Simon (1987) identified diagrams can be advantageous for certain kinds of cognitive tasks. Study conducted by Suwa and Tversky (1996) revealed relationship between concepts and graphical acts of sketching. Most of the studies on design process and drawings appear to be in agreement that- drawings play an important role in supporting design reasoning. However, a little work to date has examined the effect of using various design modalities on design process and reasoning behind shifting the modalities during various stages of design process.

Precedents, informed choice and theoretical back up helps designers developing a basis of selecting what role media ought to play in their design activity and indicate how the role of media might change in response to different design task. These selections

often influence the kind of media, type of drawings at different stages of design and analytical procedures and drawings for design synthesis.

2.8.4 Reasons of modality shift

Modality shift is a common phenomenon in any form of design. Interaction between various modalities provide a valuable supplement to traditional means – both manual and digital; for generating, developing and representing architectural form and design solutions. Recent experiments revealed many new directions for designers to use interactions between different modalities (Herbert, 1994). For better understanding of rational behind modality shift focus need to be placed on multiple rather than single interactions. Multiple interactions between manual and digital media provide a valuable complement to traditional means. During design process most interactions occur between handmade and digital media are complex. In CAD however, most interactions are simple and single. Designer shifts some substantial part of the design process from a manual to a digital medium or opposite (McLeod 1995; Fargas, 1993). This single directional shift mostly happens at the end of the conceptual stage of design generation when a designer might copy handmade conceptual sketches in to CAD program for further or detailed development (Novitsky, 1994). A backward shift is also eminent, after making 3d massing studies with a computer modeling program, a designer might generate an underlay perspective print for final rendering by hand (Danahy, 1989). In both cases, a linear modality shift closed out a unit of work altogether from one medium and open it up completely into the other; manual to digital, or digital to manual.

This research focuses on the rationale of this shift and its effect on design. To get better understanding of this shift modality theory need to be explained.

Finding reasoning behind modality shift is particularly difficult because design itself occupies a wide range of activities as well as designers initiate similar array of quite different, often unique drawing acts to synthesize and develop design solutions. The cognitive activity of design such as attention, perception, memory and processing can be observed through the act of drawings. This study, essentially is focused on identifying factors that influence designers to make selection of drawings to perform design tasks and reasoning behind switching modalities (a combination and, or sets of design tools) during design process. By observing students' activities as- design process, drawing types and its interpretations, a relationship between these categories is developed. Later by drawing links between these items with design constraints identified form literature review is executed to investigate reasoning behind selection and shifting design modalities. Among numerous design constraints design cognition, knowledge, proficiency of design tools are some of the factors taken into account in this study. Despite of facile categorization, the acts of drawing, interpreting, and design are not so easily separable.

Herbert (1993) identified three effects of integrating media as content in the design studio. First, it improves student involvement in the studio and quality of their work. Second, this may create unusual interest in design process as the graphic study media often influence the content and the form of their design. Third, it helps students to develop and engage the ability to raise many central concerns of contemporary criticism:

for instance, the relation between representation and external reality, graphic and verbal expressions, possibility of representing something that does not exists, necessity of rules and conventions and such.

By nature designers prefer quick and free flowing graphic instruments to match the pace of their thinking during conceptual investigations. The transformation from conceptual to construction drawings is a routine part of any design's development. However, designer normally makes their conceptual study drawings according to the same graphic conventions that are used in presentation drawings. This lets the information in study drawings be integrated directly into later development phase. The properties those prevent the use of this type of drawings as technical documents for construction are- lack of notes, dimensions, and cross references. The absence of these formal requirements means that designers have great opportunity to experiment with the graphic quality of their study drawings, choices of media.

Similarities observed in students' drawings suggest that they (design students) approach study drawings from a common background mostly directed by habit, intuition and circumstance. The idiosyncrasy of personal graphic style and diversifications in subject matter is responsible for the difference among designers' drawings rather than graphic traditions. The essentials skills for effective graphic communication, such as graphic conventions, rendering and presentation techniques largely dictated by instruction in design media; whereas in architectural study drawings instructions is treated peripherally (Herbert, 1993, p. 22).

Manipulation of verbal and graphic statements on the drawing page, alone with their interpretation usually constitutes the events of the design discourse. Verbal statements may be transformed into graphic one either directly by the means of design synthesis drawings or indirectly by other more analytic drawings. During transformation from verbal to graphic notation the analytic statement produced could be a composite of marks and written notes. On the other hand design synthesis drawings are more subjective and interpretive than analytic drawings. Because it brings forward more design issues than narrowly focused analytic diagram and brings them forward more ambiguously to serve as open ended statements for the next round of interpretations in the design sequence.

2.8.5 Modality theory:

Modality theory is comparatively new phenomenon in design and architecture. However, it is not a new theme as much work both empirical and semantic has been done on the information representation capabilities of selected graphical modalities. Investigation on this field mostly addressed the user interfaces, its design for web based programs and various aspects related to human computer interaction (HCI) for graphic and other software packages. Users must enter a complex mix of spatial and abstract information when operating a graphic design application (Andre, 2004). This however is true for any instance of architectural design. For instance- during schematic phase of design, verbal and textual communication provides a fluid and natural method for specifying abstract information regarding concept generation and idea formulation while spatial input device is often most intuitive for the entry of spatial information once the

previous stage is finalized. Investigations and theories in this field are mostly focused on the general problem of mapping task domain information into interactive multimodal interfaces (Bernsen, 1993). When a particular set of information (design problem) is given that need to be exchanged between its user (designer) and system (manual or digital) for constructing a solution modality shift is often inevitable. Bernsen's (1993) understanding of modality theory explicitly emphasized on task performance in context that requires identifying the input/ output modalities which constitute an optimal solution to the representation and exchange of that information. This theory also can be denoted as Modality Fusion, used by many researchers in the field of multimodal system and modality theory. With proper understanding of modality theory and rational behind its shift during design, useful support to contemporary designers can be provided.

By taking the study drawings (in multimodal and unimodal form) as an instrument the designer's (student) thought and by analyzing while focus was kept on every shift between modalities several reasons could be identified. Some external variable as the nature of the project (exhibition space/ designer product display) and instruction from instructor has explicit effect on the overall design solution hence quality of the project.

Designers need to be able to visualize several elements besides the artifacts and look of the environments. According to Lansdown(1994) such elements are *abstractions,* which makes relationship and connection between design components; *behavior,* that denotes performance and attributes of artefacts and systems; *movement*, in form of discrete and continuous. He also argued in favor of these elements as they more frequently and readily lend themselves to visualize than others. Act of design has two

basic task, internalization and externalization of ideas. Both are concurrent process unlike other scientific research. Designers accumulate knowledge and information from various sources to internalize program or design solution. Via visualization these ideas get externalized; something that is an essential feature of designing. A good designer is often accepted as better in externalization of ideas than others even though it must not assume that the best designers are necessarily the best picture makers (Lansdown, 1994). As can be seen in a perceptive article by Jones(1984) where he mentioned that , "… many architects (and most engineers) can hardly draw in the picture-makers sense at all."

Based on protocol analysis of pilot project; related literature, similar research and researcher's experience as designer and instructor, this study identified rational behind modality shift broadly under structured design strategies:

1. Externalization of ideas (Presentation/ Visualization) through Explicit Modalities (Multimodal)

    a) Comfort (User Satisfaction)

    b) Competency (Expertise/ Experience)

    c) Design Process (Formulation/ Manipulation)

    d) Individual Differences

2. Internalization of ideas (Problem solving) through Implicit Modalities (Unimodal)

    a) Studio Instructions.

    b) Individual Learning Style

    c) Cognitive Level (Design Perception)

    d) Focus / Attention

    e) Physical/ Social Context

This research will concentrate its focus on studying how Comfort (User Satisfaction), Competency (Expertise/ Experience) and Studio Instruction generates modality shift during design process. As first two reasons are explicitly related to the choice of modality and have a direct influence to initiate the shift of modality. The third one (studio instruction) is considered in the category of implicit reasoning because of the involvement of many external variables as instructor's teaching style, studio requirements, nature of the project, grading criteria etc.

Comfort:

Although creativity and other arenas as ideation, concept articulation, visualization and most important of all design thinking differentiates one from other architects. Designers with different background and knowledge feel comfortable with different approach toward evaluation and generation of design solutions. Deviation of

Interpersonal and Intrapersonal intelligence among designer causes differentiation of visual design thinking(Wael Abdelhameed, 2004) and cognition action(Kavakli & Gero, 2001) that architects perform and employ. Design can hardly be seen out of the extent of the subject to redefinition and resolution in different ways over time as their formulation depends on the viewpoint of those presenting them. During designing, designers go back and forth in a linked but nonlinear cycle of visual design thinking. This act of formulation causes a discrimination of probable design solutions, redefining the design problems or its sub problems. This rigorous act requires some extent of user (designer) satisfaction. Depending on prior training, social and physical context designers tend to show comfortness with multimodal or unimodal visualization strategies. Some designers feel comfortable with pencil and paper while others are much efficient with stylus on responsive digital screen. Use of CAAD and other CG software also plays a crucial role in design perception. Thus quality of design changes significantly if designers do not work on the canvas he is comfortable with. This research hypothesizes that based on comfort designer switches their explicit modalities. In support to this statement Lansdown's (1994) understanding of personalized design process denotes that-- perhaps design process (design sketching, idea formulation) is too personally coded, too idiosyncratic, too wedded to pen and paper techniques, also be amenable to computer working.

Competency:

Showy Sketches to photo realistic CG rendering and wonderful colored perspective, externalization of design ideas at any form are crucial modalities of design

communication and formulation. Some argument persists on importance of one modality over another. This research however, wants to focus on why designers use different modalities either by switching from one to another or mixing at the same time. From Scrivener's (Scrivener & Clark, 1993) finding it can be noted that design sketches are more akin to visual notes than illustrations as its intention is to encapsulate design ideas and aiding strategies related to design thinking than depicting objects or scene. These showy sketches are a random mixture of words, diagrams, pictorial images, arrowed lines and such. From the nature of these type of modality it is clear that masterful drawing ability is less required than clarity of organization, well developed mnemonic qualities and directness of communication (Lansdown, 1994). On the other hand cognitive scientist and researchers argue that more detail and enhanced pictorial form of presentation represents or communicates designers' idea in much clearer way. From designer's point of view, both of these findings are correct under different circumstances. During design formation internalization of design ideas transpire and an abstract, coded form of holistic image develop in designers mind. The only necessary externalization designers need is for discriminating and checking probability of each solution for the design problem. For this purpose unimodal implicit modalities can be effective tool. Whereas, during the later stage of design when peer review, critic and communication with non designers are required a more realistic representation of design ideas are imminent. In that case unimodal or multimodal explicit modalities are often used.

From the above discussion it is clear that a designer with better understanding and expertise with both implicit and explicit modalities get advantages for externalizing and

internalizing ideas. The role of Knowledge is an essential prerequisite of creative imagination and intuition. By reviewing the work of researchers who studied individual creativity (O. Akin, 1990; Gardner, 1983; Guilford, 1959; Roe, 1952), this becomes clear that – consistent creativity is not possible in a subject unless one knows a great deal about it, and that very creative people have a profound, knowledge-based understanding of those areas in which they create (Lansdown, 1994).

2.8.6 Consequences of modality shift

Information loss

Often may seemed paradoxical, but a deliberate creative act like design can be associated with information loss during the process. Thought and action are undoubtedly two principal means to generate and validate ideas. The loss or manipulation of information in design task is a part of the preexisting order of study drawings in action (Herbert, 1993; D. M. Herbert, 1994).

There are three kinds of information loss: two concerning interactions with tacit background and the other one regarding manipulations of design task that continuously evolves. The first kind of information loss has to do with the quantitative limitations of action in design. Stent(1978) described the mechanism to complement the theoretical and critical analysis of information loss. The researcher also mentioned- '…when applied to the working process of design, the neurobiological account helps to explain both the loss of information and the creation of meaning in study drawings.'

The circumstances designers intend to address can only be apprehended indirectly through abstraction. Each successive abstraction transforms initial idea into similar structures based on previous experience; incongruent information is lost through selective destruction. This process of making structures always involves abstraction and so always loses information (Minsky, 1968). Thus, the loss of information about the circumstances surrounding the design task could be termed as 'the cost of acquiring meaning' in design study drawings.

Information loss in study drawing is inevitable. Both the design synthesis drawing and the analytic diagram always lose information about the circumstances contiguous to the design task. The loss occurs first at a simple default level by dropping out foregone assumptions, next at a more complex level by a cultural grid's selection of data for relevance, and finally at a still more complex level through the formation of abstract structures whose meaning can only be understood by becoming congruent with previous experience.

Most type of drawings includes circumstantial discoveries and generates contingent information that the designer could not have conceived originally. The convergence is apparent than real, however, because the approach of tacitly assuming a drawing strategy differs from that of expressly choosing one. Peter Eisenman and several other contemporary architects have employed various algorithmic strategies for generating form, making the graphic process a foreground than a background issue and thereby challenging the tacit assumption that certainty and subjectively determined unity are intrinsic architectural values.

Eisenman has suggested a related role for computers in design:

> *"The computer can do things that the human mind can conceptualize but not visualize; it does things that you would never be able to draw, and therefore it produces things that, when you build them, clearly are not the control of the creative subject. And I have always been interested [in removing] the creative subject from the works as far as possible, that is, to diminish the creative subject: me. Even though I am still present."*

Such efforts to introduce uncertainty with a systematic, seemingly certain algorithmic process—either by hand or by computer – are not the anomalies they might seem: even an elementary geometric process like superimposing two differently oriented rectangular coordinates system within a plan, as Eisenman does in the Wexner Center at Ohio State University.

Graphic Conventions

Cognitive readiness is important to grasp and gather information from not only the drawing's content but the form the drawing is intended to take. Familiar graphic convention as plan, elevation, section, perspective or axonometric drawing derived from Euclidean geometry. It is these five graphic conventions that permit the quick access to information implied by such terms as grasp and glance in the epigraph above.

Non-conventional experience must become conventionalized if it is to be included in the work; although introspection suggests that architects can experience and remember forms and spaces without using architectural graphic conventions, any recording,

analysis, or application of these experiences in design is always challenged into certain forms of graphic conventions(Herbert, 1995). One could make the case that no experience is nonconventional, but it often means not in the form of any of the five architectural conventions. To communicate the designer's intention to the building industry that only understands plan, elevations, sections, perspectives, axonometric drawings and such; it is important for designers to get a good hold of this graphic language. These five conventions provide a readymade, economical means for the designer's cognitive system to generate or perceive images, to store them, and to recall them when needed.

Since study drawings are often so roughly made, conventions are interpreted more freely there than for presentation or working drawings. Obviously, such freedom is part of ambiguity that is essential for design development. Through graphic conventions previous experiences of design task are often brought into the cognitive system to restore and recall mental images.

From handmade drawings to CADD system

Order, representation, transparency, interpretation, ambiguity, uncertainty are the few among the role of media in design. Although these issues and their applications were derived from the analysis of handmade drawings, they can be extended to apply to CAD system. Manual drawings are considered as an interface between the designer and their thoughts

Herbert (1993) developed a diagram to explain abstracted concepts form designer-drawing interface to the designer-CAD interface which suggests the relationship between this two by evoking a new interface between manual and digital modalities which differentiates the incorporation of a new interface between the modalities integrating features from both systems instead of forcing to select between one of them.

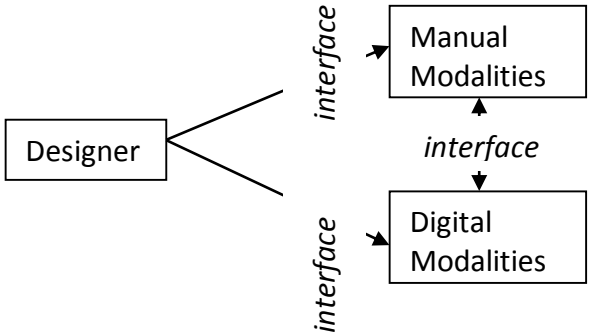

Figure 4: Modality interface

The process of drawing and interpreting ambiguous graphic representation is a fundamental characteristic of graphic thinking. The two key graphic –cognitive interactions asserts that the designer in certain situations must intend a new mark drawn into the visual field to be ambiguous—that is, subject to more than one interpretation so as to permit reading more out of a mark than went into it.

Graphic ambiguity is a valuable graphic tool. Any media with facility to produce irregular figures can produce graphic ambiguity. There is need to establish a new theoretical basis for ambiguity, locates its functions in the working process of design. To incorporate ambiguity CADD systems should go beyond the limitation of manual media that encompasses paper and pencil by inducing major reorganizations that would be impossible with average static representations.

Analysis of manual drawings indicates a close interaction between the designer and the drawings. The digital operation does not involve the designer's perception,

cognition an action systems in generating new meanings. The purpose of the exploration drawings is not just to have the drawing appear on the computer screen but to engage the designer in manipulating it.

CADD system should provide equally direct and uninterrupted access to displays with wide fields of view. Scrolling is not a substitute for a wide field of view: the workplace should incorporate head and eye movements that activate the function of the cognitive memory map. Even very fast serial displays across a single display/ monitor do not involve the kinesthetic and perceptual continuity that are essential features of the highly evolved system of human perception and cognition that every designer brings to the design task.

2.9 Analyzing Design

A large number of variables as the experimental layout, number of participants, the area of study, assignment for the study and such are to be set before the actual study of the process, because all these influence the outcome of the protocol studies. Due to the unique nature of each study and different settings of all these variables it is very hard to compare and learn from each other's work. Protocol analysis is very specific research technique that captures a few aspects of design activity with immense detail which is so labor intensive that single research projects just cannot yield statistically significant standalone data (Nigel Cross et al., 1996). At the same time it shows limitations with nonverbal thought processes carried on in design.

In design thinking, research conducted on diversified context as internal and external representation (Omer Akin, 1978), design development(Cuomo, 1988; Darke, 1979; McDermott, 1982), knowledgebase of design thinking(Omer Akin, 1986b), generating design problems(Omer Akin et al., 1992), design pedagogy(Donald A Schön, 1985), design process(Chan, 1990; Eckersley, 1988). From the early studies of design process it is observed that operations and representations are responsible for the development of designs, calibrating human cognitive system, describing design in the context of a general taxonomy of tasks. Design protocol studies and data collection is another demanding task that often comprises complementary relationship of two forms of data: verbal-conceptual and visual-graphics. This dual mode model where verbal and visual data coexist took its motivations from cognitive science.

There is ample evidence which supports the idea that human being processes information in the form of a language or other conceptual representations. Visual aspects of design are explored in the graphic mode. This is reflected in the drawings that are produced. When this is the primary activity of the designer, any verbal information generated is usually its reflection, almost like an echo.

A descriptive design study is defined as an investigation of the way in which a design process actually occurs. This investigation can be 1) real time, e.g. by observing designers; 2) retrospective, e.g. by means of interview and questionnaires; 3) a combination of these and / or other techniques. Use of retrospective methods such as questionnaires allows for large numbers of cases to be investigated in one study. The

disadvantages of these methods lie in the lime laps between the event taking place and being reported, and the technique of capturing data.

Every design process starts with a design task, and it is obvious that the type of task is of great importance for the process. The way in which the design task is solved depends on whether a designer has expert knowledge about a field or not.

Design process can be reflected upon from different points of view. We can look at the phases, problems and sub-problems of the design process. We can observe the action of designers and their steps of analyzing and making decisions in their work. But how can we comprehend all these simultaneous?

The initial application of protocol analysis to design was developed by Eastman (1970). In his work he analyzed the behavior of a designer working on a simple spatial layout problem, the configuration of a bathroom. Akin has done extensive cognitive research on different aspects of design, including identification of information processing primitives for architectural design (Omer Akin, 1979), problem structuring in design(Omer Akin, 1986a) and modeling design(Omer Akin et al., 1992). Goel &Pirolli (1989) discuss the characteristics of problem spaces which follow from the nature of design problems and hypothesized that these characteristics are valid across different design domains.

The early stages of design process in very important for the generation of good design. It is seen to be the most creative phase, its common characteristics being that it is

an ill-defined task and that it encompasses visual, search and analytical tasks. The major part of the early stage of the design process is usually devoted to information translation.

Design is a prediction which concerns how things ought to be. The designer attempts to predict the behavior of a proposed artifact using their knowledge and expertise. Over the years, many systems for describing design processes have been developed. The ‘first generation’ methods of design methodology in the early 1960s were heavily influenced by the theories of technical systems. The positivist influenced by the theories made for design being seen as a rational process. Criticism of these models raised interest in the fundamentals of design theory, the logical form and status of design.

Problem solving theories were first introduced by Simon(1992). He also provided a sound, rigorous basis for much of the existing knowledge in design methodology. This paradigm, in which design is seen as a rational problem solving process, which has been the dominant influence shaping perspective and descriptive design methodology. Simon looked at the designers as a body who objectively process ill- defined information (design problem) and act through a rational search process based on acquired knowledge on design process, methods and systems(Dorst & Dijkhuis, 1995).

A radically different paradigm was proposed by Donald A Schön (1983), describing design as a process of reflection-in-action where designer construct reality by conversing with the context of an unique design problem through the artistic procedure and knowledge (Dorst & Dijkhuis, 1995). This constructionist theory can be seen as a reaction to the problem solving approach, specifically made to address some of the blind spots and shortcomings Schön perceived in mainstream methodology. The two paradigms

for design methodology represent two fundamentally different ways of looking at the world, namely:

a) Positivism and

b) Constructionism.

Logical analysis and contemplation of design are the main ways of producing knowledge about the design process. The problem solving approach means looking at the design as a search process, in which the scope of the steps taken towards a solution is limited by the information processing capacity of the acting subject.

Table 3: *Rational problem solving and the reflection-in-action paradigm overview (after Gasson, 2011)*

Rational problem solving and the reflection-in-action paradigm		
	'Simon'	'Schön'
Designer	Process information based on objective reality	Constructing reality
Design problem	Ill defined, unstructured	Unique in nature
Design process	Rational search process	Reflective conversation
Design knowledge	Knowledge of design process, methods and systems	Knowledge procedure of design artistry
Example/model	Optimization theory, the natural sciences	Art/ the social science

In studying design as a process, one is looking at the process component of largely content based decisions. This severely limits the power of a process-oriented methodology to understand what is going on in the design activity, and to help designers that are trying to work their way through the design situation towards a solution.

2.10 Summary

In summary, it was evident that not enough studies and parables are available on importance of design modality and its shift with relation to the carryover of initially conceived design ideas through the design process. Since design is a highly individualistic act of creativity, designers more than often do not depend on a single design and/or drafting tool. Manipulating, mixing and superimposing design and drafting tools and drawings are very common among design students and professionals. This research considered modality as a mean of communicating with design process both internally and externally. Medium is understood as a hardware or tool set that modality utilizes to create and realize the expression of design information in form of tangible graphic output that essentially satisfies established architectural drawing conventions as well as provide immersive and cognitive imagery of design product. However, designers do not stay with the same modality throughout the whole design process. They tend to shift and switch as well as improvise and mix between modalities for a number of reasons. Design method, process, students' individual characteristics, background, comfort, competencies, nature of studio environment, project type and studio instructions are among the attributes that cause a shift of modality. As a result of this phenomenon, information loss, excessive manipulation, non-carryover of initially conceived design ideas (concept) toward the final design could happen. Following chapters present how the data was collected, documented from observed studios and how it was analyzed to identify these issues in students' design and find how it affect their final design outcome.

CHAPTER THREE: RESEARCH METHOD

A mixed method research (Ataman & Lonnman, 1996; Cash, Stanković, & Štorga, 2013; J. Creswell, Clark, Gutmann, & Hanson, 2008; John W. Creswell, 1999; John W Creswell & Clark, 2007) is used in this study because, in mixed method research a combination of qualitative and quantitative approaches are used together for taking advantages of breadth and depth of understanding and corroboration (Johnson et al. 2007). At the same time it is expected that mixed method research will provide a better understanding of the research problem than either type by itself (Greene, *et al.*, 1989). Mixed method collects and analyzes qualitative and quantitative data in a rigorous way which is framed epistemologically.

The rationale of mixing is - neither quantitative nor qualitative methods are sufficient by themselves to capture the trends and details of situation and complex issue like- why shift of modality happens; what are the constraints and triggering factors that motivate or direct students to switch between design modalities during various stages of design process in the academic studio setting. When used in combination, quantitative and qualitative methods complement each other and allow for more complete analysis (Morse, 1991; William & McCullough, 1991).

Researchers depend on numerical data in quantitative research (Tashakkori & Teddlie, 2003). To develop knowledge on cause and effect of thinking, reduction to specific variables, use of measurement and observation, hypotheses and questions, and test of theories- post positivist claims are generally used. The magnitude and frequency of

relationships are determined by isolating the variables and casually relating those. Depending on research question researchers determine which variables to investigate and make selection of instruments to be used for acquiring high reliability and validity.

Qualitative research, on the other hand is “an inquiry process of understanding” for developing a “complex, holistic picture, analyzes words, reports detailed views of informants, and conducts the study in a natural setting” (Creswell, 2012, p. 15). Knowledge claims are also developed based on constructivist (Greene, 2007) or participatory (Steckler, *et al.*, 1992) perspectives. Data is collected from everyday life or phenomena within the setting in which the study is framed. Analysis of data occurs based on the values and perception of the participants on their world. Qualitative research presents a comprehensive understanding of the problem by examining multiple contextual factors.

Whereas, in a mixed methods approach, the researchers build the knowledge on pragmatic grounds (Creswell, 2003; Maxcy, 2003). Gathering and stating truth is something “what works” (Howe, 1988) where approaches, variables and units of analysis are selected based on what appears to be most appropriate for finding an answer to the research question (Tashakkori & Teddlie, 1998). The essential theory of pragmatism is based on the compatibility of quantitative and qualitative methods. Thus, both numerical and text data collected either sequentially or concurrently helps to understand the research problem better.

This study used sequential explanatory mixed methods design, consisting of two distinct phases (Creswell, 2002, 2003; Creswell et al., 2003). Quantitative, numeric, data

was collected in the first phase, using questionnaire survey. The data was subjected to a descriptive statistical analysis. The goal of the quantitative phase is to identify students' skill, level of knowledge, background and to build up ground for general assumptions and expectations before analyzing data from observation in second phase.

In the second phase, a qualitative case study approach was undertaken to collect data through observation, documentation and semi-structured interviews to help explain why and which external and internal factors are significantly responsible for modality shift. The rationale for this approach is that the quantitative data and results provide a general picture of the research problem, i.e., what internal and external factors contribute or motivates students to switch their design tools. The purpose of this qualitative data and its analysis is to corroborate, refine and explain previously gathered statistical results by exploring participants' views in greater depth.

3.1 Philosophical assumptions of explanatory design.

This study started quantitatively. Since design studio is unique in nature and several factors such as studio environment, students' knowledge, background, values, studio project type, requirements and such can influence design – a post-positivist approach seems to be useful to develop instruments, measure variables and evaluate statistical results. In second phase, to get multiple viewpoints and comprehensive description qualitative research method was adopted under the assumption of constructivism.

In the realm of mixed method design explanatory design is often considered as the most open and simple research designs (Creswell, 2013). Figure 5 below provides an overview of the procedural steps used to implement a typical two-phase explanatory design.

Stage 1	Quantitative research design and data collection	QUAN data collection	Quantitative
	Determination and Implementation of quantitative strand		
	Questionnaire survey		
	Analyzing quantitative data using descriptive statistics (SPSS program)	QUAN data analysis	
	Identification of significant, non-significant results and group difference		
	Determine participants and design strategies for qualitative data collection		
Stage 2	Qualitative research design and data collection	QUAL Data collection	Qualitative
	Determination and Implementation of qualitative strand		
	Purposeful selection of sample		
	Participant observation		
	Collection of open ended data through observation		
	Analyze qualitative data using code and theme specific to qualitative and mixed method approach with focus on research questions	QUAL data analysis	
Stage 3	Interpretation of associated results	Interpretation and analysis	Analysis
	Summarize, interpret and overlap quantitative results		
	Summarize, interpret and overlap qualitative results		
	Identification of common theme that answer research questions		

Figure 5: *Basic procedure adopted to implement Explanatory Design*.

During second stage qualitative strands were developed by identifying specific quantitative results. This also helped developing an interface for mixing data so as refinement of already developed qualitative research questions, purposeful sampling procedures, and data collection protocol (Creswell, 2013). As such, the qualitative phase depends on the quantitative results.

After collecting and analyzing data from the qualitative phase it was interpreted to understand - to what extent and how these qualitative results bring insights into the quantitative result gathered earlier.

Sequential Explanatory Design

The main purpose of using the sequential explanatory study is to use quantitative results to develop qualitative study and then to use qualitative data to explain and interpret the findings from quantitative study. According to Morse (1991) the qualitative data collection and analysis is given the priority. The quantitative data and its analysis is used to guide the sampling procedure and preliminary qualitative study.

> "A mixed methods study involves the collection or analysis of both quantitative and/or qualitative data in a single study in which the data in a single study in which the data are collected concurrently or sequentially, are given a priority and involve the integration of the data at one or more stages in the process of research"(Creswell, *et al.*, 2003, p. 212).

Among all major mixed methods design sequential explanatory design is considered as the most straightforward where quantitative data is collected before collection and analysis of qualitative data. Both types of data are integrated and juxtaposed during the interpretation phase of the study. Precise and detailed theoretical perspectives often ignored during implementation of mixed method design(Creswell, 1999).

In this study I followed qualitative methodological framework (Brannen, 1992; Cash, *et al.*, 2013; William & McCullough, 1991) as a major strand and quantitative as supplemental.

3.2 Research Paradigm

There are many definitions of a paradigm available. ‘A paradigm is a way of looking at the world. It is composed of certain philosophical assumptions that guide and direct thinking and action’ (Mertens, 2009, p. 7). (Bernard & Bernard, 2012, p. 81) defined paradigm as ‘A general organizing framework for theory and research that includes basic assumptions, key issues, models of quality research, and methods for seeking answers’. (Denzin & Lincoln, 2005, p. 22) describe it as, “The net that contains the researcher’s epistemological, ontological, and methodological premises may be termed a paradigm. Researchers normally hold a set of belief and understanding about the world which makes the research imperative in nature and help researchers comprehend how it should be realized and studied.

Within the members of a community some commonalities found regarding the beliefs, values, and techniques- in research methodologies and theories this commonalities are known as paradigm. Research paradigm helps developing framework and direction for the research by reflecting the worldview, knowledge and value. However, in educational context, paradigm defines the norms that helps researcher to understand how the world is observed, what knowledge is gathered and how it is perceived. In social science context, paradigm deals with the basic belief principles which often known as metaphysics (Guba & Lincoln, 1994). To make sense of the world researchers use the dominant part of the construct of paradigm (Crotty, 1998, p. 35).

Proponents of mixed methods acknowledged the controversies and challenges while executing mixed methods research (Mingers 2001; Tashakkori and Teddlie 2003; Onwuegbuzie and Collins 2007 in Cameron, 2011). Methodological choice, according to Brannen (1992) is driven by philosophical (ontological and epistemological) assumptions. Paradigmatically positioning a research is one of the most important tasks researcher needs to undertake. Hatch (2002) identified five common paradigms in education research-, constructivist, critical/feminist, poststructuralist, positivist and post-positivist. In social science, positivism, constructivism and critical theory is considered to be commonly used paradigms. Designers as human being construct their own thoughts and world view subjectively and in relation to one another as well as from the reflections of their own experience. Here same reality can be observed in different ways. Approach to address the design issue is often than not holistic but findings could be idiosyncratic and seldom generalized. From this point of view the paradigm of this research is closely associated with constructivism because individual designers constructs their own view and presence of multiple interpretations. Paradigms are characterized by their ontology, epistemology and methodology (Guba, 1990). Constructivist paradigm usually consists of relativist ontology, constructionist epistemology, value-laden axiology, and naturalistic methodology (Hatch, 2002). Since designers perceive and experience their world differently depending on their own experience, viewpoint and exposure which produces multiple realties. Regarding epistemology, design knowledge is subjective in nature that greatly depends on interactions, situations and circumstances. In case of this study, I believe, meaning and insight of students' use and shift of modality can be derived from the understanding of two primary factors- students' knowledge and background; studio

culture; and instructions and project requirements. The goal is to understand the reality behind students' selection of design and drafting tools and switching between them during the process of design. Reviewing the paradigm the constructivist point of view appeared to be the most befitting for this study.

3.3 Quantitative Research Method: Questionnaire Survey

Quantitative research methods defined by (Aliaga & Gunderson, 2003) as: 'Explaining phenomena by collecting numerical data that are analyzed using mathematically based methods (in particular statistics)'.

Quantitative research emphasizes on the facts of human behavior (Bogdan & Biklen, 1998; Golafshani, 2003) where research questions are used for identifying the phenomenon to be investigated (Salkind, 2003). Usually the information is expressed numerically and a mathematical process is used to analyze the numerical data. The final result is reported in a statistical manner (Charles, 1998; Golafshani, 2003). Questionnaires (close-ended questions), rankings and rating are used to collect data in a quantitative approach (Salkind, 2003).

The first phase of the research started with the collection of quantitative data to develop basic understanding on research participants' (design students) background and demographic information; as well as their level of comfort and competency with digital and manual design and drafting tools, known computing applications and students' level of expertise, use of various modalities during different phases of design as such. A

questionnaire survey was conducted to collect these information (see Appendix E and F). Quantitative data revealed students' self-assessment of comfort and competencies with various modalities and their perception of using and switching design and drafting tools during different design phases. When this information was cross matched with qualitative data collected through studio observation a rich, valid information was accumulated. This information was crucial for identifying reasons, frequency, amplitude, timing and effects of modality shift as well as to validate the research.

3.4 Qualitative Research Method: Case Study Approach

A multiple-case study is conducted using qualitative research method during the second phase of data collection. Alongside developing generalized idea from quantitative research a holistic and naturalistic approach of qualitative research was adopted to acquire real phenomenon within a relevant context. Qualitative research focuses on how people make sense of their own circumstances and stresses on the interpretation and meaning of the activities they perform. A wide range of procedures are performed in qualitative research (Creswell, 2003; Denzin & Lincoln, 1998; Groat & Wang, 2002) like questionnaires, face-to-face interviews, diaries, photographs, or sketches. Second phase of this research implements a qualitative inquiry through case study of two different design studios. According to Yin (as cited in Groat & Wang, 2002, p. 346) a case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly

evident". The primary characteristics of case study suggested by Groat &Wang (2002, p. 346) are : "1) a focus on either single or multiple cases, studied in their real life context; 2) the capacity to explain casual links; 3) the importance of theory development in the research design phase; 4) a reliance on multiple sources of evidence, with data needing to converge in a triangulating fashion; and 5) the power to generalize to theory." The goal of this study is – to understand the rational and effect of modality shift during design process in studio settings. Groat and Wang's (2002) five aspects suggests appropriateness of using case study approach because, i) design studios are the 'real life context' where complex and dynamic act of design occurs. In other word, it focuses the case in its own context; ii) Strategies used by the studio instructors and given program for the design projects can be considered as a potential factors that determines the casual links, which also can explain students' tendency to switch between various design modalities; iii) the intent to develop a theory primarily assumed through initial descriptive data analysis also will explain the reasoning of modality shift; iv) the assimilation of multiple sources of evidence such as, differential factors due to experience, knowledge, cognitive ability of individual designers.

In order to understand what causes designers to switch between modalities during design in design studios, the research must be undertaken in real life context and should involve multiple sources of evidence that will help researchers find answer to the research questions. As qualitative case study is considered to be one of the best possible method to understand events in educational setting.

3.5 Sampling Criteria

A purposeful sampling was used for the sampling process. The research is designed to use a qualitative strand to explain initial quantitative results (Creswell, Plano Clark, et al., 2003) and explain the reasoning behind the shift in depth. The explanatory design is well suited when the researcher needs qualitative data to explain quantitatively significant (or non-significant) results (Bradley et al., 2009; Morse, 1991) and to form groups for subsequent qualitative research where purposeful sampling is executed to understand participant' characteristics and responses in context (Creswell, Plano Clark, et al., 2003; Morgan,1998; Tashakkori & Teddlie, 1998). Purposeful sampling targets the one believed to be the most central (Sommer & Sommer, 1992) to the research question, in this case the students of architectural design studios. The *information –rich* (Glaser & Strauss, 2009) cases which "one can learn a great deal about issues of central importance to the purpose of the inquiry" (Glaser & Strauss, 2009, p. 203) are selected purposefully and strategically.

3.5.1 *Research Sampling: Selection of Studios*

Two design studios were selected from an Architectural Studies program (pre architecture) of a mid-western University. This particular program includes both pre-architecture and interior design as majors. The selection of the program was based on the geographic convenience, access, reputation and quality of the program that is accredited by the Council for Interior Design Accreditation (CIDA).

The studios were selected based on two major criteria (see Table 4):

a) Experience of the students, and

b) Nature of the studio project.

An intermediate (studio B) and advanced (studio A) level students were selected to identify the impact of experience, expertise and knowledge over modality shift. Since these students have taken all visual design and design communication related courses before. At the same time these group of students have taken sufficient amount of studio courses to comprehend fundamentals of design process.

Again, projects given in these two studios were different type. Studio A worked on designing a branded environment where focus was given mainly on designing interior for a high end retail inside a local shopping complex (a Midwestern mall). Studio be on the other hand designed a complete two storied residence for an artist couple beside a lake.

For this study, it was important that participating design student have sufficient knowledge over multiple modalities (both digital and traditional), sufficient studio experience to understand and manipulate design process and studio projects with slightly different focus and program. These variations between students' academic standing, studio projects, helped to find correlations and differences causing modality shift during design process and its effects on design.

The characteristics of each studio are summarized in Table below.

Table 4: *Summary of Nature of the Studio*

STUDIO NAME	RESEARCH PERIOD	STUDENT GRADE	NUMBER OF PARTICIPANTS	PROJECT TYPE	PROJECT TOPIC
STUDIO A	Fall 2009	Senior Level undergraduate	16	Individual project	Branded Environment
STUDIO B	Summer 2010	Intermediate level undergraduate	12	Individual project	Residential

3.6 Method of Data Collection

3.6.1 *Observations*

Observations were conducted twice a week for one academic semester for studio one and four days a week for studio two. Starting from the first day of the class when syllabus, structure of the course, nature and methods of delivering instructions as well as design projects were introduced to every subsequent lecture, desk critiques and final design reviews. Class activities, student-instructor interactions as well as students' design development and progresses were documented in every other class period. To understand why design students shift and adopt new modality it is important to understand- in what context, at which stage of design, to synthesize what type of design problem, using which design modality, to what capacity design ideation is being communicated and the level of competency and experience of each participating student.

Besides observing the class activities and interactions between instructors and students, field notes of important discussion and nonverbal behaviors were also documented. Photograph of students notebook, sketchpad, drawing sheets and other format of study drawings along with massing models and screenshots of CAD drawings were documented and sequenced too. Interpretation of these sequential images and notes of student's activities and interactions is believed to help better understand how design ideation, synthesis, its development, decision making, communication and documentation took place. These interpretations will also show- to what capacity design modalities as well as factors like designers' competency, background, constraints and instructions influence various stages of design.

3.6.2 *Documentation and Review of Visual Material*

Photograph of sketches, notes, printed webpages, study drawings, physical models, computer generated pre-renderings, Sketch Up, Revit Architecture, AutoCAD screenshots and print outs, presentation boards and such other visual materials were collected. Students' design process as well as factors influencing modality shift are reflected through these documentation. Besides observing and documenting students' design activity class materials including instructors' sketches, desk critiques, syllabi, project descriptions, class handouts, notes, lecture references, textbooks and such were also collected. These items help describing instructors' influence as a potential constraint that deemed to be one of the reasons for modality shift.

Each student was approached once a week (every other class) to show any designs changes and improvements done since last visit.

3.6.3 *Interviews*

To understand what is occurring with people from their point of view (Bloomberg & Volpe, 2012), what they are experiencing and how they are assigning meaning interactive interviews are considered to be an effective mean to gather data (Charmaz, 2006b; Michael Quinn Patton, 2005). Different kinds of interview strategies can be used to conduct a qualitative interview (Michael Quinn Patton, 2005). Interviews can be administrated through formal, informal, conversational, guided, standardized, and open or close ended questions to gather data that is 'rich' in meaning (Charmaz, 2006a; Glaser & Strauss, 2009; Groat & Wang, 2002). With some limitation like participants' cooperation, ability to articulate, interview skills, interaction between interviewer-interviewee and context that influences data (Bloomberg & Volpe, 2012) interviewing is a method to reveal hidden meaning and thoughts those are seemingly hidden.

Students were interviewed during the documentation phase when most of the design decisions are already implemented. All students were individually interviewed on their perception and process of design ideation, formulation and interpretation; experience, competency and constraints; studio experiences, methods of design communication, number of modality shift administrated and designers (students) explanation for each of the incidents. Photographs of students' design process, specifically when a shift of modality happened were indicated to the respective designer to understand reasoning of their actions. The interview took between 15 to 20 minutes for each student (in several class period). Instead of using strictly structured interview questions, a semi-structured format was followed.

Table 5: *Example of interview questions*

1	**What design and drafting tools you find most useful for you?**
2	How much your instructor does influence your selection and use of design tools?
3	While on computer what do you do when you got stuck with modeling?
4	During transforming concepts in to tangible design drawings what design/ drawings tools do you use?
5	How often have you modified/ manipulated design features and details? Why? (To get different design perspective, difficulty with producing drawing/ model)
6	Does changing modality improved outcome?
7	What constraints forced you to switch/ change design modality? Did it help? How do you justify?

Table 6: *Matrix of research questions*

Research question	Goal	Source
How design and drawing tools are related with modality shift?	To understand the degree of competency and constraints those trigger modality shift	Literature, Students' self-assessment survey
Why and when shift of modality occurs in the process of design?	To identify conceptual carryover through design development	Observation, Document/visual material review
What are the reasoning behind modality shift?	To identify purpose of modality shift	Observation, Interview
How does modality shift effect design outcome?	To see the discrepancies and manipulation of design development process	Observation, Document/visual material review Interview

3.7 Methods of Data Analysis and Synthesis

A mixed method approach was followed to analyze and synthesize collected data to understand characteristics of design modalities and switching between those.

3.7.1 *Qualitative Data Analysis*

By identifying themes and patterns, (Bloomberg & Volpe, 2012) data in qualitative research is analyzed through " an intensive, open-ended, and iterative processes that simultaneously involves data collection, coding (data analysis), and memo-writing (theory building)" (Groat & Wang, 2002, p. 181). A mixed method with qualitative emphasis was implemented where grounded theory method was used throughout the majority of the process. According to Creswell (2009, p. 14) – when conducting grounding theory researcher "attempts to derive a general, abstract theory of a process, action, or interaction grounded in the views of participants in a study".

During the second phase of this study, data collection and analysis were performed simultaneously. Memos, notes were taken on important discussions, instructor's feedback, major improvements, manipulations and incorporation of new components to one's design. After gathering a reasonable amount of data (field notes, memos, photographs), it was arrayed and organized to develop a sense of student's design activity with focus on identifying reasons and factors that may have caused them to switch design modality. Thus a constant comparison, an important foundation of grounded theory, occurred throughout the whole analysis process(Charmaz, 2006a; Glaser & Strauss, 2009; Miles & Huberman, 1984). It is also considered as a systematic way of comparing and analyzing data that often is done through creation of code and memos. Coding process includes both analysis in a deconstructive manner and synthesis to develops and reconstructs a holistic and integrated understanding (Bloomberg & Volpe, 2012).

3.7.2 *Coding*

Code in simple form is label that assigns a meaning to data (Miles & Huberman, 1984). It is a process of "organizing the materials into 'chunks' before bringing meaning to those 'chunks'" (Rossman & Rallis, as cited in Creswell, 2003, p. 192). Codes are not static (Miles & Huberman, 1984), it rather evolves through the research and its most important aspect is the 'meaning' that is assigned to the data. Charmaz (2006a) explained it as a method of "categorizing segments of data with a short name that simultaneously summarizes and accounts for each piece of data" (p. 43).

While following grounded method- to clarify and define category (Strauss, 1987) *'Constant comparison'* of data analysis is considered as one of the principal features (Bloomberg & Volpe, 2012) where "researchers engage in detailed analytic processes that require repeated confirmations of potential explanatory patterns discovered in the data" (Hatch, 2002, p. 26). Coding can be of several types as- open, axial and selective (Creswell & Clark, 2007). *Open coding* often referred as substantive coding which is used for conceptualizing the first phase of abstraction and developing categories of information. Raw data, photographs and field notes are conceptualized line by line to create initial tag for chunks of data. *Axial coding*, as proposed by Strauss &Corbin (1990) is "a set of procedures whereby data are put back together in new ways after open coding, by making connections between categories." Their coding paradigm involves "conditions, context, action/ interactional strategies and consequences" (Strauss & Corbin, 1990, p. 96). Axial coding focuses on the "strategies for addressing the phenomenon, the context and intervening conditions that shape the strategies, and the consequences of undertaking

the strategies" (Creswell, 2007, p. 151). Once the core variable (or tentative core) that includes all of the data is found, *Selective coding* is performed. Researchers reevaluate raw data and selectively code any data relates to the core variable identified earlier. When researchers select one or more than one categories as core category they use selective coding. Selective coding restricts the use of codes only those which are significantly relevant to the core codes as they are to be used in a parsimonious theory (Strauss, 1987).

On the other hand Charmaz (2006a) identified three types of coding as: initial coding, focused coding, and theoretical coding where *initial coding* has significant similarities with open coding defined by Strauss &Corbin (1990). Recurrent and important codes from initial codes are separated through a reduction process based on relevance and effectiveness in the stage of *Focused coding.* Finally, in *Theoretical coding* researchers try to seek relationships between codes and categories (Charmaz, 2006a) with the intention to develop theory form theoretical coding.

Coding process continues during data analysis until 'saturation' occurs. *Saturation* level is usually achieved when same pattern appears to develop or new properties become scarce form the data collected. Iterative clustering and coding is engaged by researchers using grounded theory to identify themes and patterns to develop a theory or a "set of theoretical propositions" (Creswell & Clark, 2007). Theory emerges from coding, as Strauss (1987) mentioned – when "analyst looks at the data line by line for _empirical indicators' consisting of behavioral actions and events, observed and described in documents and in the words of interviewees and informants' (p. 27).

In this study saturation occurred when each student's design process reached the design development and presentation phase, again when the comparative analysis was performed. Obtaining saturation within the design projects (from both studios) was difficult in this study because of the nature, focus, instructions and requirements of each studio projects as well as designers individualities such as their level of knowledge, comfort and competencies. This study attempted to attain saturation in each case and then, tried to reach reasonable level of saturation during the comparative data analysis from all studios. Due to the nature of design studio, some coding categories were unique to the situation of the corresponding studios (see codes and categories in Appendix A, B).

For coding researchers use several procedures as- initial coding, focused coding and theoretical coding(Charmaz, 2006a). *Initial coding* is the fundamental coding of categories that develops cluster of basic information and similarities. To identify recurrent, important and useful codes form the already developed categories *focused coding* is used. Finally, *theoretical coding* is used to develop theory by identifying relationships between codes and categories.

Another method of coding that researchers administrates are - *open coding* to sort categories of information, *axial coding* to interconnect those categories and identify relationship among those categories and *selective coding* for developing a view that connects the categories (Corbin & Strauss, as cited in Creswell & Clark, 2007, p. 150). Upon completion of open coding researchers investigate and explore relationships among categories through axial coding. According to Creswell (2007, p. 151) axial coding is the- "central phenomenon, the strategies for addressing the phenomenon, the context and

intervening conditions that shape the strategies, and the consequences of undertaking the strategies". From this categories researchers than select one or a few central categories relating to the core codes in a "significant ways as to be used in a parsimonious theory"(Strauss, 1987). A set of theoretical propositions is developed at the end of this axial coding and analysis. This process continues until the saturation occurs and patterns and themes are evolved.

3.8 *Data Analysis and Synthesis in this Study*

This study followed the following steps to analyze data. First of all, survey questionnaires were tabulated to administrate a descriptive statistics. This numerical data provided with an understanding of students demographics, degree of studio experience and expertise, participants' preferences over modalities constraints and such. Example of interview questions are provided in Table 5: *Example of interview questions*

Phase 2, photograph coding: Data reduction process was utilized to analyze visual materials. To understand when designers switched their modalities and what happened because of that particular switch, twenty six students' complete design process was photographed and analyzed in depth. After sequencing the photographs of each students it was tagged based on the type of modality (digital, manual or mixed), nature of modalities (explicit, implicit or spontaneous). Then I looked carefully to mark each modality shift and its context. Marked images were then cross referenced with previous and later images from the image sequence to identify the realm of shift and possible

reasons as studio instructions, studio culture, competency, focus etc. See Table 8: Code and Category from Observation and Appendix C for definitions.

Phase 3, transcription of interviews: Collected observation and interview data was transcribed as the data collection process continued. Transcribed data was reviewed and compared with written memos and notes to verify its contents. During this whole period of the research, all transcribed data was rechecked and reread until it made sense and direction for analysis was found.

Table 7: *Code and Category from Student Interview and questionnaire survey*

Category	**Background**	**Experience**	**Studio project**	**Perception**	**Constraints**	**Curriculum and Studio culture**
Code	Studio experience	Courses taken related to design drawings	Project type and duration	Perception level and drawing types	Preference	Courses regarding design and drafting tools
	Frequency of computer use	Courses taken related to design method and process	Project requirements	Nature of studio instructions	Conceptual transformation and design formulation	Courses taken related to design and drafting
			Emphasis on design modalities	Design modality and cognition	Design ideation and transformation	Preferred courses
			Presentation requirements	Preferred visualization techniques		Overall emphasis on design modalities in curriculum
				Modality types		

Table 8: *Code and Category from Observation*

Category	**Type of modalities used**	**Nature of modalities**	**Reasons for changing modalities**	**Realm of Modality Shift**	**Purpose of drawings**	**Studio project**	**Design stages**	**Effects of Modality Shift**
Code	Manual	Implicit	Studio instructions	Design ideation	Internalization	Emphasis on Design/ Drawing tools	Conceptual	Creativity
	Digital	Explicit	Studio Environment and culture	Conceptual transformation	Externalization	Focus on project	Development	Integrity

Mixed	Spontaneous	Competency	Form and geometry	Documentation	Presentation	Information loss
		Cognition/ Focus	Detail			Representation
		Constraints / limitation	Exterior and façade			
			Interior and finish			
			Circulation, spatial organization			
			Lighting			
			Material			
			Scale and proportion			
			Presentation			

Phase 4, coding transcribed data: In this phase all transcribed data is initially coded line by line, incident by incident method (Charmaz, 2006a) to look closely at what was said and to avoid or overlook any information that might be useful(Charmaz, 2006a; Glaser & Strauss, 2009). First of all open coding of data from students' interview was conducted based on the meaning emerged from the data- not form any existing theory. Then a focused coding was developed to identify recurrent, important and useful codes form the already developed categories. Ambiguous, irrelevant (to research questions), redundant and less frequent codes were separated. At this time, categories were dimensionalized as (a) studio experience and frequency of computer use; (b) known design tools, experience with performing design modalities (using and mixing design and drafting tools and media) and competency with design process and methods; (c) given studio project and duration, project and presentation requirements etc. See Table 7 for more examples and Appendix B for definition of codes and categories.

In order to identify relationships between codes axial coding was conducted. Developed codes were categorized and labeled to find those items most significant and

frequently appeared throughout the process. Final codes developed from interview were students' background, experience, project types, perception level, constraints, and curriculum (see Table 7). Codes developed from observations were used modality, reasons and effects of shift, purpose of drawings and nature of modalities, project types and design stages (see Table 8).

Phase 5, overlapping and identifying common theme: Codes and categories identified in earlier phase were compared with analyzed visual material, memos, and notes. This comparisons was conducted to determine any relationships among different types of data. By searching common patterns and themes, six categories were identified from student interviews and questionnaire survey; and eight categories from design process observation which is presented in the following tables (see definitions for codes and categories and detailed tables in Appendix A, B)

Once both cases were analyzed a cross-case analysis was performed between the two studios to see if there was any common features regarding when and why modality shift happened as well as the influence of modality shift on design process. Students' self-evaluation and responses from questionnaire survey was juxtaposed to see if any other patterns emerges. This cross-case analysis of data from multiple sources generated rich information and thick descriptions of modality shift and its effect on design. Final theme was then emerged (final themes, categories, and codes can be found in Appendix C).

Final themes helped to develop a theory which described the design process, modality shift, reasoning (behind) and its effect on design in architectural design studio.

Table 9: *Final Themes, Categories and Codes*

Category	Sub category	Code
Students' characteristics	Background	Studio experience
		Frequency of computer
		Undergraduate major
	Relevant experience	Work experience
		Exposure and travel experience
Experience	Competency	Known design/ drafting conventions and tools
		Competency with design methods and processes
		Lack of expertise with design modality
Studio structure	Studio environment	Studio culture and overall ambience
		Motivation from instructor
	Studio project	Project type and duration
		Project requirements
		Focus on project
		Emphasis on design modality
Modality	Types	Manual
		Digital
		mixed
	Nature	Implicit
		Explicit
		Spontaneous
	Reasons of shift	Studio instruction
		Studio culture and Overall ambiance
		Competency
		Cognition/ Focus
		Constraints / limitation
	Realm of shift	Design ideation
		Conceptual transformation
		Circulation, sequence and spatial organization
		Presentation
	Effects of shift	Creativity
		Integrity
		Information loss
		Representation
	Purpose of drawings	Internalization
		Externalization
		Documentation
Design process	Design phases	Conceptual
		Development
		Presentation
	Constraints	Preferences
		Conceptual transformation
		Design ideation and representation

3.8.1 Examination of the design drawings:

Examining the case studies is an attempt to identify relationships between design drawings as a way to understand design process. Through several iteration of sorting, classification and coding the results were compared with designers' perceived competence, knowledge, level of cognition, and retrospective analogy (of their action).

All the drawings were looked at the same time to develop relationship (spatial or visual) between different type drawings and identify whenever there is a change of design and drawing tools. The method undertaken in this study to analyze design drawings is different than the conventional protocol analysis. This study examined actual design project drawings from academic studios. To identify relationship of drawings, sketches and their functions in early design stage a non-sequential analysis (Do, *et al.*, 2000; Bennett Neiman, *et al.*, 1999) was performed. The span of these projects was several months long instead of controlled and short spanned design task performed in protocol analysis study. Protocol studies usually cover a short term experiments. Academic studios are more appropriate settings to study designers' activity instead of short laboratory settings for design charrette. Because designers do not work under artificially set norm and rules in the isolation of a laboratory as they would do in protocol analysis. At the same time design process has much resemblances with puzzle solving (Bennett Neiman et al., 1999), except for there are no defined goals like problem solving. Designers "treat design as a search for the most appropriate effects that can be attained in a unique context" and their mode of action is best described as puzzle making" (Archea, 1987).

3.8.2 Analysis of drawings

To understand the relationship between switching design modalities and their corresponding effects on design first of all drawings representing conceptual ideas, references, and drawings developed during later phase in the process were identified. All these drawings were sorted into six categories:

- Multiple viewpoints/ concepts,
- Schematic variations,
- Section views, spatial links and arrangements
- Paraline projections/ oblique,
- Isometric and Perspectives,
- Reflections/ precedents/ analogies.

These categories of drawing represented thematic differences and alternatives (façade studies), exploration of ideas (plan section, 3d), conceptual explorations (free hand sketches, notes, doodles) and such. Drawings from each categories then grouped and sequenced together according to the purpose of the drawing as:

- Reference sketch,
- Variations of spatial arrangements,
- Change of shape and sizes,
- Circulation studies,
- Design development and details.

At the same time any shift of modality was marked down as well to see if there is any relationship. The sequence was then analyzed to identify any shift or change in design ideas. A coding scheme was developed to classify these drawings based on drawings types (plan section isometric); medium used (pencil, CAD, marker); drawing intention etc.

Table 10: *Coding for design drawing*

Drawing Type (D)	Medium (M)	Intention (I)
Plan, section	Pencil sketch	I1: variation
Elevation	Pen	I2: Dimension
Isometric	Crayon	I3: grid
Frontal projection	Marker	I4: volume
Perspective	Hardline	Wall attachment
Note	Measured soft line	Reference
Quick sketch	CAD	Sequence
Other	Inverted color	Entry
	Hybrid	Service
	other	Concept
		other

3.9 Validity

Mixing quantitative with qualitative methods or paradigm, approaches, and concepts with harmonizing strengths in to research studies is the main attribute of mixed method research (Onwuegbuzie & Johnson, 2004; Tashakkori & Teddlie, 1998, 2003). Fundamental principle of mixed research should be examined holistically not independently as “it is not limited to triangulation or corroboration” (Brewer & Hunter, 1989; Johnson & Turner, 2003 as cited in Onwuegbuzie & Johnson, 2006).

Qualitative research seeks answers by the analysis of unstructured information like interview transcripts, open-ended survey responses, notes, feedback, photos and such. According to Creswell “a qualitative study is defined as an inquiry process of understanding a social or human problem based on building a complex, holistic picture, formed with words, detailed report and using informants conducted in natural settings.

Alternatively a quantitative study, consistent with the quantitative paradigm, is an inquiry into a social or human problem, based on testing a theory composed of variables, measured with numbers, and analyzed with statistical procedures, in order to determine whether the predictive generalizations of the theory hold true "(Creswell, 2009).

Much like this scientific process of observation qualitative research has its foundation on world view that offers a holistic picture and richer data. In this form of research it is believed that there are no single reality as reality is based on perception that varies over time and between subjects, also the meaning acquired may be true for only a given situation and context (Burns & Grove, 1993). Thus the reasoning process is considered extremely complicated unless a proper standard is followed based on the nature of research and evaluated for its credibility.

To verify “whether the findings are accurate from the standpoint of the researcher, the participant, or the readers” (Creswell & Miller, as cited in Creswell, 2003, p. 196) point of view validity acts as a determining tools. Qualitative research often refers validity with different terminology as *credibility* or *transferability* (Guba & Lincoln, 1994). With the naturalistic approach, qualitative research tries to understand phenomena in "real world setting where the researcher does not attempt to manipulate the phenomenon of interest" (Patton, 2001, p. 39). In the naturalistic paradigm of qualitative research validity is confirmed through four major aspects as credibility, transferability, dependability and conformability.

By using *credibility* researchers corroborate whether the participants’ perception verifies researchers interpretation that leads to a credible findings (Guba 1981).

According to Michael Q Patton (1999) “credibility issue for qualitative inquiry depends on three distinct but related inquiry elements:

1. Vigorous techniques and methods for gathering high quality data that are carefully analyzed, with attention to issues of identity, reliability, and triangulation.

2. The credibility of the researcher, which is dependent on training, experience, track record, status, and presentation of self.

3. Philosophical belief in the value of qualitative inquiry that is fundamental appreciation of naturalistic inquiry, quantitative methods, inductive analysis, purposeful sampling and holistic thinking.”

Whereas Guba (1981 p. 84-86) stressed on extended site engagement, persistent observation, triangulation, referential materials and adequacy, member check, corroboration, quality of analysis etc. for ensuring credibility.

Transferability is the process implementing outcome of one research to another similar situation. It is usually performed by the readers through “context bound”(Lewis, 2009, p. 86) findings. The measure of transferability depends on-“how well the study has made it possible for the reader to decide whether similar processes will be at work in their own settings and communities by understanding in depth how they occur at the research site”(Lewis, 2009, p. 83). During the study q naturalistic qualitative researcher should i) peruse theoretical/purposive sampling, ii) Collect "thick" descriptive data, iii) Develop thick description to enrich transferability.

Dependability focuses on the stability of data (Lewis, 2009, p. 86). Dependability in qualitative research depends on careful conceptualization of the study, data collection, interpretation of findings and how it is being reported. By providing "dependability audit, overlap methods, stepwise replication" (Lewis, 2009) researchers can assess dependability.

Conformability refers to the capacity to which results of the research can be corroborated without the investigator. It measures the degree of coherence between the inquiry's findings and the data collected (Guba & Lincoln, 1994). Lewis (2009, p. 87) proposed a few necessary steps that researchers should take during their study to as: "triangulation, practice reflexivity and arrange for a conformability audit to enhance conformability.

Bazely (2004) reported regarding validity in mixed method research –

> "Mixed methods are inherently neither more nor less valid than specific approaches to research. As with any research, validity stems more from the appropriateness, thoroughness and effectiveness with which those methods are applied and the care given to thoughtful weighing of the evidence than from the application of a particular set of rules or adherence to an established tradition."

Validity is a "straightforward commonsense way to refer the correctness or credibility of a description, conclusion, explanation, interpretation or other sort of account"(Maxwell, 1996, p. 87). One of the main purpose of conducting validity study is to check if participants' perceptions matches researcher's interpretations. By persistent and extended engagement with the subjects in context, detailed observation, peer debriefing, triangulation, member checks, corroboration, collecting adequate reference and material credibility of any research can be enhanced (Guba, 1981, pp. 84-88). Guba

&Lincoln (1994) used the term trustworthiness which they explained as: " how can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of? What arguments can be mounted, what criteria invoked, what questions asked, that would be persuasive on this issue? (p. 290)".

Beside trustworthiness, to ensure whether a research is track able and its process is reproducible (Bloomberg & Volpe, 2007) the findings need to be dependable. Dependability, according to Guba (1981) can be achieved by overlapping methods, using stepwise replication, and establishing audit trail (p. 86). Researchers in naturalistic paradigm performs triangulation and practicing reflexivity to achieve conformability.

"Researchers depend implicitly or explicitly — on a variety of understandings and corresponding types of validity in the process of describing, interpreting, and explaining phenomena of interest"(Glaser & Strauss, 2009, p. 279). Based on the nature of validity Maxwell (2009) identified three different types of validity as: descriptive, interpretative, and theoretical. *'Descriptive validity'* refers to the accuracy of the data (Maxwell, 1992) that must reflect what the participant has said or done. Reporting of the data should have the same level of accuracy refrained from any distortion or manipulation. Descriptive validity, therefore is the basis of all other kind of validity (Maxwell). "Without an accurate account of the formative data all else is irrelevant" (Glaser & Strauss, 1967 in Maxwell, 1992).

'Interpretive validity' verifies the authenticity of researchers' report on participants' activity, behaviors and expressions, events, objects (Glaser & Strauss,

2009). This helps to comprehend the phenomena form participants' point of view rather researcher's. "Interpretive validity is inherently a matter of inference from the words and actions of participants in the situations studied' (1992, p. 49).

'Theoretical validity' "goes beyond concrete description and interpretation and explicitly addresses the theoretical constructions that the researcher brings to, or develops during, the study" (Maxwell, 1992, p. 50). Theoretical validity evaluates the soundness of the concepts and how relationships among those are theorized within the context of phenomena. The coherence of theoretical construct is ensured through the patterns, concepts, categories, properties, and dimensions of the phenomena in context.

Maxwell (1996) suggested four ways to implement validity namely- *description, interpretation, theory and generalization*. To judge trustworthiness of any research Guba &Lincoln (1994) has pointed four aspects within scientific paradigm: the true value, applicability, consistency and neutrality .

Researchers, no matter what methodology they follow are required to test and demonstrate the credibility of their study. This credibility depends on 'instrument construction' in quantitative research and in case of qualitative research, "the researcher is the instrument" (Patton, 2002, p. 14). Thus credibility of a research in qualitative method largely depends on the effort and ability of the researcher.

3.9.1 Methods for Enhancing Validity in this study

Most of the studies involving qualitative method have laid importance on ensuring the validity (Creswell & Miller, 2000; Denzin & Lincoln, 1998; Kvale, 1996;

Lincoln & Guba, 1985). Triangulation is one of the methods used in this study. To improve validity and reliability of research many researchers (McMillan & Schumacher, 2006; Lincoln & Guba, 1985; Seale, 1999; Stenbacka, 2001) used triangulation as a strategy. Patton (2001) stated "triangulation strengthens a study by combining methods. This can mean using several kinds of methods or data, including use of both quantitative and qualitative approaches".

Denzin (1978, p. 291) is one of principal advocate of triangulation defined it as a "combination of methodologies in the study of the same phenomenon." This is fundamentally collecting different types of data on same phenomena that helps researchers to improve judgmental and interpretational accuracy. Denzin (as cited in Patton, p. 247) proposed four types of triangulation based on use of multiple sources: *data triangulation* by using multiple data sources; *investigator triangulation* that involves multiple researchers; *theory triangulation* through different interpretation of single set of problem and *methodological triangulation* done by implementing multiple methods in the study. To reinforce this research triangulation is used by combing methods.

This study has followed data triangulation, theory triangulation and methodological triangulation. A variety of data source was utilized as questionnaire survey, design studio observation, student interviews and photographs of design process. Since every design problem is unique and due to the scarcity of well-established theory on selecting and effects of switching design modalities during design process, ideas from the study on design methods and process, types and differences between manual and

digital design tools, design modality interaction and theory, CAD and design creativity was used as conceptual foundation.

To increase researcher's truthfulness and eliminate bias researchers use a combination of strategies. McMillan &Schumacher (2006) recommended ten strategies; Maxwell (1996) suggested a list of eight methods to test validity (pp. 109-114). This research, however, implemented following six methods to confirm validity:

a) Prolonged and persistent involvement. This allowed me to conduct interim data analysis and corroboration for staying persistent between findings and real world context. In this study, I was involved with the research location closely. I observed each studio twice a week on a regular basis for the whole academic semester per studio. This prolonged, in depth observations helped me to develop direct and rich raw data.

b) Observing participants' (design students) activity (design process) in its real-world context (design studio) without interference (additional instructions) allowed me to get rid of any "spurious association" and "premature theories" (Maxwell, 1996).

c) Rich data, full of description and details form survey, observation and interview were tabulated, coded and transcribed to be analyzed thoroughly. During observation notes and photographs with all possible details were taken in to account. This helped researcher to comprehend the phenomena within context from participant's point of view.

d) Researcher's bias associated with the study is often inevitable since qualitative researchers are directly related with interpretation and research findings. An open narrative is provided to acknowledge personal interest and reflections related to the research.

e) Discrepant evidence and negative cases were addressed as the data were being analyzed. Special considerations were given to the data that appeared outside of the normal pattern. The complex nature of the design studio and real world context was explained as it was recorded during observation. Students were asked to explain their course of action during the end of the design development phase. Some of the responses showed conflict to the report provided in survey and researcher's interpretation of documented design process.

f) Research finding were discussed with other qualitative researchers as peer debriefing with intent to enhance the accuracy of research procedures, interpretation and analysis.

CHAPTER FOUR: FINDINGS

Findings from the data analysis are discussed here. Findings are organized in the following sections:

1. Studio course structures and participants' characteristics.
2. Studio culture and motivation of modality experimentation.
3. Constraints related to modality shift.
4. Participant's perception on modality shift.
5. Common themes of modality shift among the studios.

4.1 Studio Course Structure and Participants' Characteristics

Studio A

The studio observations were conducted during 2009 fall semester. Both studio A and B are in a CIDA (Council for Interior Design Accreditation) accredited undergraduate program which offers both interior design and pre- architecture. Studio A is a senior level three credit-hours studio course with prerequisites of 2 junior studios. Class met every Tuesday and Thursday from 1:00 pm to 4:30 pm. Studio session held in a conventional setting as well as computer lab. To understand students' current experience and perspective on using design and drawings tools to pursue given design task, a short questionnaire survey was conducted at the beginning of the semester. I

observed almost every class to get a better understanding on the nature of the project, studio instructions, students' design processes and developments and most importantly the use of various design and drawing tools both independently and in combination. Last week of the semester was not observed since at that time students were producing final presentations only.

During the semester, I documented students' day to day activity by taking photograph of students' notebook, sketch pad, tracing paper, and laptop screen. I also asked students if they have made any substantial changes to their design since I visited them last time. At the beginning of the semester a survey was conducted to understand student's level of competency on various design and drawing tools, background, exposure and experience. This information is particularly helpful to identify external design constraints based on designer's knowledge and level of expertise. A semi-structured interview was conducted during the beginning of documentation phase for clarification and explanation of identified modality shift. Following table shows the data collection period for the studio.

Table 11 : *Data Collection period for Studio A*

	Fall 2009										
	Week										
	1	2	3	4	5	6	7	8	9	10	Total
Activities	Intro	Pre-Ana/P-up		D- Crit		M-Crit	D-Crit		Pres	F-Crit	
Observation	16			8	8		6	6	4		16
Interview	Survey (16)							Interview(12)			

Note: Pre-Ana/P-up Student presentation and Pin ups=; D- Crit=Desk critique ; M-Crit= Midsemester critique ; Presentation board= ; F-Crit=Final critique

Studio A - Project one was Architect Branded Environment. This was essentially focused on designing interior for a branded commercial environment. Students were asked to pay special attention to three dimensional branding, furniture design and window treatment. Project comprised of three activities and assignments: 1) learn and understand nature and characteristics of branded environments; 2) develop concept and prepare schematic and overall layouts; 3) prepare detailed drawings and final presentation.

Students were given three different products to be branded: a) watch store for 'Steel Cake', a company based out of Brooklyn- founded by design Mathew Burnett; b) Paint store for 'Miller Paint Co. Inc.' and c) a Shoe shop for 'Kathryn Kerrigan'.

There were 16 students, eleven female and five male. And all the students participated in this study. Students met in traditional design studio as well as in a separate computer lab. The studio environment was intimate, proportionately scaled. Class participation, discussion was encouraged by the instructor. The course objective, design challenges requirements and presentation criteria was mentioned as described in Table 12 below.

Table 12: *Class Structure of Studio A*

Studio Environment	**Independent Classroom**
Design Problem	Architect Branded Environments
The Design challenge	The proposed building will be located in a store of Columbia Mall on the south-west side currently occupied by Pacific Sunwear showroom (next to American Outfitters). It has a net area of 24'0"x96'0" amounting to 2450SF net area. The retail showroom will be 1500 SF, storage 600SF, rest rooms 50SF and mechanical will be 200SF. The Columbia Mall management has very specific design constraints. The demising walls are made of 6" metal studs at 24" spacing and the neutral pier is 1'0" wide steel channel. The slab to slab height is 20'0". You need to provide at least two exits. Mezzanines are not permitted. The storefront opening cannot exceed 50% of the total

	storefront width and only one entry per elevation is permitted. Entry height should be a minimum of 9'0" above finished floor and swing doors are to be in the direction of egress. Doors should be fully recessed doors when in open position. Glass storefronts systems that exceed 10'0" must be a minimum of 3/4" thick. It is recommended that you provide 5'0" minimum of hard surface transition flooring material past the entry.
Final Presentation:	(1) Concept Board showing a graphical description of your brand and how you achieved brand equity (2) Context plan showing the location of your store in relation to the mall@1/16" = 1'0"(3) Main Plan with Furniture Layout @ 1/4"= 1'0" (m) One display window and storefront elevation showing the facade @ 1/4" = 1'O"(4) One furniture detail (display shelf) showing joinery and materials @ 1/2" = 1'O"(5) One detail of signage @ 1/2" = 1'O" . Indicate letter height, typical letter section, method of mounting, colors and materials and location. Signage should not exceed 70% of the width if its placed in the storefront.(6) One longitudinal section through the storefront @ 1/4"= 1'O"(7) Reflected ceiling Plan @ 1/4"= 1'O". Provide lighting plan and ceiling heights/materials. Include a symbol legend with luminaries specifications. (8) Two Interior Vignettes. Larger 2'O"x1'6" and smaller 1'0"x 1'0". The vignettes must be those that best characterize the design concept. It is recommended that you show one with day lighting and other with night lighting. This could be hand drawn pr done through computers (9) Color Boards. Detailed materials, furniture and decorative elements selection for rooms of your choice. Mount all the samples on a board. Provide a key plan to illustrate the location of the selected furniture, finishes, and decorative elements.(10)Actual fabric and finish samples must be used in the presentation. Do not use computer-generated finishes or fabrics.
Presentation considerations	- Final drawings are to be mounted on 30" x 40" boards, and are to be "effectively" homogenous. Final drawings should be easily reproduced in an 8.5" x 11" format without loss of clarity (scale lettering accordingly). Indeed, reductions should result in a more convincing presentation. These reductions will serve as pages of your portfolio. Order your boards in such a way as to reveal or explain your design logically and attractively. Consider graphics (line weight, fonts, words, conventional symbols) as an integral part of your design. Graphic design should sense as a means of reinforcing the aesthetic adopted for your design.
Evaluation of student project (quoted from course syllabus)	<u>Brand Identity and Execution:</u> How well have you captured the brand in terms of architectural elements. Attention should be provided for not only physical characteristics such as finishes or hues, but also aesthetic qualities such as texture, visual weight and material density. Materials and colors should be chosen and expressed as meaningful design intentions that emphasize the brand identity. Remember that the qualities of these materials and colors are not absolute but is relative to other materials and colors used in the composition. <u>Spatial Choreography:</u> The ability to choreograph space in a deliberate and intentional way is an important facet of designing. Spatial choreography not only involves physical placement of space but also engagement of sensation brought about by light, movement, smell and sound. Hence, the spaces should be able to convey mood and ambience appropriate to the brand.

Table 13: *Student Demographics of Studio A*

Studio A	Student	Gender	Ethnicity	Major	Studio Experience
	1	Female	White	Interior design	3rd studio
	2	Female	White	Interior design	3rd studio
	3	Female	White	Interior design	3rd studio
	4	Female	White	Interior design	3rd studio
	5	Female	White	Interior design	3rd studio
	6	Female	White	Interior design	3rd studio
	7	Female	White	Interior design	3rd studio
	8	Female	Asian	Interior design	3rd studio
	9	Female	Asian American	Architecture	3rd studio
	10	Female	Asian American	Architecture	3rd studio
	11	Female	Asian American	Architecture	3rd studio
	12	Male	White	Architecture	3rd studio
	13	Male	White	Interior design	3rd studio
	14	Male	White	Interior design	3rd studio
	15	Male	White	Architecture	3rd studio
	16	Male	White	Interior design	3rd studio
Total	16	Male (5)	White (12)	Interior design (11)	
		Female (11)	Asian (1)	Architecture (5)	
			Asian American (3)		

The overall environment of the studio was rather collaborative than competitive. Students walked around, had conversation with other students. They learned/shared various drawing methods and techniques from each other.

Studio B

The studio observations were conducted during 2010 summer semester. Studio B was also a CIDA (Council for Interior Design Accreditation) accredited undergraduate program which offers both interior design and pre- architecture. Studio B was a four credit-hours architecture/ interior design hybrid studio (third studio course) for intermediate level students. Class met every Monday, Tuesday, Wednesday and Thursday from 8:30 am to 11:45 am. I observed almost every classes and followed the same procedure as described earlier for Studio A to get overall understanding on the nature of

the project, studio instructions, students' design processes and developments and most importantly the use of various design and drawing tools both independently and in combination with others.

Following table shows the data collection period and course syllabus.

Table 14: *Data Collection Period for Studio B*

	Summer 2010								
	Week								
	1	2	3	4	5	6	7	8	Total
Activities	Pre-Ana/P-up	Plan/ Sec Review		Elev/ Exp Axon/ Model Review		M-Crit	Dev/ Pres	Pres F-Crit	
Observation	12			12	12		12		12
Interview	Survey (12)							Interview (10)	

Note: Pre-Ana/P-up Student presentation and Pin ups=; D- Crit=Desk critique ; M-Crit= Midsemester critique ; Presentation board= ; F-Crit=Final critique

Table 15: *Class Structure of Studio B (quoted from course syllabus)*

Studio Environment	**Independent Classroom**
Required books	a. Susanka, S. (2004). Home by Design. The Taunton Press. b. Moreno, E., and Vranckx, B. (2008). 200 Outstanding House Ideas. Buffalo, NY: Firefly Books. c. Ching, F. D.K. (2008). Building Construction Illustrated. New York: Wiley.
Design Problem	Living at the Water Edge
The Design challenge	A Medical Doctor and his wife who is an amateur artist recently purchased a lot on Lake Union in Michigan. The couple wants to build a summerhouse on the lake for them and their two children, (Age 5, 7). What attracted them to the place are the breathtaking views over the unspoiled landscapes and the activities associated with lakefront living. The couple wants to live far from the maddening crowd, indulge in childhood reverie, put down roots and take in the natural rhythm of sun and the changing seasons. The house should attest to the aims of its dwellers. It needs to realize their ambitions or ways of seeing the world and their dreams.
Considerations and restrictions:	• The house should be limited to 2400 sq. ft. of finished space. • The owner's budget is limited to $300,000. • The owners wish to have an open floor plan. The public areas in the house should be designed with an easy flow among the kitchen, dining, and living areas. The dining area should be expandable for special events. Formal and informal spaces should be combined. Create double-duty rooms—everyday living spaces that can be

	shared. For instance, the informal and formal eating functions should be accommodated in the same place. • The entrance should be welcoming. Consider opening the back door from the garage and the front door into the same entryway offering a pleasant view, such as a window or special feature of the house. Incorporate half bathroom (powder room) and a coat closet near the entryway. • The house should make maximum use of daylight. Consider the size and the location of the windows and develop good connections to nature. Consider alcoves and window seats to allow various activities in the rooms and to make the living spaces more homey and comfortable. • The main floor should include an entrance, half bathroom, kitchen, dining area, living room, a master bedroom with closet rooms for him and for her, and a master bathroom attached to the master bedroom. • The kitchen should be large enough to accommodate several people. Consider a good connection from the garage to the kitchen. The kitchen should have access to an outdoor area (a deck?) for cooking and eating outside. The kitchen should be designed so that the odors of cooking do not spread all over the house. Consider appropriate ventilation and exhaust systems. • The house should include 3 bedrooms (2 children bedrooms beside the master bedroom). A study should be located in the basement. • The house should have a variety of ceiling heights. Avoid uniform heights in the design. The height of a space is critical to the way it is experienced. Spaces are enlivened and better defined when ceilings are raised or lowered. • The basement area should include large space for storage and unexpected needs such as a studio or a hobby area. • The master bedroom should include a private, cozy reading/study area. • The master bathroom should be adjacent to the master bedroom and should include two sinks, a toilet, a shower and a large bathtub. The other bathrooms should include a sink, toilet, and a shower. • Laundry room should be designed on the main level with an ample area for hanging and drying clothes, and a space for ironing. • The house should include a lot of built-in storage and bookcases. Rather than spending a lot of money on furniture, the owners want the built-ins to serve the function of furniture as a natural extension of the house. • Consider connecting the inside to the outdoors. Spacious decks and porches can increase the space considerably. Screened-in porches provide a sheltered way to celebrate summer weather, allowing residents to experience the light and beauty of nature in an outdoor room. • Choose the finishing materials to allow minimal indoor and outdoor maintenance. The materials should be durable and should reflect the local context of the site. • Include a 2-car garage with an additional space for storage of yard equipment
Presentation considerations	1. Concept Statement: Provide a written description of the design concept on the first presentation board. 2. Required Drawings: • Site Plan 1”=10.0’ • Floor Plans @ 1/4” = 1’-0”. The floor plans of all the different levels will include furniture and fixtures layout. • At least two building sections 1/4” = 1’-0” • Exploded Axonometric of the Building in a scale that fits the page • At least four Interior Perspectives. These may be at whatever size you choose. The views must be those that best characterize the design and overall ‘decor’. Choose your rendering style based on your design concept. Survey the work of various designers for extant perspectives of this kind. • Model @ 1/8” =1’-0”

	• Finishes' Board Detailed furniture and decorative elements selection for rooms of your selection. Mount all the samples on a board. Provide a key plan to illustrate the location of the selected furniture, finishes, and decorative elements. • Final drawings are to be mounted on 20" x 30" or 30" x 40" boards, and are to be "effectively" homogenous, though it is acceptable to employ various adhesives, "sticky backs", press type transfer lettering, shading and color "screens." • Final drawings should be easily reproduced in 8.5" x 11" format without loss of clarity (scale lettering accordingly). Indeed, reductions should result in a more convincing presentation. These reductions will serve as pages of your portfolio. • Order your boards in such a way as to reveal or explain your design logically and attractively • Consider graphics (line weight, fonts, words, conventional symbols) as an integral part of your design. Graphic design should serve as a means of reinforcing the aesthetic adopted for your design.
Other Requirements	• Students will develop their individual solutions for the design of the country house. • During the first three weeks of the class, students will present in class one house in detail. The choice of the house is yours, however you must submit your proposal for your instructor's approval. The presentation should include full documentation of the house (floor plans, sections, color images, concept statement, etc.) The presentations will include each of the following nine categories: 1) Plan organization; 2) Section organization; 3) Interior circulation; 4) Light; 5) Façades; 6) Surface and material effects; 7) Public/private relationships; 8) Building/landscape relationships; and, 9) One other category of your choice that you feel has particular importance to your building. • The final design proposal should reflect the design process, including the evolution of design from the program schematics, the exploration of design alternatives, and evidence for the development and refinement of the design solution. The final presentation of the projects will be evaluated based on the visual and verbal quality. Special attention will be given to format clarity, aesthetics, innovation and creativity of the concept and the actual design proposal.

Table 16: *Student Demographics of Studio B*

Studio A	**Student**	**Gender**	**Ethnicity**	**Major**	**Studio Experience**
	1	Female	White	Interior design	5th studio
	2	Female	White	Interior design	5th studio
	3	Female	White	Interior design	5th studio
	4	Female	White	Interior design	5th studio
	5	Female	White	Interior design	5th studio
	6	Female	White	Interior design	5th studio
	7	Female	White	Interior design	5th studio
	8	Female	White	Interior design	5th studio
	9	Female	Asian American	Architecture	5th studio
	10	Female	Asian American	Architecture	5th studio
	11	Male	White	Architecture	5th studio
	12	Male	White	Interior design	5th studio
Total	12	Male (10)	White (10)	Interior design (8)	
		Female (2)	Asian American (2)	Architecture (4)	

None of the studios instructed or required any specific method of design representation and use of modality. Therefore, use of variety of design and drawing tools in a wide array of combination has been observed during different stages of design.

4.2 Identifying modality shift

Exact moment and process when of modality shift is hard to identify and document. Generally modality shift happens when designers talk back with their own design and identify new features or shortcoming of their existing design. This also can happen when designers need a different perspective while facing trouble perceiving certain design features as formal and spatial attributes and relationships. Since the

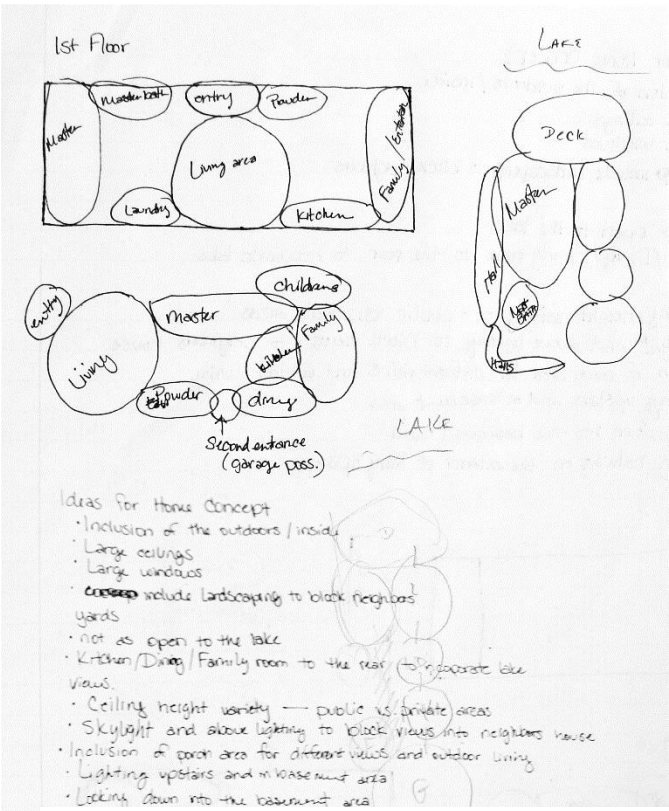

Figure 7 Concept generation

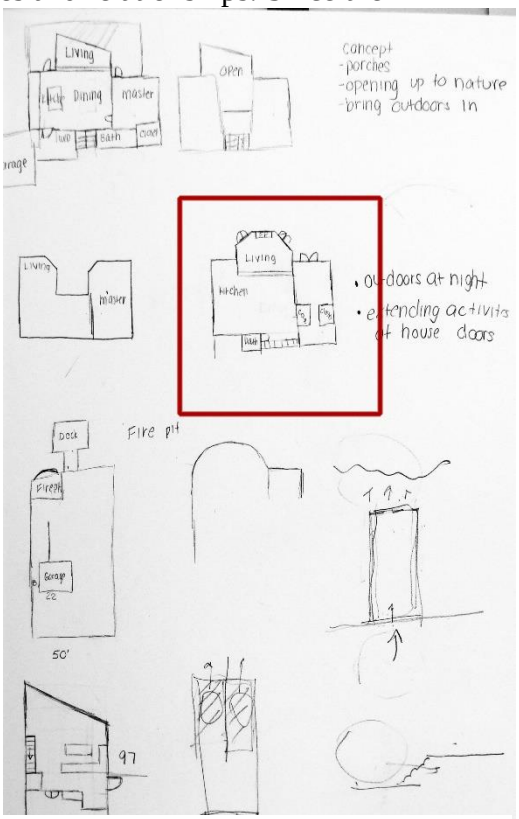

Figure 6: Form generation

process of design is highly individualistic in nature where each designers possess certain strength and weakness over design thinking and externalizing those thoughts. Besides aptitude and preference over modalities and their constraints; studio environment and culture, instructions, project requirements are some of the variables that dictates shifting modalities during the process of design.

In this study identification of modality shift depended mostly on discrepancies, gap and changes between connected drawings and designer's retrospective reflections about their design developments and manipulations. It was also identified that modality shift in majority of times was executed to manipulate form and details more than other aspects of design. For instance, one studio B student started with text and diagrams (see Figure 7 Concept generation) to document her ideas, basic schematic layout in bubble diagram and some rudimentary shapes of the building as can be seen in Figure 6. Highlighted shape is the one that this student preferred to develop farther.

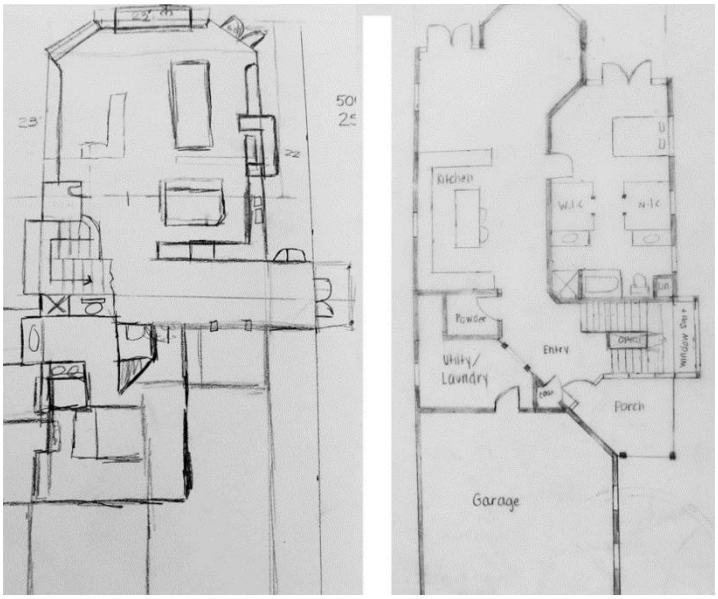

Figure 9: Study Drawings. Single line layout (left) and preliminary scaled floor plan (right)

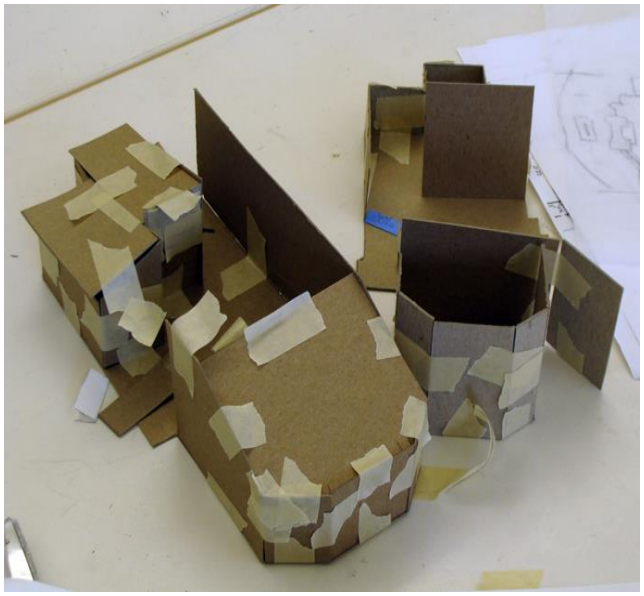

Figure 8: Initial massing study model

After selecting the preliminary form designer envisioned a rough space layout. Figure 9 shows an attempt of transforming ideas of generous and free flowing living space by adding ‘large windows’, ‘large ceilings’; to ‘bring outside (nature) in the building; privacy from neighbors; hallway and skylight (see Figure 7 for ideas for house concept) in to drawings (floor plans). Once preliminary layout is verified, designer made a rough model (Figure 8) to visualize various formal attributes as scale, formal relationships, roof slope and such. As a part of studio instruction, designer created two versions of floor plans as presented in Figure 9.

An altered version of space layout for main level (Figure 11) was prepared after building the massing model with references and details taken from both initial drawings (Figure 9). As result of studying massing model and influence of studio instructor, this designer decided to manipulate some of the design features as omitting nook type of space (Figure 9, left), screened porch and reshaped the deck (Figure 11, left).

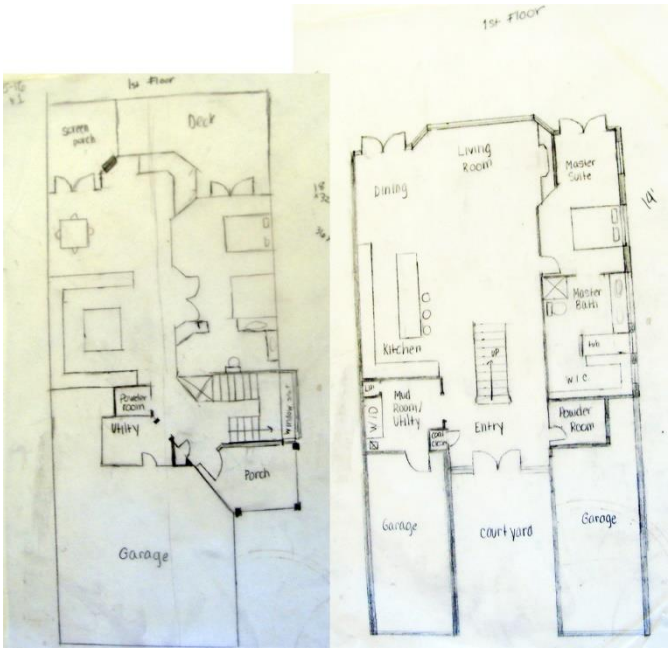

Figure 10: Design development with manual modalities

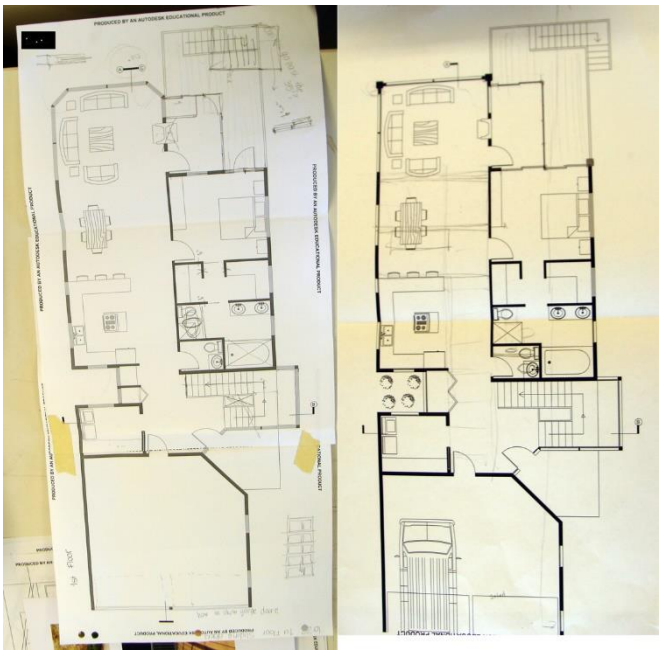

Figure 11: Design development in Auto CAD

Once the designer shifted to digital modality (AutoCAD in this case), she further edited her design by inserting a notch between laundry and kitchen to bring light into both of these two spaces (Figure 10). Shape and location of master bed was adjusted and repositioned as well as stair connecting deck to ground below. These changes are significant and in this research it was marked as result of modality shift that occurred because of designers' brainstorming with design constraints, gaining new perspective by producing scaled drawing form initial study drawing, continuous research and inspiration from precedents. It is safe to assume that this designer from studio B selected favorable solution once alternatives are visualized, comprehended and documented with proper modality that helped her to rationalize the selection. Final floor plan is presented in Figure 12.

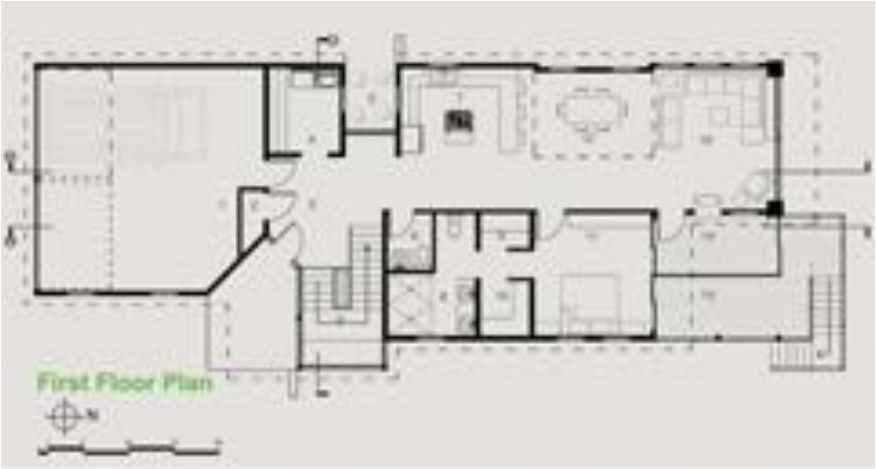

Figure 12: Final floor plan

Figure 13: Developing details and features on elevation using multiple modalities

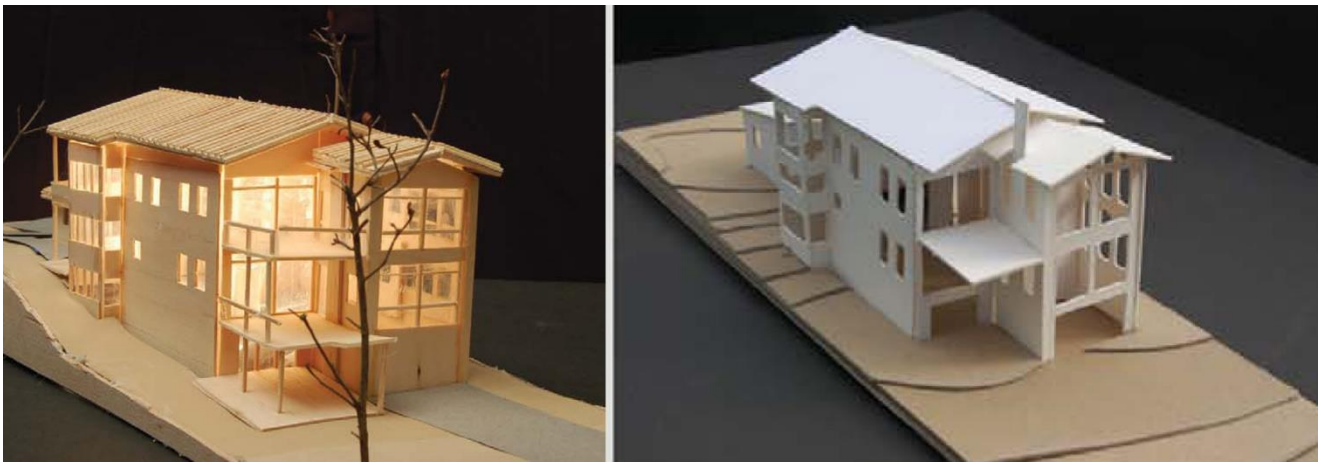

Figure 14: Final presentation model and second study model

Besides working on tracing paper with pencil and in AutoCAD, designer often took printouts from the CAD application and experimented alternatives to develop design ideas that was unperceivable before in either of these modalities alone. Figure 13 demonstrates (from right to left) the process of finalizing front elevation of the building using AutoCAD, developing alternatives with pencil on CAD printouts, and finally recreating the elevation in AutoCAD again. A second study model (Figure 14, right).

Another example from the same studio demonstrating the beginning of design process as previous instance. This designer envisaged to design a residence that will facilitate various kind of creativity for the children and the artist wife (owner).

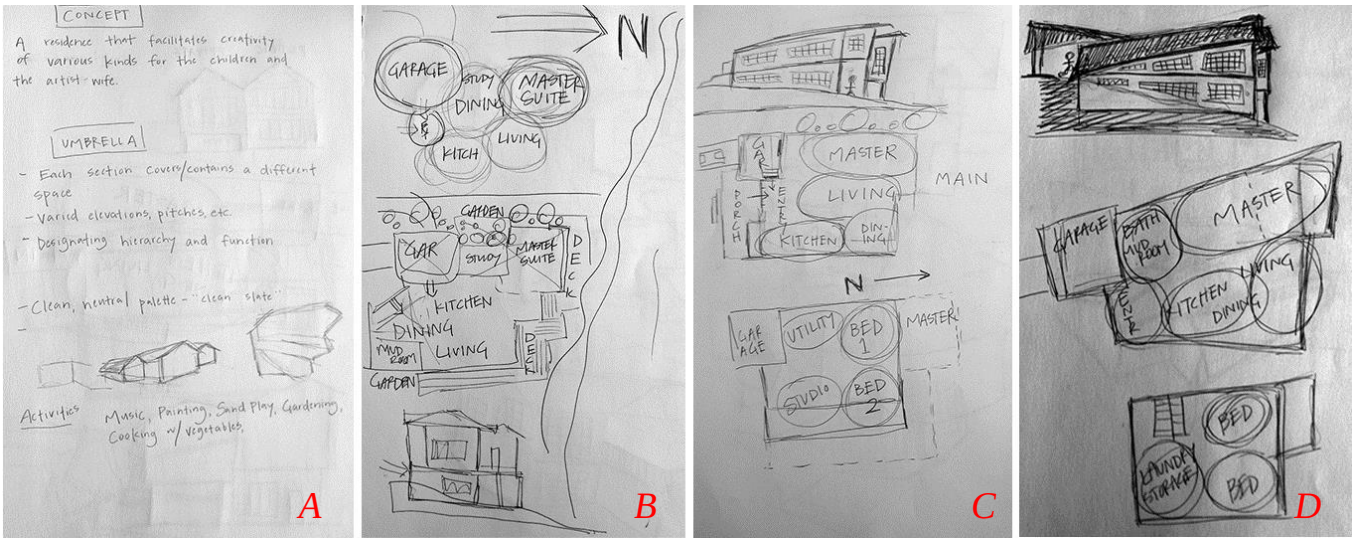

Figure 15: Concept and architectural study drawings for form generation.

The shape of an umbrella (see Figure 15 *A*) was taken as the inspiration for form of the building where each section was considered to house different spaces. Designer also wanted to bring hierarchy in function as well as varied elevations and pitches. Starting with bubble diagram to lay out major functions designer drew a rough layout of built form and assigned required functions in it with relative ease. These two drawings (Figure 15 *B*) exhibit designer's competency on seeing spatial relationships in her mind. Figure 15, part *C* and *D* are the due courses of design development, its evaluation and verification.

However, in next set of drawings the designer prepared several three dimensional sketches to study the roof as one of the key features of the whole design which also translates her abstract concept into tangible form. Figure 16 shows the designer's attempts of experimenting roof slops. The designer made paper study model (Figure 16, 3) in order to get new ideas and perspectives as well as a visual aid for drawing orthographic projection.

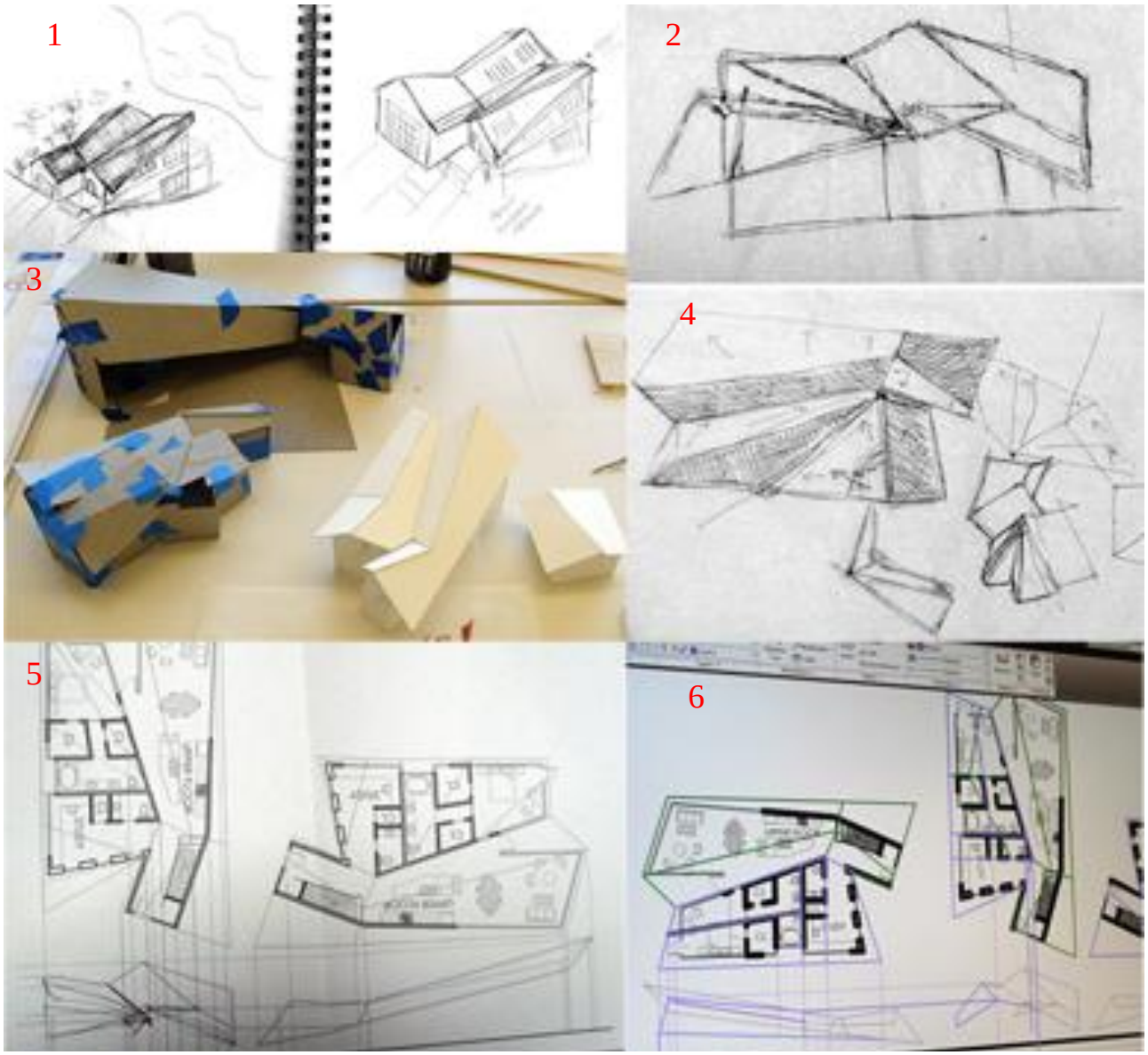

Figure 16: Design Development in multiple modalities

According to the designer -

> I was never confused with how my roof would look like (Figure 16, 1) but it was so hard to draw (Figure 16, 2) in scale. I can see it, draw it (freehand sketch) really easy but when I tried it in CAD; I guess, I get confused with different heights and slopes. This model (Figure 16,3 : first study model) helped me a lot to understand the relationships of slope and direction …… A few things I am having trouble with AutoCAD is building 3d model, aligning the roof slope but I found some good tutorials ….. (from Studio B student's interview).

A simple shift of modality from two dimensional manual sketches to volumetric paper model aided designer to perceive certain specific characteristics that was unclear before (Figure 16, 4). Designer moved back to digital modality once the shape of the roof was clarified and generated other relevant drawings as elevations and perspectives. This designers demonstrated certain creativity and aptitude with manual modalities during ideation and form generation phase but due to slight lack of knowledge on digital modality some important details conceived during conceptualization phase was compromised. For instance, windows on roof or skylights (Figure 16,1) was taken off rom during development and documentation phase because of its complex 3D modeling and detailing procedure (Figure 17).

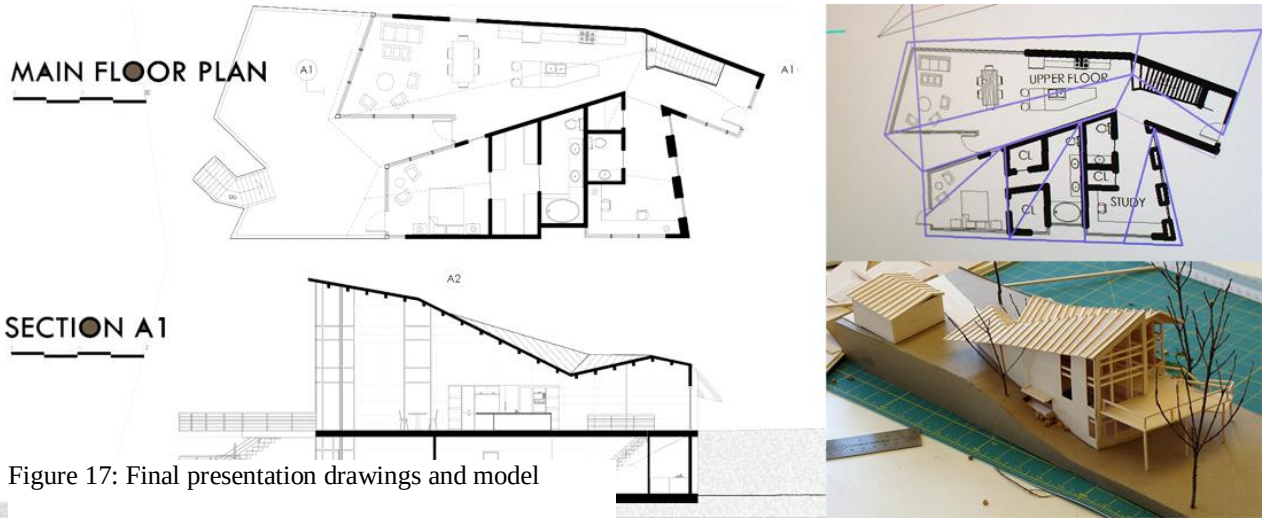

Figure 17: Final presentation drawings and model

Most of the designers in studio B spent large amount of time with various manual modalities to generate and develop their designs. Computer mediated tools were primarily used for documentation and presentation purposes. These intermediate level students in generally were relatively unfamiliar with advanced computer 3D modeling and complex 2D drawings. Form studio observation and interview with the students it was further clear that instructors' direction, and influences also worked as a dominant factor for the selection of modalities.

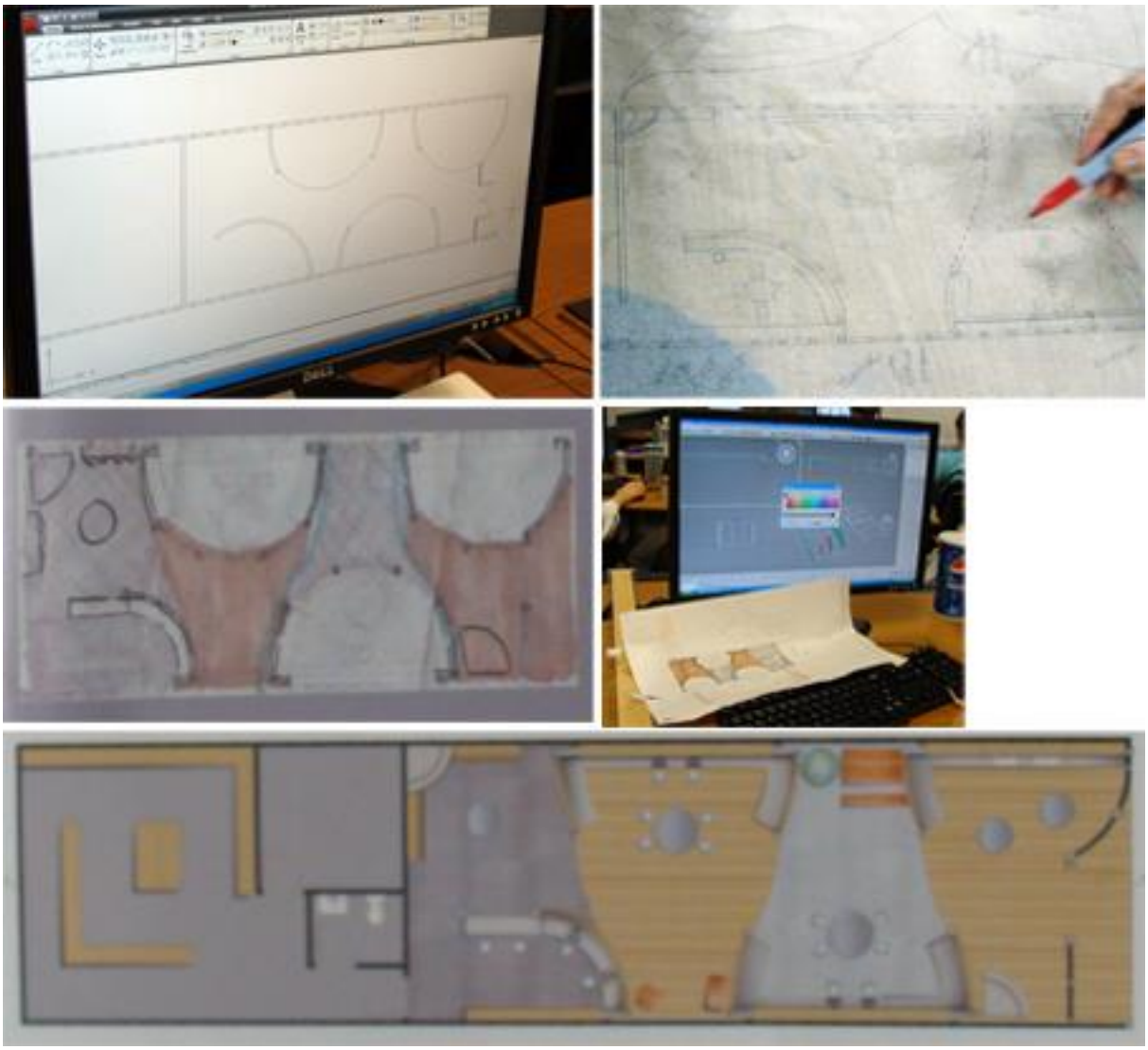

Figure 18: Study of flooring pattern and material.

In Studio A, however a slight different mixture of using and mixing modalities were observed. Studio A students were more experienced senior level students with competitively greater and divers studio as well as modality experience. For instance, in Figure 18 one student started her design development in AutoCAD but composed and examined her floor pattern on hand drawn floor plan with color markers. She moved back to computer to see alternatives choices of color in computer because of its convenience. Result of her final solution to the design problem can be seen in the floor plan presented at bottom row. Unlike most of the studio B students this studio A student did not go back and forth between various modalities both digital and manual to develop the solution of her problem. Another student form the same studio started with a number of study drawings before moving into CAD program (see Figure 19). Most of the design details and decisions were made using manual modalities. AutoCAD printout was used (as underlay) with pencil to briefly design reflected ceiling plan and lighting layout. This designer moved between computer applications (from AutoCAD to SketchUp) to generate 3D model of the showroom interior which he could not satisfactorily construct in AutoCAD. By shifting modality this student did not necessarily bring any significantly visible change to his design but the clear and augmented perception that the Sketchup model provided may helped him to verify all design decisions made with other modalities earlier.

A different course of actions were identified in Figure 20 where the designer did not demonstrated any noticeable shift of modality. Design process started with significant amount of textual and very methodical detailed drawings (close to scale). The level of abstraction presented to express design concept and initial thoughts demonstrates this student's significant strength over externalizing her imagination, formal and spatial perception as well as competency over drawing conventions. AutoCAD was used for preparing final presentation drawings and making 3D model for generating perspectives views as every other projects in both of these two studios. Even though the final presentation media was kept free for both the studio projects, unanimous use of digital

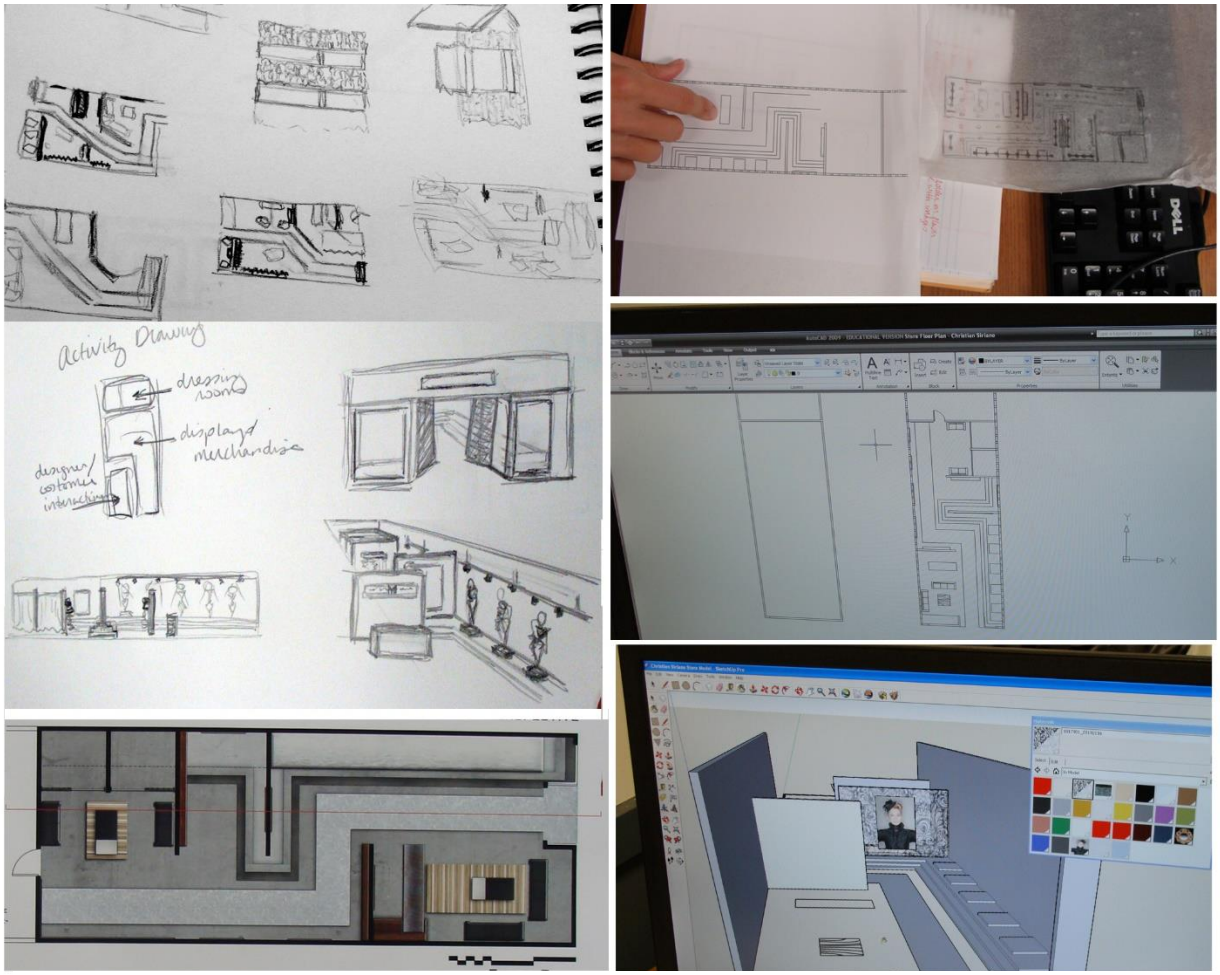

Figure 19: One of the Studio A student's design process

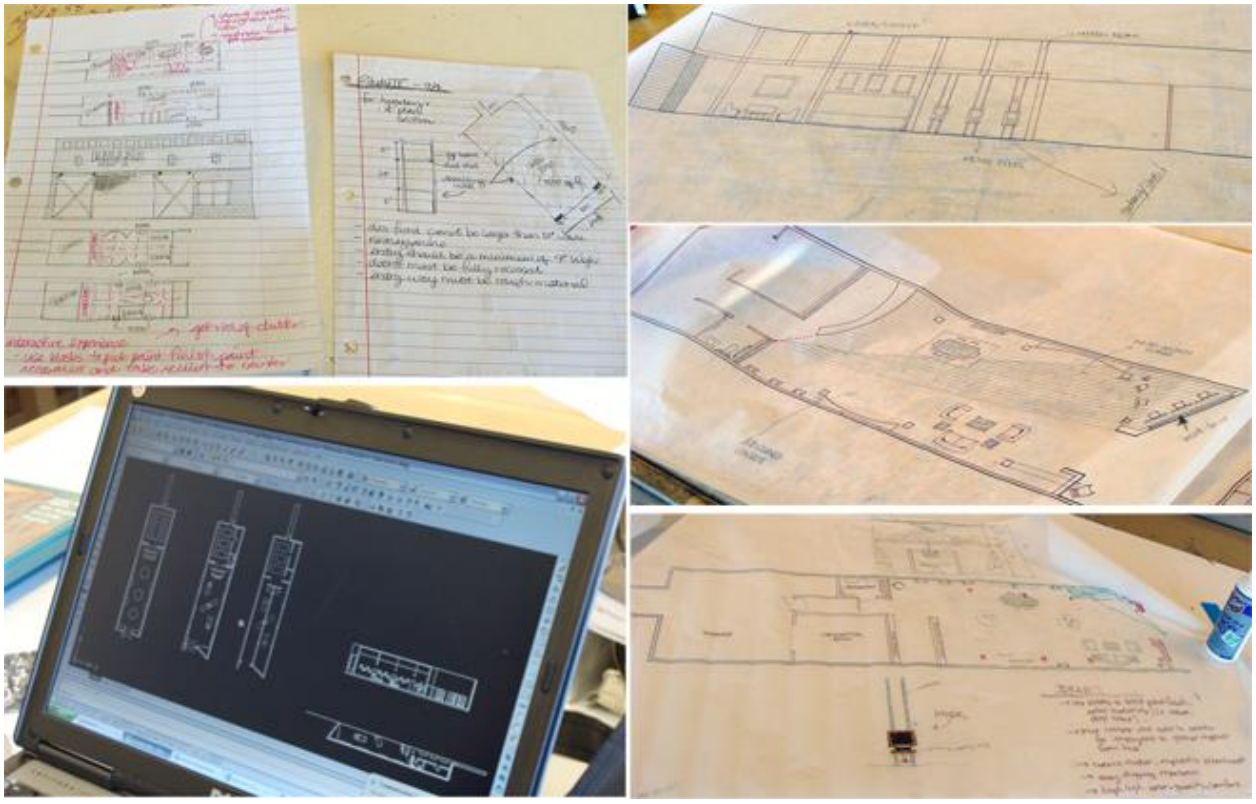

Figure 20: Studio A student's example of design process

modalities for final documentation and presentation could be because of studio environment, culture of using computational media, convenience and such.

It is important to note that possessing this skills may not necessarily impact the quality of design as effectively as its communication but in most cases experience and competency on multiple modalities aid designers to perceive design attributes in greater depth and detail.

4.3 Designer's Experience and Modality Constraints

As it was discussed in earlier sections that- design process dialogues are primarily conducted through visual language that design students learn by visually combining different sources of information. Different design and drawing tools help designers think graphically and communicate with their thoughts and ideas. The challenge is to implement this within the context of the individual design process that takes practice, practical experience and observation. Design researchers as Bryan Lawson (2004), Pamela Schenk (2005) pointed that designer's skill and competency on design tools largely contribute to the development and support of design thinking. It can be assumed that experience designers can see a significant attribute of their developing design in their own drawings.

Both 'studio A' and 'B' students were free to choose their representational-media. A descriptive analysis of collected data from survey provided a general overview of the sample. Students assessed their competency on understanding and execution of digital applications on a Likert scale of 1 to 3. The results showed that majority of the students (70%) are familiar with four or more commonly used CAD applications (see Figure 21). 56% of the students reported that they have frequently used digital media and 33% used it

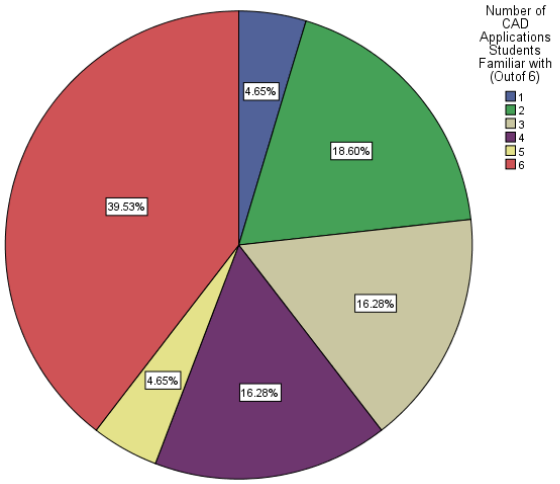

Figure 21: *Student's familiarity on common computer application*

occasionally (with a Std. Deviation of 0.7). Table below provides a visual indication of the students' self-assessment scores.

Table 17: Frequency of computer use, number of known software and self-assessed computer proficiency.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Number of software known to students (out of 6)	28	1	6	4.16	1.731
Frequency of computer use during design process	28	1	3	1.56	.700
Computer knowledge (self-assessment)	28	1	3	1.95	.872

Most of the students installed three or more commonly used CAAD and graphic applications (Autodesk AutoCAD, Revit Architecture, 3d Studio Max, SketchUp, Adobe Photoshop, Adobe Illustrator), and 100% had internet access. Access to internet and availability of abundant video description, tutorial and 'how-to' videos have proved to be very effective and helpful learning tool. Van Dijk (2005) discussed this in his 'learning by doing' theory as an very effective learning tool. Students learned more digital media applications as they get more studio experience (Figure 22). Between studio A (Senior level) and B (Intermediate level) it is normal to assume that senior students will demonstrate greater depth of computer knowledge which also confirmed (see Figure 22) significant effect on frequency of modality shift during design. It was identified that the probability of modality shift is higher when students have less knowledge over representational media (both digital and manual). In studio B, student with moderate to strong computer knowledge reported less

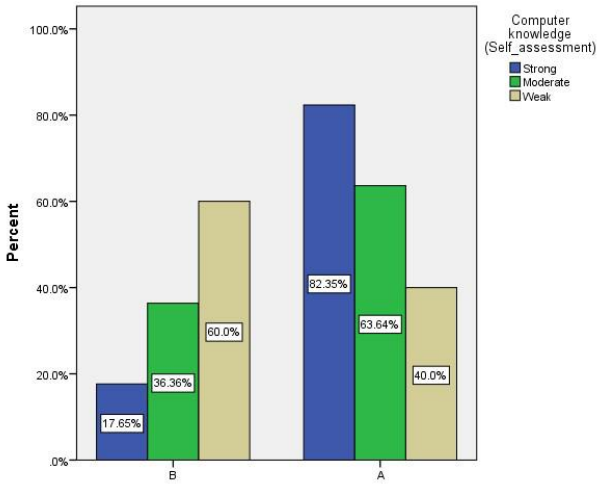

Figure 22: *Beginning and advanced studio student's computer knowledge*

frequent shift of modality than the comparatively expert studio A students. Pearson chi-square statistic for Studio B (of 1.778 with p-value of 0.441, which is not significant) indicates higher association (see table 18) between computer knowledge and modality shift compare to Studio A (of 11.282 with p-value of 0.024 which is significant). This also verifies that experienced students (with the design process and both representational media) are able to make decisions regarding appropriate design and drawing tools as they move forward in the design process.

*Table 18:*Chi-Square Test of correlation between computer knowledge and frequency of shift

Chi-Square Tests

Studio		Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
B	Pearson Chi-Square	1.778[c]	2	.411	.578		
	Likelihood Ratio	2.718	2	.257	.489		
	Fisher's Exact Test	1.717			.578		
	Linear-by-Linear Association	.128[d]	1	.720	1.000	.511	.257
	N of Valid Cases	12					
A	Pearson Chi-Square	11.282[e]	4	.024	.020		
	Likelihood Ratio	13.646	4	.009	.017		
	Fisher's Exact Test	10.124			.023		
	Linear-by-Linear Association	9.070[f]	1	.003	.002	.001	.001
	N of Valid Cases	16					
Total	Pearson Chi-Square	11.669[a]	4	.020	.017		
	Likelihood Ratio	14.464	4	.006	.012		
	Fisher's Exact Test	11.896			.012		
	Linear-by-Linear Association	10.952[b]	1	.001	.001	.000	.000
	N of Valid Cases	28					

These results suggest that students were consistent in assessing their selection and assimilation of architectural design modality only when they acquire sufficient knowledge and skill on design process and representational media. At the same time within the same studio, students also reported slight inconsistency in assessing their CAAD skill by scoring various levels of CAAD experience. Additionally, from the survey the sample's attitudes towards CAAD, their biases and skills in respect to digital

modality were better understood. The majority of the sample (84%) used CAAD regularly in the design process. Among those 33% used various form of digital media for design development; 27% used it for idea and form generation and documentation, whilst 30% used it during the final phase only. 5% of the students reported that they use digital modalities throughout the whole design process.

In another note, 66% of the sample stated that they have used digital modality for designing and drafting where 34% used it as a drafting tool only. While many similar study concluded that computational tools are useful as an architectural representational media, 54% of the sample in this experiment experienced that digital modalities positively affect their work by providing design alternatives, stimulating holistic perception, corroborating pre-conceptual ideas and identifying design problems successfully. However, a large portion of the students (51% strongly and 37% moderately) agreed that sketching had been very helpful for ideation as well as an important activity to start the design process before moving on to CAAD.

Mean plots (Figure 23 and 24) created based on students self-assessment portrays that comparatively expert designers with manual modality preferred to use CAAD applications for the final phase, specifically for presentation and documentation. Their use of digital modalities increases as the design progresses toward final phase. While experienced computer users (Figure 37) used it frequently for early design phase (conceptual and formal development) with varied combination of CAD and modeling applications as well as during final phase of design for three dimensional rendering, presentation and documentation.

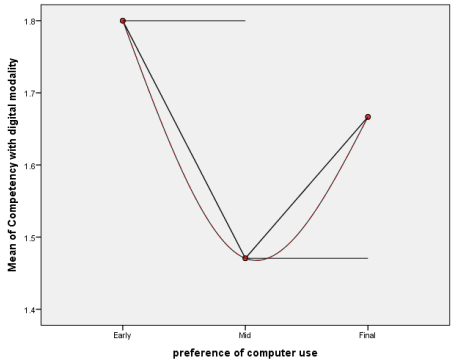

Figure 23: *Mean Plot for digital modality and designers' preference of its use in design phases*

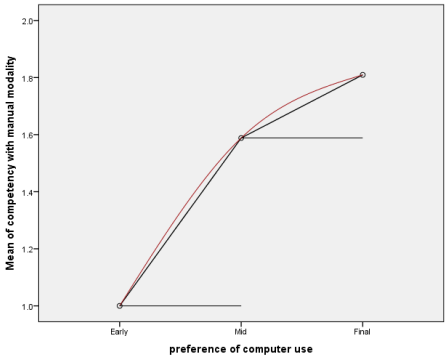

Figure 24: *Mean Plot for manual modality and designers' preference of its use in design phases*

Additionally, students who assessed their CAAD skills as fair (basic 2D) during survey was not efficient in their 3D skills to develop computer generated 3D model. To generate design alternatives and verify solutions, instead of using computer modeling they used traditional drawing methods (see Figure 25) to study and analyze conceptual engagements (in 3D forms). 'Studio B' students reported in their interview that they have started with drawing basic layout in CAD and looked at few pre-design aspects as site, probable building orientation, existing structure on site and context to relate those with other analysis methods. Quick sketches, study drawings have helped them (students) make sense of numerous aspects which was hard to understand before. Simple orthographic (Multiview) projections that represents 3D objects in 2D

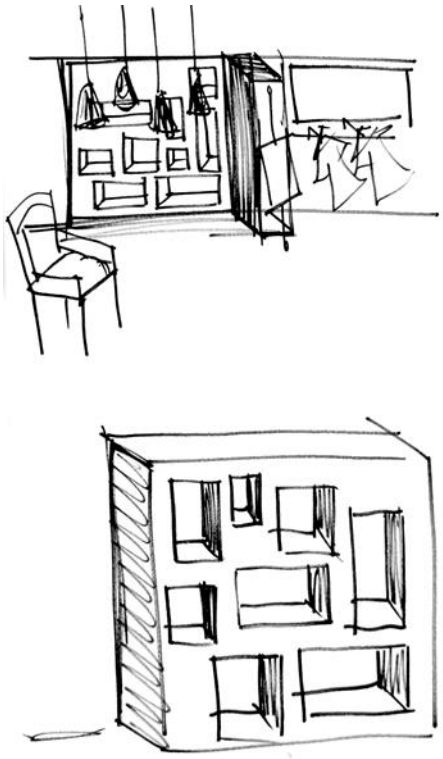

Figure 25: *'Studio A' student's work - experimenting design alternatives*

drawings which some students drew in an isometric manner to sense the third dimension. Such drawings offered better understanding and a continual analysis of the built form.

Designers conceive, develop and refine their thoughts step by step in iterative design ‘loops’ (Zeissel, 1984). Throughout the whole duration designers stay busy determining the ‘course of action’. This was done with ‘Designerly’ investigation (Archer, 1981), reference material, reflection from experience, precedents, previously developed conceptions and by constructing explicit preferences which trigger the decisions for design solutions. During the course of design, various kinds of visual information is recurrently being developed, selected, verified, and consequently either rejected or developed further. Statistical analysis of gathered data showed a significant positive correlation ($r = .331$, $n = 28$, $p < .05$) between students’ expertise in manual modalities and their preferences of computer use (Table 19); however, it was found that- a positive correlation which is not statistically significant ($r = .015$, $n = 28$, $p > .05$) between preferences of using digital modalities and designers’ level of expertise in digital modalities (Table 20). Perhaps this is because of the small sample not population.

Table 19: Correlation between CAAD preference and competency with manual modalities

Correlations

		competency with manual modality	preference of computer use
competency with manual modality	Pearson Correlation	1	.331*
	Sig. (2-tailed)		.030
	N	28	28
preference of computer use	Pearson Correlation	.331*	1
	Sig. (2-tailed)	.030	
	N	28	28

*. Correlation is significant at the 0.05 level (2-tailed).

Table 20: Correlation between CAAD preference and competency with digital modalities

Correlations

		preference of computer use	Competency with digital modality
preference of computer use	Pearson Correlation	1	.015
	Sig. (2-tailed)		.925
	N	28	28
Competency with digital modality	Pearson Correlation	.015	1
	Sig. (2-tailed)	.925	
	N	28	28

Designers did not rely solely on one type of drawings. They have proven to be inventive in developing or adapting a wide range of other design ‘instruments’ for both physical and conceptual model, schemes, diagrams, collages, photomontages, as well as to employ various codes, symbols and legends. Digital drafting may have initially attracted most attention, in recent years various forms of virtual modelling and image manipulation have greatly expanded the creative palette of the contemporary designer. The introduction of such tools has led to more personal and varied working methods, whereby active use can be made of different combinations of digital techniques.

Familiar conventional and physical media have not altogether been replaced by computerized design media, though it is undoubtedly true that computer driven media have taken over the role of certain techniques, such as that of traditional technical drawing. However, some ‘tangible’ design media as sketching and physical modelling, still play an important role; in design education as well as in practice. One of the most interesting developments that have become evident is the increasing tendency towards working with different sorts of media – in conjunction – digital as well as traditional.

4.3.1 Effect of level of experience

There were some differences between experienced and relatively inexperienced designers. In relation to circumscribed thinking, it was found that experienced designers are more likely to be driven by requirements, and not affected by constrained thinking. Designers with substantial CAD experience are more likely to be consciously driven by project requirements which often may result in restricted ideation. As the process goes deeper experienced CAD (and dependent) users show lack of enthusiasm and motivation that influence creative process. This study however, identified a little bounded ideation.

4.3.2 Effect of level of CAD usage

It was found that the competent and constant CAD users were more likely to execute less modality shift. This may also mean that frequent CAD users experience less ``negative" circumscribed thinking. Designer with greater CAD knowledge switched less between modalities. Table 21 shows significant ($r = -.446$, $n = 28$, $p > .01$) negative

correlation between competency with digital modality and frequency of modality shift. At the same time Table 22 shows that frequent modality shift results in significantly greater ($r = .440$, $n = 28$, $p > .01$) amount of modification and drift from initially conceived design ideas.

Table 21: Correlation between frequency of modality shift and CAD applications.

Correlations

		Frequency of Modality Shift	Computer knowledge
Frequency of Modality Shift	Pearson Correlation	1	-.446**
	Sig. (2-tailed)		.003
	N	28	28
Computer knowledge	Pearson Correlation	-.446**	1
	Sig. (2-tailed)	.003	
	N	28	28

**. Correlation is significant at the 0.01 level (2-tailed).

Table 22: Correlation between frequency of modality shift and change of initial design ideas.

Correlations

		Frequency of Modality Shift	Frequency of initial idea modification
Frequency of Modality Shift	Pearson Correlation	1	.440**
	Sig. (2-tailed)		.003
	N	28	28
How often have you modified your initial idea	Pearson Correlation	.440**	1
	Sig. (2-tailed)	.003	
	N	28	28

**. Correlation is significant at the 0.01 level (2-tailed).

However, from these data it cannot definitively be concluded whether the constant CAD use and incompetency with manual modality (or vice versa) has motivated students'

behavior to change initial concept and design ideas rather than developing it further or whether it is because of studio culture, confidence or necessary knowledge on multiple design modalities.

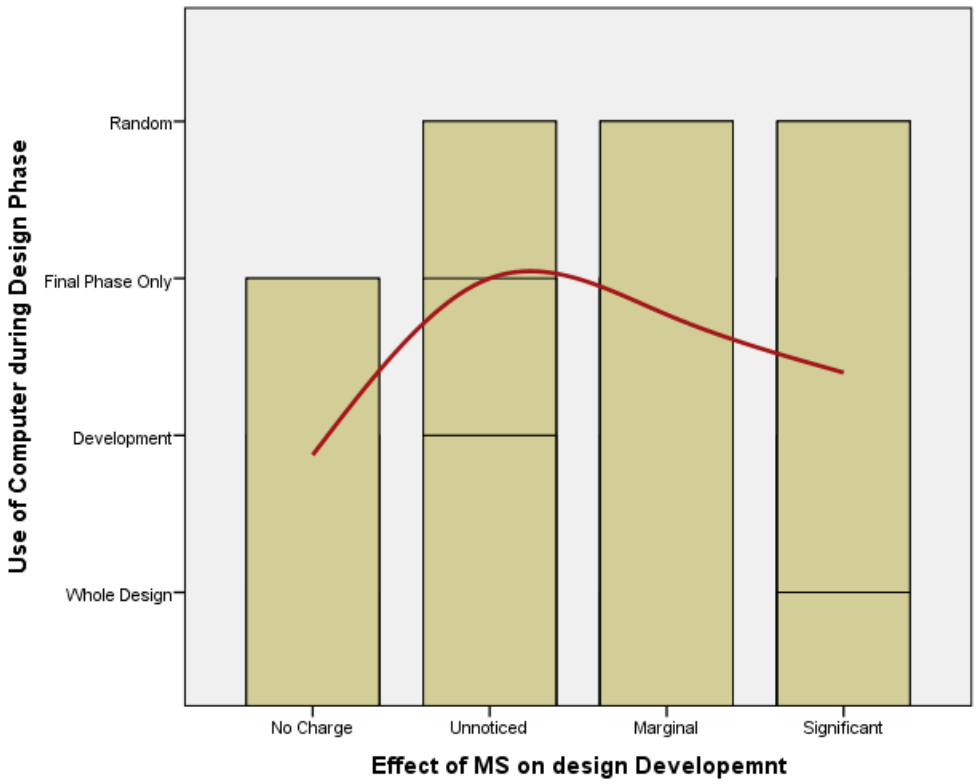

Figure 26: Effects of modality shift on design development and use of computers during design phases.

But it is safe to assume that constant CAD use may not be an obstruction to creative thinking and may improve it. However, the difficulty with this conclusion is that the direction of reasoning is again unclear.

4.3.3 Effect of Constraints and Stuckness:

Ideation and externalization of design is similar to any other creative thinking process that frequently encounters difficulties, constraints, stuckness (Sachs, 1999), blocks (Adams, 2001), breakdowns (Winograd & Flores, 1986) etc. Designer's limitation of design knowledge, skill over modalities and externalization of thoughts restrict them to continue dialogue within the design process. A summary of designers' constraints map is presented in Table 23. Predominant effect of three independent variables on the design process was identified in this study are - a) manual communication/ presentation skills, b) CAAD software skill and c) ability to externalization of thoughts. Despite the fact that technology plays a vital role in creating and presenting architecture in digital age, it is also considered as a noteworthy source of 'distraction'. It was observed that sound knowledge over traditional design process and manual modalities (i.e manual design and drafting tools) tends to help developing better understanding and control over digitization of design (drawings). Whereas comparatively less competent students tend to misuse the tool regardless of its type. The beguiling effects of the digital media often misleads or distracts designers resulting in producing poor design solutions. It was also observed that students with greater grasp over manual modalities and tactile presentation methods, expressed less enthusiasm for using digital media during early design phases.

External representations has a number of characteristics that enable the facilitation of problem solving and creative thinking by serving as visual aid. Postman (2011) interpreted medium as a message that "embedded in every tool is an ideological bias, a predisposition to construct the world as one thing rather than another, to value one

medium over another, to amplify one's sense or skill or attitude more loudly than another". This means that different media has its own constraints and limitations so as designers' expertise and manipulative skill to put that particular media in use.

Table 23: Constraints concept map (Herbert, 1993)

Constraints	Designer	Capability	Cognition	Imagination		
				Knowledge	Learned	
					Innate	
			Artistry	Style		
				Quality		
				Technique on Media	Illustrative	
					Communicative	
		Design considerations	Form	Scale	Internal	Ergonomics
					External	
				Size		
				Proportion		
			Functionality			
			Material			
		Information	History	Precedents		
			Research & design	Evidences		
		Knowledge	Modality			
			Design process	Concept formulation		
				De-abstraction		
				Design development		
			Design communication			
		Background	Exposure			
			Ethics			
	Design	Techniques	Capability			
			Development	New tools		
				Conventional CAD		
				Conventional manual tools		
		Time	Presentation			
			Collaboration			
			Research			
		Standards	Project requirements			
			Presentation criteria			

In the interview students most frequently allied constraints that leads to modality shift as- getting 'baffled with progress', 'not certain about how to proceed', 'unable to translate abstract concept' into credible form, and 'perceive spatial and formal relations' within the project.

> At the beginning - I was stuck and desk critique was due in a couple of days. As you have seen, I had a lot of conceptual sketches, mostly two dimensional. But, I didn't like those…. It was so frustrating. I think I don't sketch very well, so I decided to work in SketchUp before making cardboard model. The most important thing for me at that point was to come up with a good idea. I went through the Susanka's book (Home by Design), "200 Outstanding House Designs" and a few others. After I drew the schematic- I realized that- the form that I want is not exactly supporting (fitting) this schematic layout. (Studio A student)

Both the studios had different project requirements; most explicit and probably the most important of all was to produce a novel solution for the given design problem within a specific period. Where the emphasis lied on the progress in developing design solution or object that requires a visual representation of it. Thus, visible demonstration of what designers are thinking and synthesizing to address given design problem is commonly considered as design progress. This architectural production is usually done with a series of drawings and models, each of which is a mature expansion of its predecessors where designers' reflection, research and rigorous analysis is involved. Constraints and impediment those appear during design is a relative factor that largely depends on designer's previous work, exposure and knowledge of design media and method. However, discovering this hinder-ness not necessarily imply the identification of either a cause or solution since many complex phenomena are responsible for this to happen.

This situation continues until the discord continues and until the designer identifies a solution what many researchers called 'breakthrough'. As the act of design is mostly visual, designers' perception of formal and spatial connection depends heavily on drawings and imageries. During the conversation few of the students remarked that when

such stuckness occurred, more often than not it was related to the perception and proper externalization of design theme and details. Trying different drawing types (2D orthographic projections to 3D isometric), changing viewing angle (perspectives), addition of color and texture (adding depth cues), making 3D draft models (cardboard models) and such have proved to be effective solution to this problem. By looking into owns' design from a new point of view, according to Pressman (1993) as cited in Sachs, A. (1999) designers can find a way to overcome these constraints. Author stated:

> 'If frozen, work on an unrelated task; come back to the problem at a later time from a different perspective. Isolate the problem do more research, become more informed about it; return to the site; visit or read about a related and architecturally significant work. Try changing drawing scales or media (if drawing build a quick and dirty model and vice versa.)'

Even though many explanations of these situations were gathered in the studio, it is almost impossible to determine any particular cause because of the complicated nature of the studio setting and its activities. Often students experiencing this type of situation cannot determine definitely what, if any, is the reason. Source of the problem could lie within the conflict between one's concepts and his/her lack of knowledge on externalization. Switching and combining multiple of these design modalities of manual and digital origin invoke and stimulate designer's perception by bringing new perspective to the problem in hand. However, this switch of modality at the same time often alters designer's course of action and even the original conceptual transformation of form and space. As one of the studio B student mentioned during interview-

> I was having hard time seeing how the form would shape up. My concept was related with the lake and its breeze and I wanted to use some free flowing shapes for whole massing and you know to create other spaces. And the curve lines stopped working for me, there was only so much that I know of 3ds Max that I could be able to make it. And I was afraid to, well since I had started with the curve lines and I like it a lot because I liked what I had gotten so far, I wanted to hold on to it but I could see clearly that I couldn't do much more with it, ah, and so that's where I was stuck for a long time. (Studio B student)

Students also reported that they have changed tools because of not being certain about the nature of the next step of the design process. Adopting new design procedure, experiencing the model from different viewing angle and manipulating drawings are have helped them to development new and holistic view.

> Well, when I started with this idea and started to get more real something to get a real shape; I guess I started having lots of ideas. I did some sketching and modeling and I made my first mass model. I started making pieces and once I finished a step I automatically got a bunch of ideas of how to play with this more. I always had something and I got to this point and I did not have any other, I started getting very attached with this and I don't know how to break it….. (Studio B Student)

One relatively experienced student from studio B mentioned her uncertainty above regarding how her model sequence would represent or differ from her conceptual model while working in the early phase of design. Whereas for novice designers from studio A this problem seems to be further complicated since they are still learning and therefore may lack information that is vital to decision making in design process. At the same time younger designers showed greater dependency on their instructor's opinion and like to follow the requirements stated in the project handout as checklist.

During the conversation it was also identified that students often have abandoned their fundamental design schemes because it was monotonous. Even though most of the designers failed to pin point the exact un-interesting feature of their design but working on a new scheme and getting new perspectives provided them with rather sustainable alternatives. In many cases the complex and competitive nature of the design studio also builds a social pressure to create something exciting which also vacillated primary ideation as a result.

In the early stage (conceptual) of the design process, it is typical for a designer to use several relatively unstructured forms of pictorial representation such as sketches, free hand drawings and such. As the design develops, other form of more structured and pictorial representations as scaled plans, sections, elevations become integral part of the process. As essential these pictorial representations are for the design process a more unstructured form is believed to be more creative and innovative in design(Herbert, 1993). Evidences regarding these beliefs is however relatively sparse in this study.

During studio observations it was found that the most common tradition to illustrate two dimensional diagrams of an abstract drawing were plans, sections and elevations. However, in case of studio-A most of the students showed a tendency to use various CAAD program as their drawing medium to carry out formal analysis. To set project design strategy, conceptual outline, generate, synthesize and later translate their architectural form and functions most of the designers studied similar precedents, reflected back to their experience and then moved into computer mediated design process. Their conceptual design cycle began by looking at branded website, line of

products, various architects, their design methods and architecture. These precedent studies can be identified as a key aspect that motivated students toward conceptual formation of the design. Hence, CAAD competency seems to be an important factor that delineates students' successful transformation of their abstract concepts.

One of the Studio-A student reported that she started to formulate and analyze her concept in CAAD as many other students in the class but only discover that lack of fluency of CAAD tools and perhaps her experience with those particular modalities are acting as an impediment over seeing and perceiving the intended

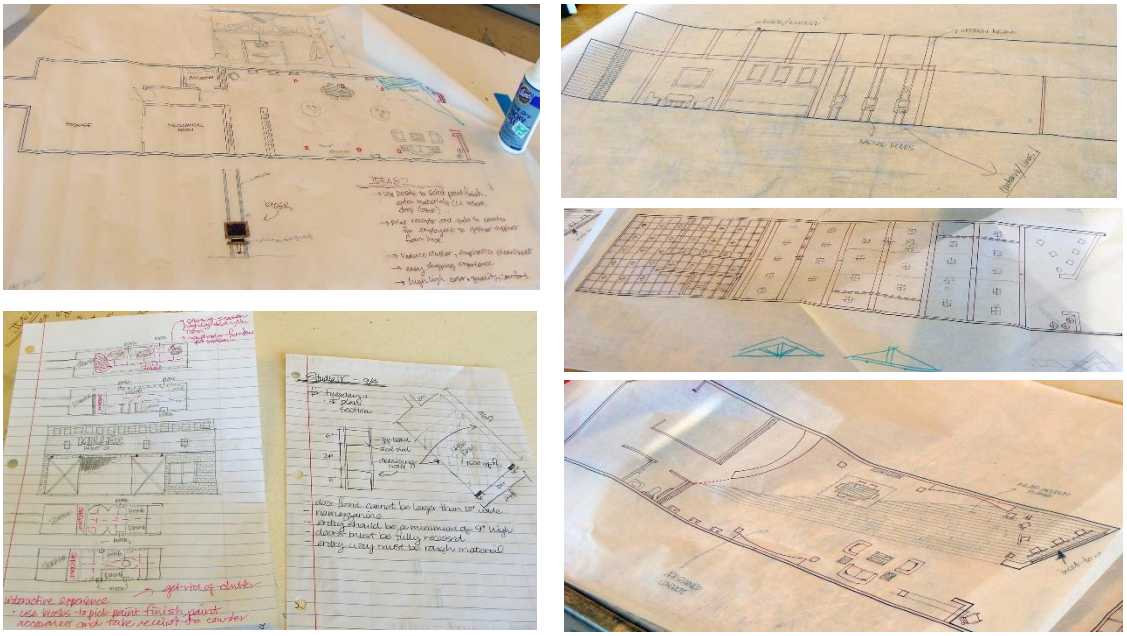

Figure 27: Studio A student's design development and final presentation

externalization of her abstract ideas. Later, through manual drawing, she was able to tackle these issues and other aspects of design details that she never understood before (see Figure 27). From her perspective - these manual drawings assisted in her design development and continual analysis of the form, function, details and their harmonious amalgamation.

Designer's performance are also affected by a range of factors from psychological to technical issues related to design. Designers' behavior, perception, knowledge, experience, communication and above all addressing design problem itself are among many of these factors affecting designer's act. Effective communication of design ideas both internally and externally helps designers getting a holistic view by providing adequate cues that help building up spatial knowledge.

Every design problem is unique thus a single set of prescriptive drawings always may not be sufficient for complete spatial representation. To explore and acquire spatial knowledge, holistic understanding, develop cognitive map (Weatherford, 1985) designers need to practice a varieties of modalities. Spatial representation depends on spatial knowledge, its manipulation, retrieval and reflections form of memory. Designers with less perceptual ability benefit from virtual representation of environment which helps them to navigate and see design from new perspective. At the same time new architectural task was performed by rethinking and manipulating forms, details and new spatial representation was developed in their imagination.

Designers who were using multiple modalities, in most cases have developed better spatial organization. Switching and mixing modalities provide essential visual cues

to aid orientations, proportion, and scale, spatial and formal relationships. As defined by Sweller (1999) in ‘cognitive load theory’- optimum learning occurs in humans when the load on working memory is kept to a minimum to best facilitate the changes in long term memory.

Another rather indirect type of constraints or limitation of designer is caused by the capability of CAD tools. Designers’ ideas and thoughts are circumscribed by the properties of CAD. Each CAD tools has its limitation. Differences of designers’ personality, background, level of expertise, knowledge and perception often may hinder interpretation and manipulation of design ideas using a single CAD tool. Sometimes, this forced design decisions away from possible best solution that satisfies design criteria to something that is easiest to generate with the given or used tools. Creative thinking process is potentially constrained by this ‘negative’ thinking. Comparative analysis between the two studio shows that more experienced and proficient designers produced relatively complex forms and the design philosophy shifts from simplicity to distinct. More often than not, the functionality of the tool allowed students freedom to be creative. However, this also may introduce some unnecessary complexity into the design.

On the course of the design process, CAD models acquire more details so as designer’s reluctance to make major changes even if those appeared to be required. The near finished models create an inertia; and designers tends to become stationary as these drawings gather more details. A phenomenon called ‘design fixation’ happens tends to make designers’ concept frozen (Purcell & Gero, 1996).

Designers who are less competent with developing designs ideas and variations, displayed a low level of CAD usage and more free hand sketching and verbal discussions. General observation throughout the two studio students' work infer that CAD as a tool is better suited for detailed design than for conceptual design. Students' response provided elaboration on the nature of this difference:

> ".. when I looked at my friend's design and her work, especially after her first desk critic with the professor, I thought using Revit only to experiment form and section is making her design rigid, I mean less flexible. So, I stepped away from the CAD and start quick sketching, drawings spot details and stuff like that. These helped me to develop some rough prototypes and I think I have got some good solution" (Studio B student).

These findings also can be interpreted as- digital modalities by itself work better for developing and manipulating production drawings at mature stages than early design phases, however designers experienced with multiple techniques and design process can use this tool for both tasks. On the other hand, collected data in this research (as well as argued by many other studies) identifies that – the tendency of over using CAAD is occurring frequently even in situations where other tools seems to be more appropriate, especially in conceptual design phase.

One of the studio A student who was using CAAD form the early stage of design expressed her concern as-

> "I think I am getting more dependent on AutoCad and SketchUp as I am using those for modelling very early in the conceptual stage. I also think it is diminishing my ability to think freely" (Studio A student).

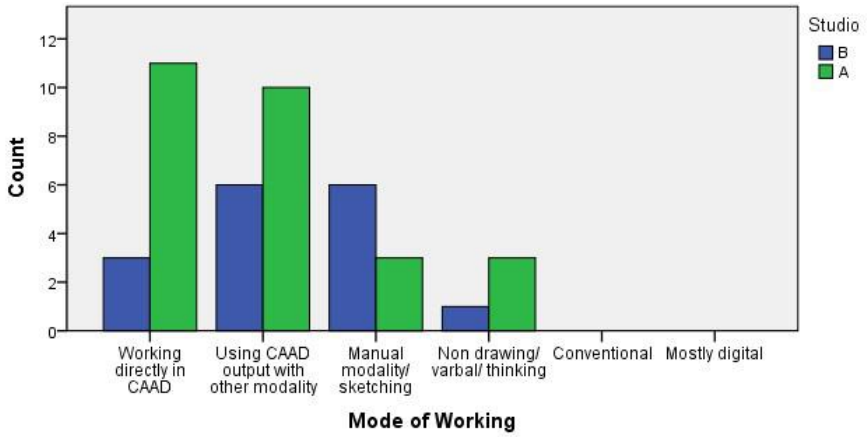

Figure 28: Comparison of preferred mode of work between Studio A and B

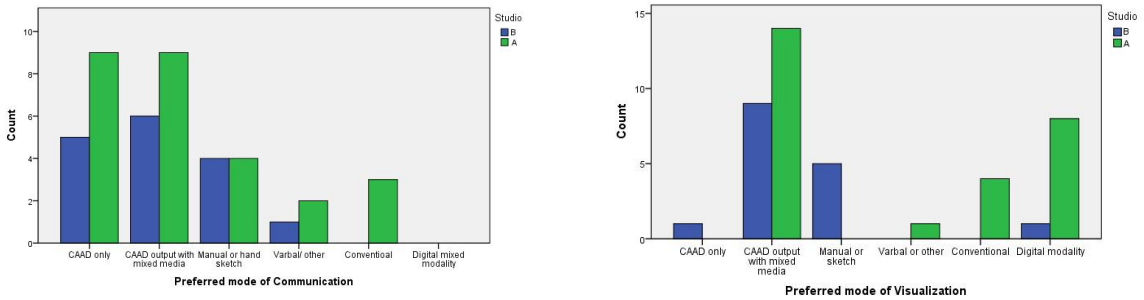

Figure 29: Comparative use of different modes of working for communication and visualization.

A comparison of preference (Figure 28) and use of various modalities for communication and visualization, shows that for visualization there is a higher incidence of working with CAAD outputs often mixed with other media than conventional or digital media only. Whereas for communication, digitally produced drawings and graphics are preferred. In both cases advanced design students (studio A) responded higher in support of computer mediated design communication and visualization as demonstrated in Figure 29 above.

4.4 Emphasis and use of Drawing and Design Tools in Studio Projects

This section identifies and analyzes emphasis given on tools used to accomplish specific design tasks for all design studios. As an integral part of design education, creating effective and engaging representation of designers' thoughts and abstract ideas are paramount to success of this professional practice. Drawings are the primary vehicle for communicating architectural intent to its audience. Despite actual act of design conception, design drawings, presentation theme and their respective level of finish are independent to designer, a substantial amount of decision making on what type of drawings to produce and present during final presentation depends on studio instructions. Novice design students normally struggle to bring their representation skills up to the level as their design intent whereas relatively experienced students often displays their skills in design representations which exceeds their skill in design. Effective design representation is largely dependent upon its authors' engagement and personal commitment to generate a presentation that satisfies both function and aesthetics. The tools selection is often irrelevant since poor representation can be a result of either hand or computer program.

General discussions and instructions regarding the use of drawing tools did not occur in either studios as a major topic. However, it (discussion on modalities) occasionally appeared as a part of discussion on topics like generating form, selecting material, color scheme, solving circulation, experimenting details, visualizing and analyzing spatial experiences and such.

In independent occasions students inquired about specific representational methods to get verification from the instructor. Students were free to select and use any kind of design modality. However, students' use of modality largely intertwined with other factors as syllabus, requirements and instructor's directions on presentation considerations and overall studio environment regarding the tradition and use of presentation. It is more common practice than ever that design students carry and finalize their conceptual design using one or more computing programs as a representational mode of thinking (Al-Qawasmi, 2004, 2005; Ataman, 1999). While analyzing discussion and documented design process of students from the studios, I tried to understand – to what extent studio instructions and presentation requirements dictates students' use of different type of drawing and design tools.

Studio A: Branded Environment

> According to designer Kiku Obata & Company, all elements that comprise a place- architecture, interiors, lightings, graphics, landscape- should be integrated to create an intuitive brand experience. This is not about applying the company logo as an afterthought. It is about branding in 3-D (Herman-Miller Inc. 2003). In other words, in architect branded environments, space should then be viewed as a dynamic billboard or an extension of product packaging, with attention given to size, shape, materials, and colors.
>
> According to Jos de Vries (2004), recognition factor and surprise factor are becoming increasingly important to ensure balance between continuity and regeneration. The target group must feel at home, must be enthralled by the product range, by the price, the image projected by the personnel or by the ambience of the store and in doing so its expectations must be exceeded: the 'wow' factor. Lighting, odors, time and temperature have now also become important factors, with the intention of stimulating the customers' purchasing behavior. The customer becomes an actor in the scene, the retail context becomes both catwalk and theme trail. The theatrical element is clear in projects where the route followed by visitors is designed as a mini-drama full of surprises, retail stage-set or changing displays. (Course syllabus, p. 1)

This discussion on design problem sets the overall ambiance of the project. Students were expected to study and highlight the branded products, their nature of commercialization and the way it is being presented to attract the target group. Good composition, sensible selection of color, attractive form and visually appealing graphics are some of the major aspects that can clearly be identified in those referred branded literature. These highly dynamic and sophisticated product representations worked as an influential factor on students' design ideation, selection of form, material, construction and décor.

> Develop a graphical scheme for the brand equity as a plate analytique of seven by eleven for the product you choose. You can use graphic software such as adobe publisher, imagemaker or photoshop to present your brand. The analytique should contain logo, product and concept statement of your brand. Refer the following websites for a fair idea: http://www.therogersco.com/display.cfm?p=22&p_p=13&l=Graphic%2ODesign and http:llwww.desiqnan_gel.comlproiects/store2.html (Course syllabus, p. 3)

Instructors' recommendation on using graphic editing software to prepare predesign analytiques over traditional clipping, note taking, sketches, diagram drawings may also act as silent direction toward selection of design tools during design development. Since most of the students already had taken several courses and gained basic understanding on graphic editing software as Adobe Photoshop, Adobe Illustrator as well as CAD applications like Autodesk AutoCad, Autodesk Revit Architecture, Sketchup, 3D Studio Max and such during previous semesters, these design communication and drawing tools were not discussed as a central issue in the class.

Outcome of this analytiques exercise and precedent analysis which are performed and presented mostly through digital media seemed to establish an overall theme on use

of modalities in this studio. Short duration (eight weeks) and the nature of the project by itself have inspired students to select digitally influenced modalities as well.

The instructor explained the process of synthesizing brand identity. He emphasized on the characteristics of architectural elements, attributes, aesthetics, visual weight and density as well as making meaningful selection on color and material:

> Brand Identity and Execution: How well have you captured the brand in terms of architectural elements. Attention should be provided for not only physical characteristics such as finishes or hues, but also aesthetic qualities such as texture, visual weight and material density. Materials and colors should be chosen and expressed as meaningful design intentions that emphasize the brand identity. Remember that the qualities of these materials and colors are not absolute but is relative to other materials and colors used in the composition. (Course syllabus, p.4)

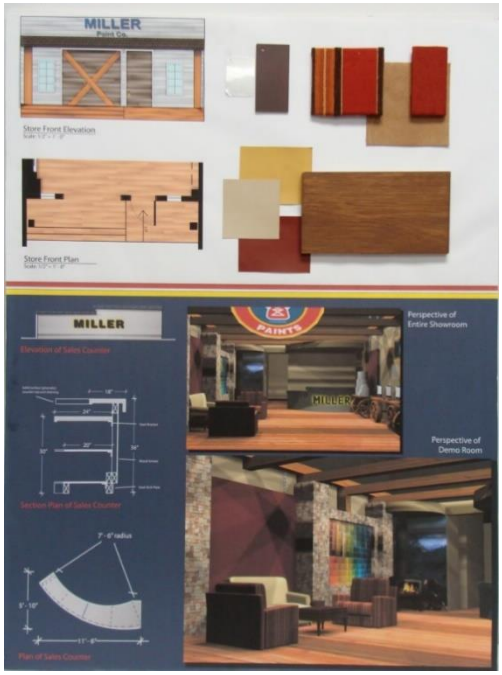

Figure 30: One of the final presentation boards

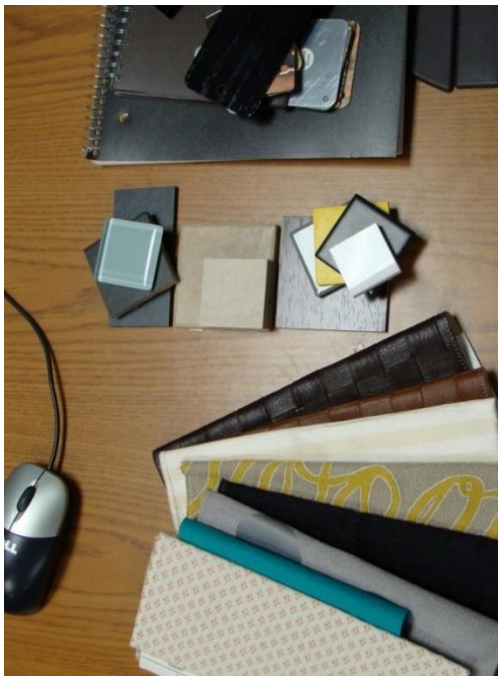

Figure 31: Students using physical material samples.

Students have used a wide range of design and drawing tools, often in combination to complete this project. Sample material and finishes were used alongside CAD applications (see Figure 30 and Figure 31) as a process of design refinement. Digital modalities were used for a greater duration and by majority of the students. In couple of cases, the whole design process was performed through various computer applications only.

Final presentation requirements and considerations, as listed in the project handout reflect no specific instructions on the use of modality. Instructor was rather open to media selection except for asking to present real fabric and finish samples instead of computer generated or digitized finishes and fabrics. Two interior vignettes were required in final presentation which 'could be hand drawn or done through computers'. In their final presentation (Figure 30 shows example of final presentation) none of the students have showcased any vignettes produced through manual or traditional media. It was submitted separately.

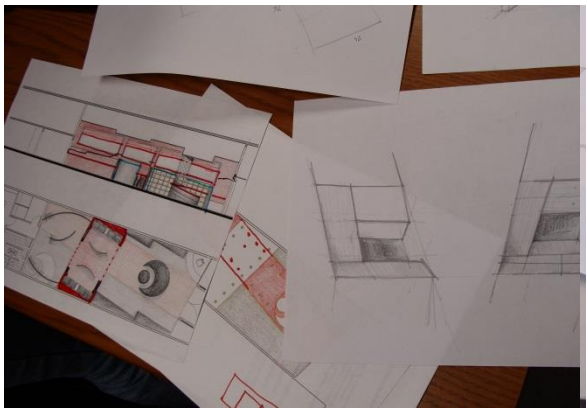

Figure 32: Multiple modalities in use for design development.

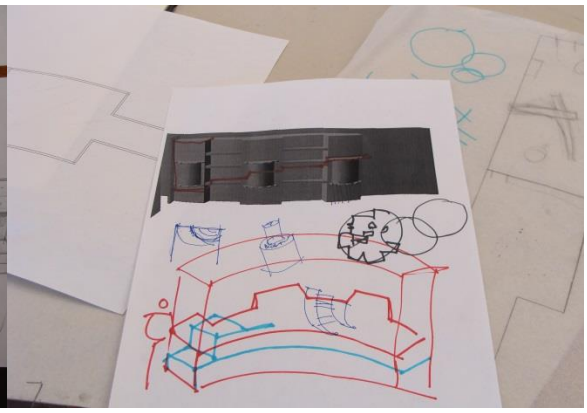

Figure 33: Manipulation and refinement.

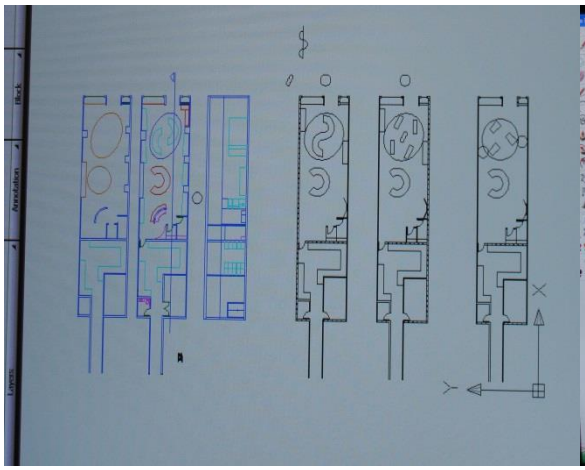

Figure 34: Producing design alternatives with 2d CAD drawings.

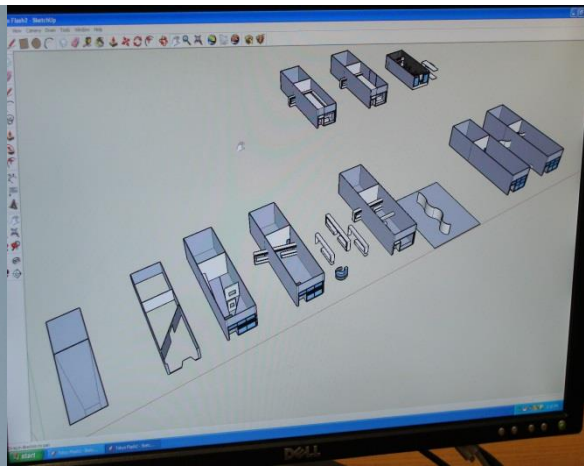

Figure 35: Experimenting design alternatives in 3d environemnt.

During design development phases multiple cases were observed where students juxtaposed both digital and manual drawings to investigate further. Figure 32 and Figure 33 demonstrate an example of manipulation and refinement of design ideas with color marker over printout of computer generated 3d model. These assimilation of modalities helped them to construct new ideas, understand, manipulate and evaluate previously developed solutions. On the other hand several students have used various computational tools to explore, develop design alternatives and solutions (see Figure 34 and Figure 35). Various CAD, 3d modeling and graphic editing software namely, AutoCAD, 3d Studio Max, Revit, SketchUp, Photoshop, Illustrator were used with varied level of expertise.

In studio A, short duration, high end commercial type nature of the project, emphasis on digitally available precedents and other review material led student to emphasize on using various computational tools. In the example below (Figure 36) initial concept of the branded environment is developed through using multiple combination of

design tools. Figure 36 demonstrates design process with hybrid modality and final presentation board. Working with hybrid modality by combining drawings form more than one media (Figure 37) developed indigenous visualizations as well as or the reduced effort needed to transform and manipulate analog representations.

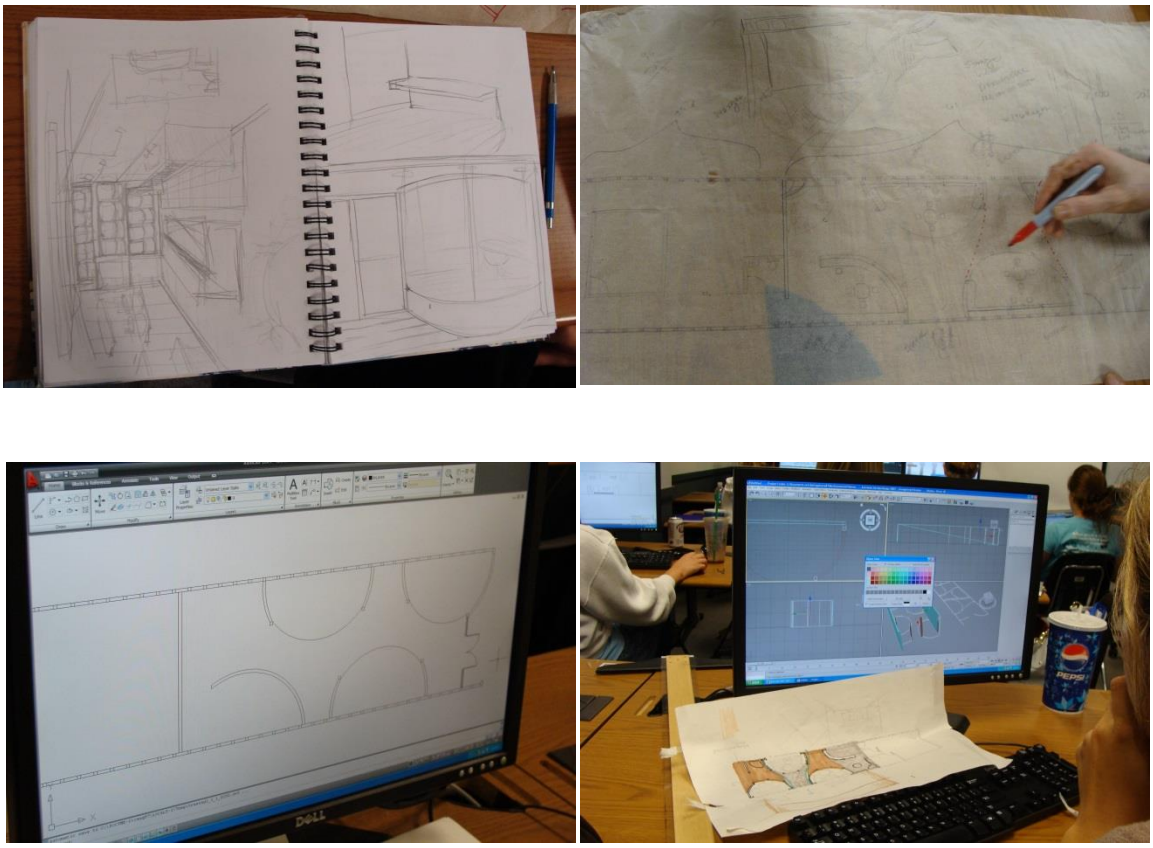

Figure 36: Student working with multiple drawing and design tools

Media interface hardware (scanner, computer screen, printer, etc.) and software (image editing–e.g., Photoshop, etc.) often seems to be more useful than CAD in advancing and supporting the design process, particularly during the beginning phases. (Bermudez 1998; Herbert 1995; Neiman 1994; Neiman 1997; Smulevich 1997: as cited in Bermudez, J. & King, K. 1998).

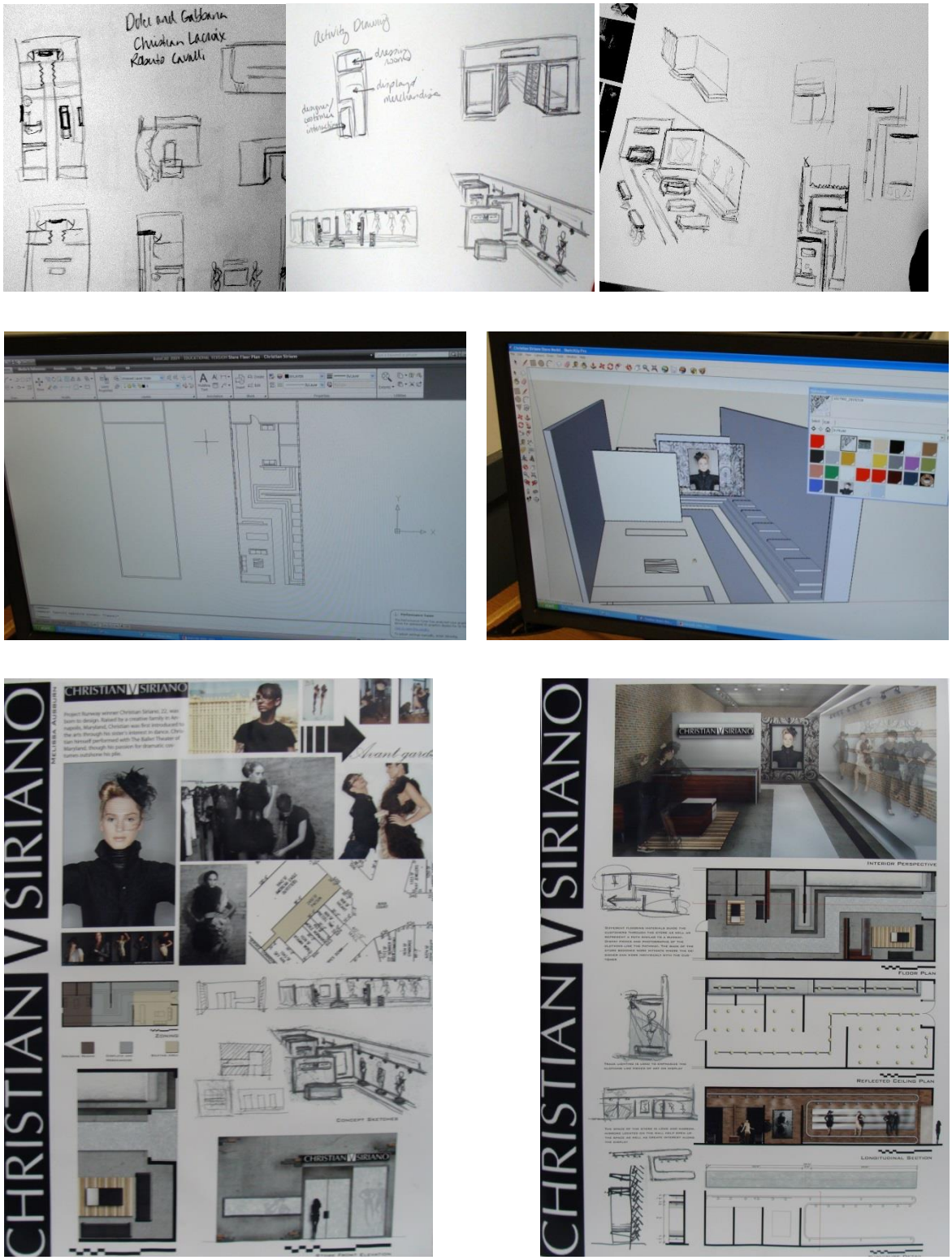

Figure 37: Design Process showing concept refinement, development, documentation and final presentation.

Studio B: Architecture that reflects self-expression and individual experience.

> Architecture is not an art form of pure self-expression. Architectural meaning resides in human experience. It is evoked in the acts of occupying and inhabiting space, in one's experiences of space, matter, gravity, and light.
>
> Juhani Pallasamaa, 2001 (from syllabus)

This design project emphasized on designing architecture that animates its future dweller's experience and desire. At the beginning of the project the instructor(s) introduced several guiding principles of residential design as well as human experience of built environment. A residence (summerhouse) was to be designed for four overseeing a lake with 2400 sq. ft. finished space with a budget limited to $300,000. Open floor plan, easy access to major functions and formal, informal spaces. Easy indoor outdoor access, built in storages, expandable dining, welcoming entrance and specially offering a pleasant view from the entry way.

Among many other specifics, the instructor stressed on considering daylight and variations in ceiling heights (see Table 15). Instructor also required students to present Full documentation of a house of their choice in detail.

This particular assignment was to encourage students to research precedents and develop a comprehensive understanding on home design through diverse analysis and critical thinking. Required list of drawings to complete architectural documentation is provided in Table 15 (from syllabus). For the first three weeks students analyzed precedents and had pin-up presentations. At the same time they worked on developing conceptual models and study drawings that included plans, sections, and sketches. The next set of drawings students produced was elevations and exploded paraline drawings.

For intermediate presentation, instructor asked students to include Models, Floor plans and Furniture layout, Sections, and exploded axonometric. Analyzing precedents through presented architectural drawings, literature and photographs encouraged students to identify critical design issues, develop concept and their own approach to address the given studio project. The instructors also emphasized on developing an image of the building that reflects its user's need and desire than simply fitting the programming or required square footage. With intent to direct students to think in more creative and imaginative ways, from his long teaching experience the instructor guided students to approach architecture from inside out. He guided students to follow a comprehensive design process that rigorously synthesize and evaluate design decisions with variety of modalities such as architectural study drawings, diagrams, massing models, scaled schematic drawings etc.

Some of the final presentation requirements regarding design representation were: site plan, detailed floor plans with furniture and fixtures layout, at least two building sections, exploded axonometric in a scale, at least four interior perspectives, physical models etc. (see table 15). Students were free to choose their rendering style based on their design concept. However, he recommended surveying work of famous designers to expand perspectives and gather inspiration. It is noteworthy to mention that even though the instructor kept the presentation media open, the overall ambience of the studio environment was focused on developing design solution through extensive formal and spatial analysis using manual modalities. Example of various architectural study drawings can be found in Figure 38 and Figure 39. Students were instructed to develop multiple study models to test and understand the rational of the form (of the home) as a

container. This conceptual model is essentially an object not a space, but the instructor forced them (students) to think creatively and in an imaginative way to know enough about what it will contain. Manual modality as design formulation tool has proven to be considerably fluid and appropriate than digital media for initial development of ideas, stimulation of the imagination, effective inquiry, cross-referencing and such (Bermudez & King, 2000a; Nancy Y Cheng, 1995; Jansson & Smith, 1991; Kalisperis & Pehlivanidou-Liakata, 1998).

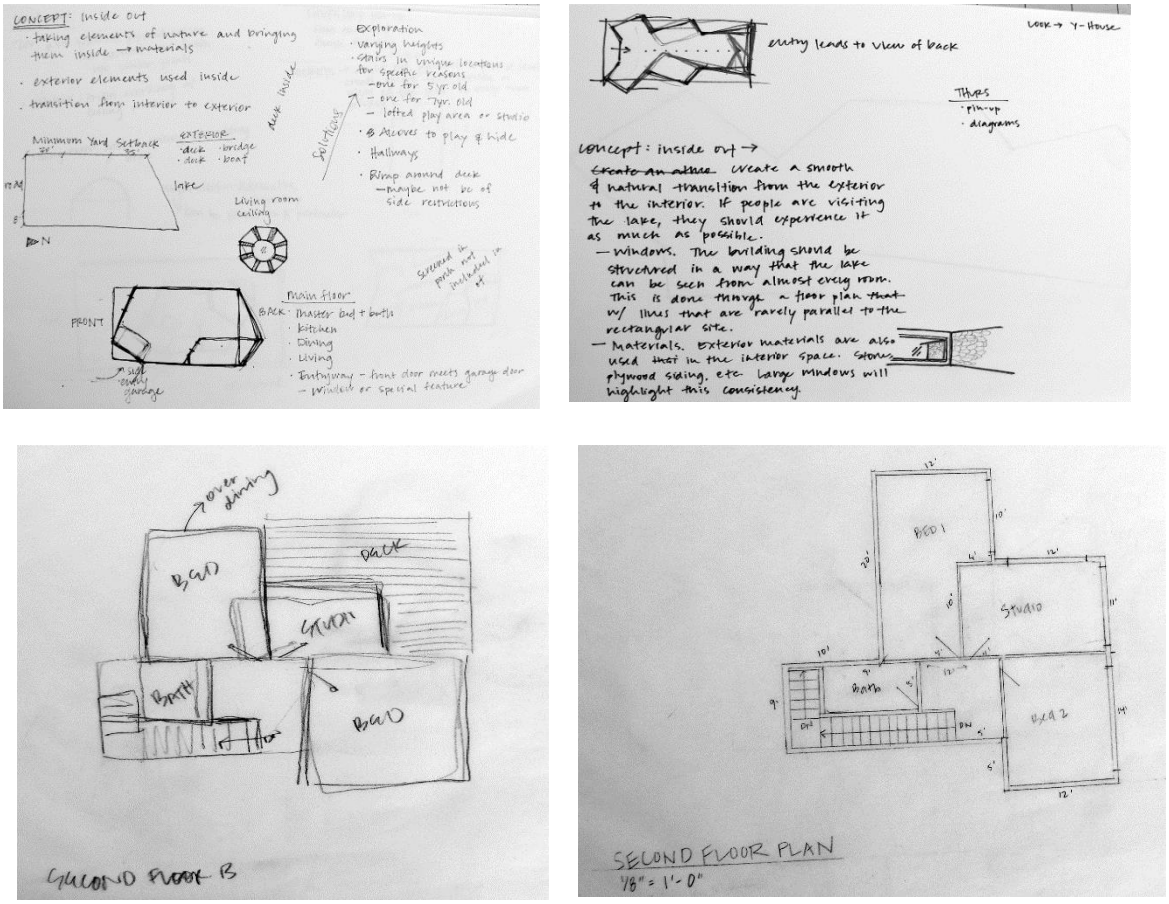

Figure 38: Study drawings

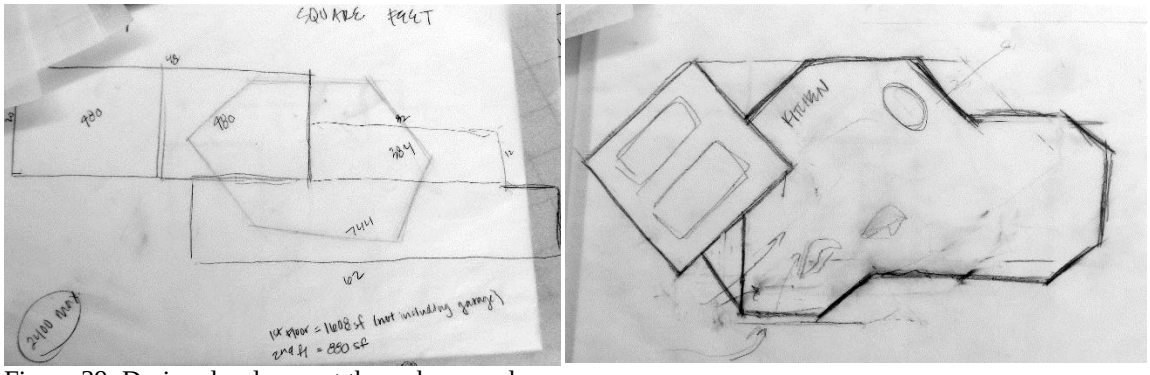

Figure 39: Design development through manual modalities

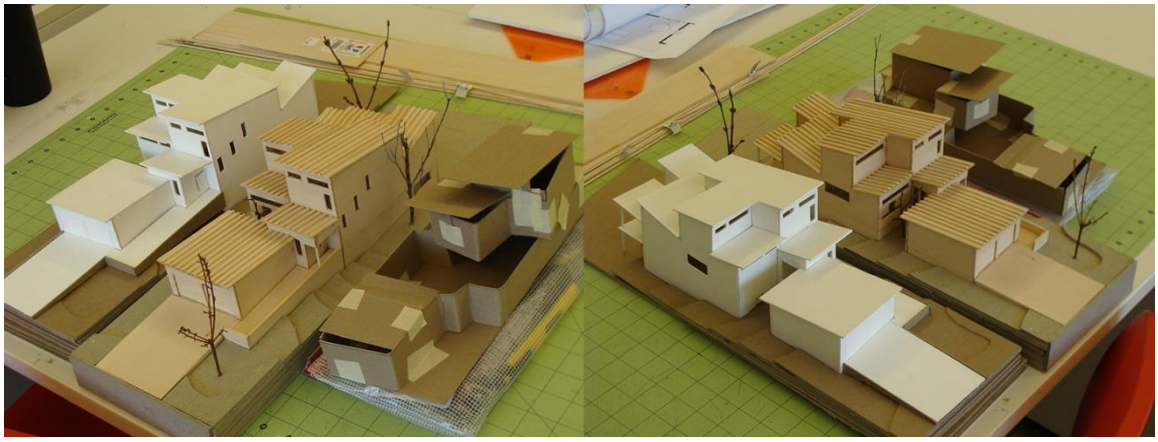

Figure 40: Design developemnt through manual modalities

It was also recommended in the course handout to –

> Consider graphics (line weight, fonts, words, conventional symbols) as an integral part of your design. Graphic design should serve as a means of reinforcing the aesthetic adopted for your design. (from project handout)

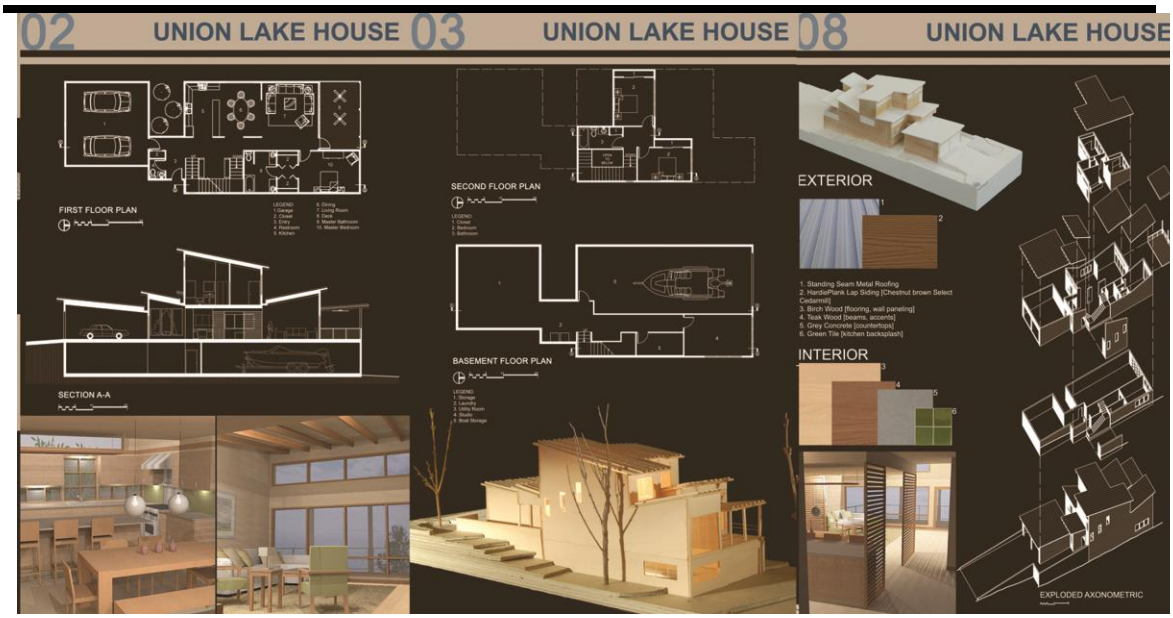

Figure 41: Final Presentation board of same project demonstrated in previous figures.

Among 12 students in this studio, six students knew Autodesk Revit Architecture, all of them were familiar with AutoCAD, six to seven of them knew 3d Studio MAX and seven students claimed that they knew SketchUp. Final presentation boards in this particular example (Figure 41) demonstrates student's use of multiple CAD and graphics applications simultaneously. Even though the instructor let students decide their medium of design he at the same time encouraged them to use manual modalities during the early phase of design. He also asked for bringing print outs before coming to class everyday so that they (students) can refine (design) ideas. Other instructor of this class (who is considerably younger, less experienced but relatively competent with computer modeling and CAD applications) encouraged students to use sketches in collaboration with computer generated drawings.

Architectural study and process drawings (Figure 43 and Figure 43) of another student from the same studio indicate an extensive use of sketches and study drawings, specifically for developing the dynamic shape of the roof. She (the student) stated her concept as -

"A residence that facilitates creativity of various kinds for the children and the artist wife". She transformed her concept into form using the metaphor of an umbrella where "each section, covers/ contains a different space" that "varied in elevations, pitches etc. and "designates hierarchy and function".

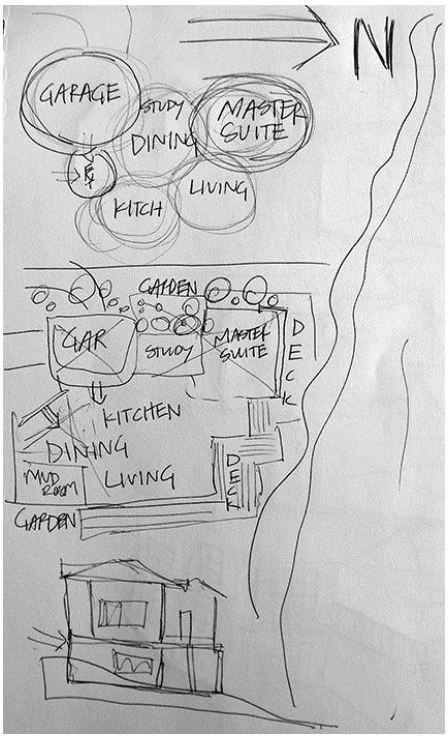

Figure 43: Bubble diagram showing space adjacency.

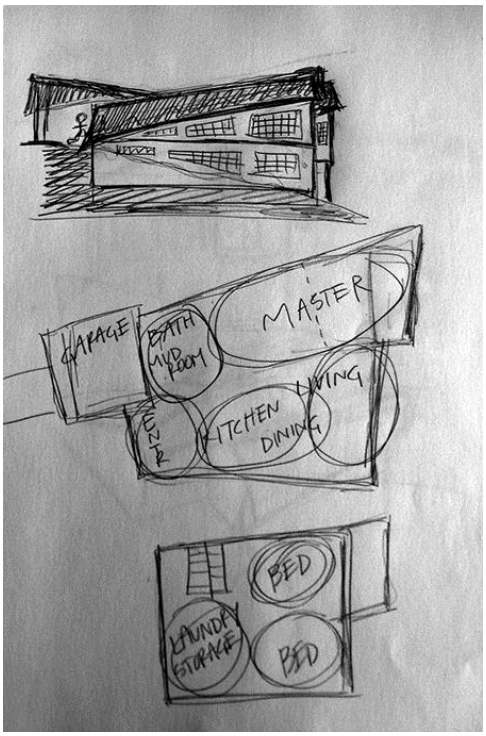

Figure 43: Preliminary sketches on formal ideation

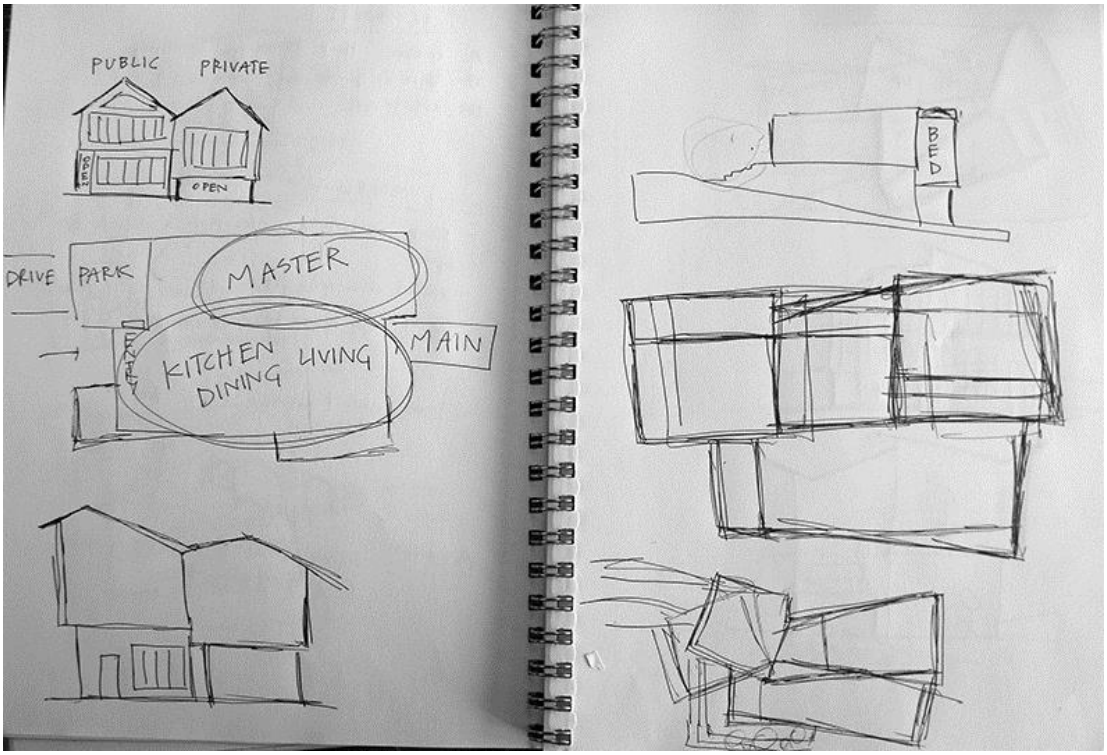

Figure 45: Space planning, Section studies

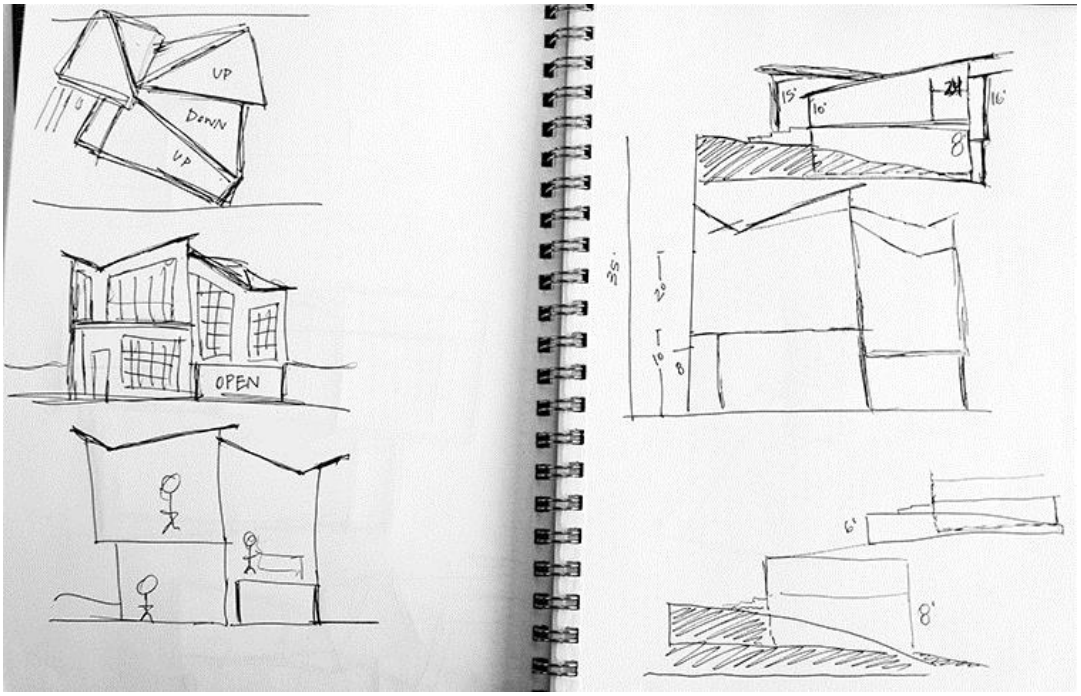

Figure 44:Section studies

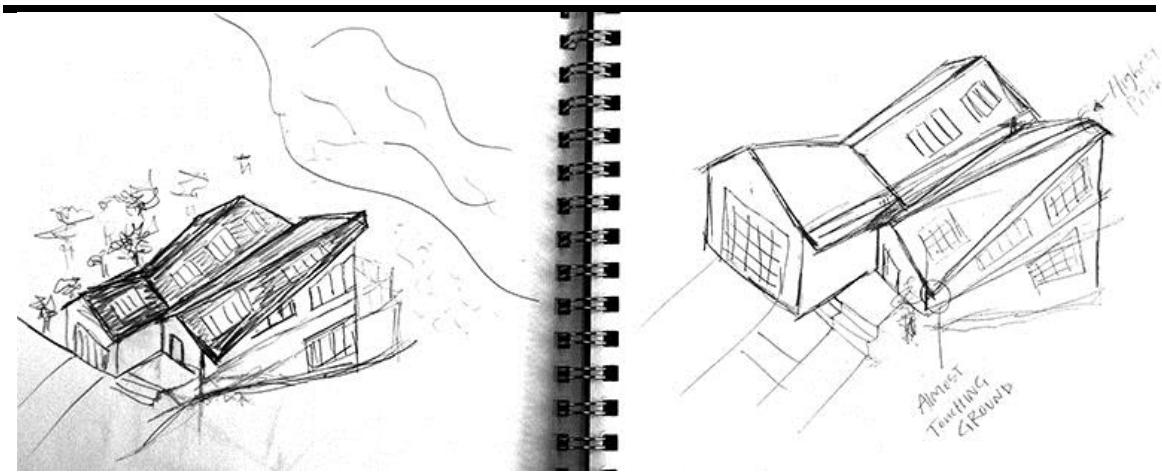

Figure 46: Formal studies using axonometric.

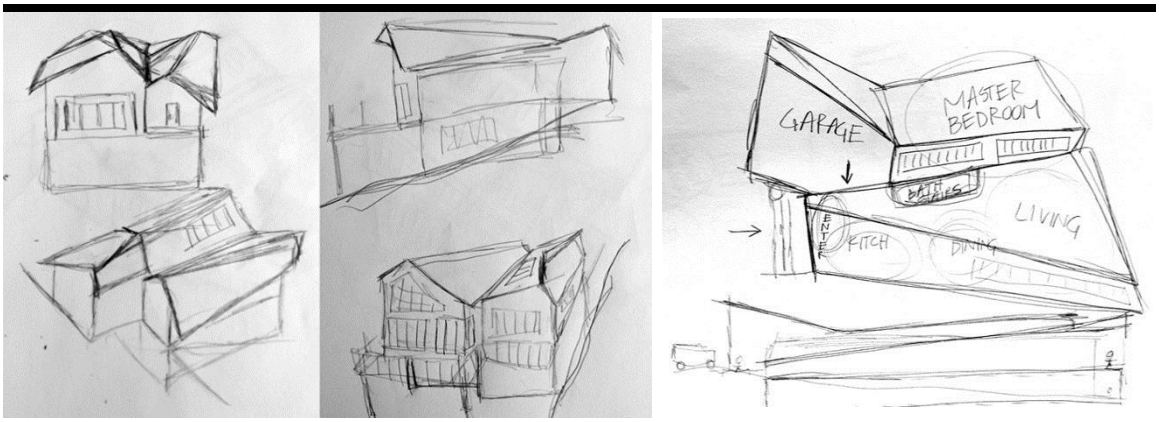

Figure 47: Formal analysis and elevation study.

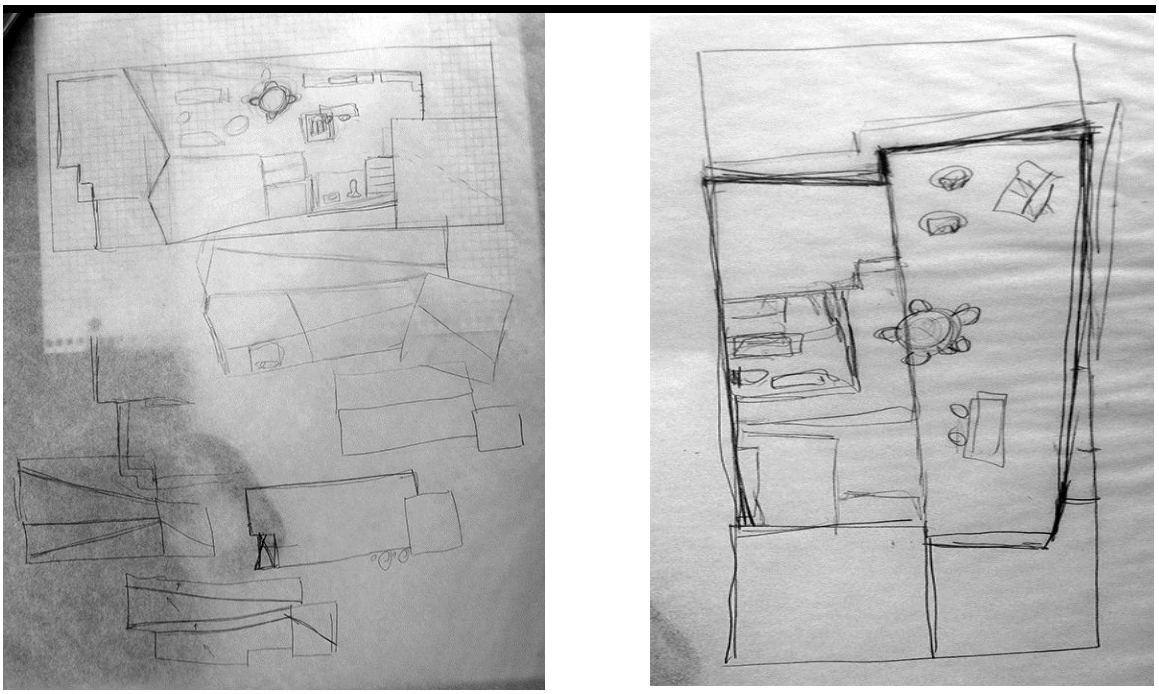

Figure 48: Early design development,

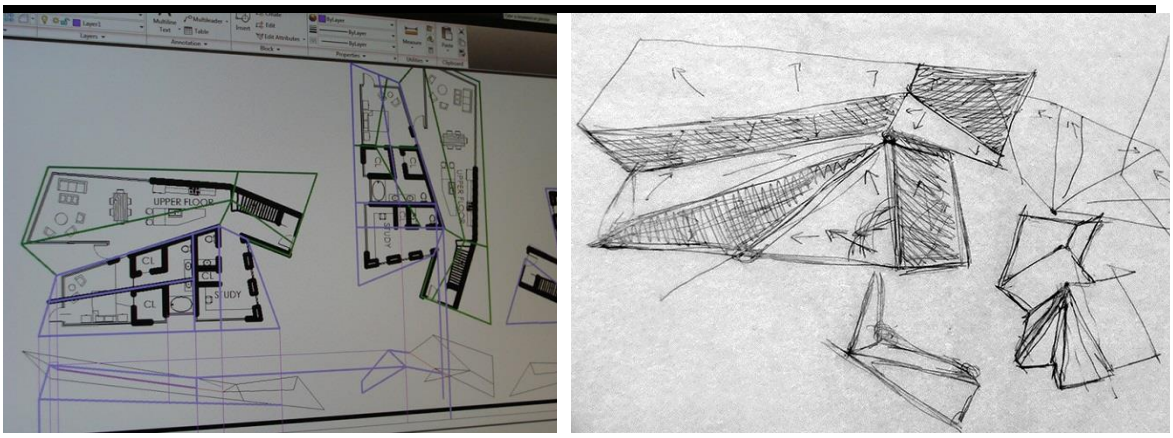

Figure 49: Transforming sketches to AutoCAD

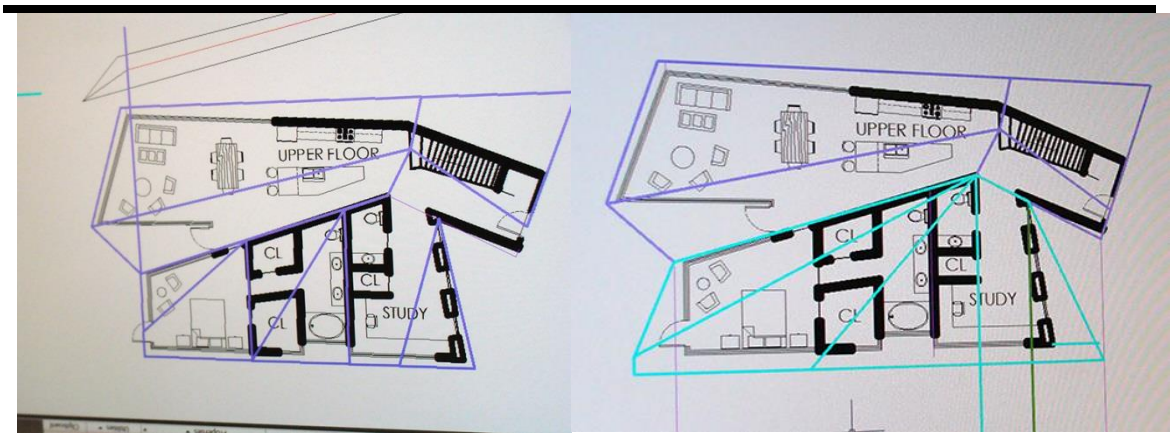

Figure 50: Design development in AutoCAD

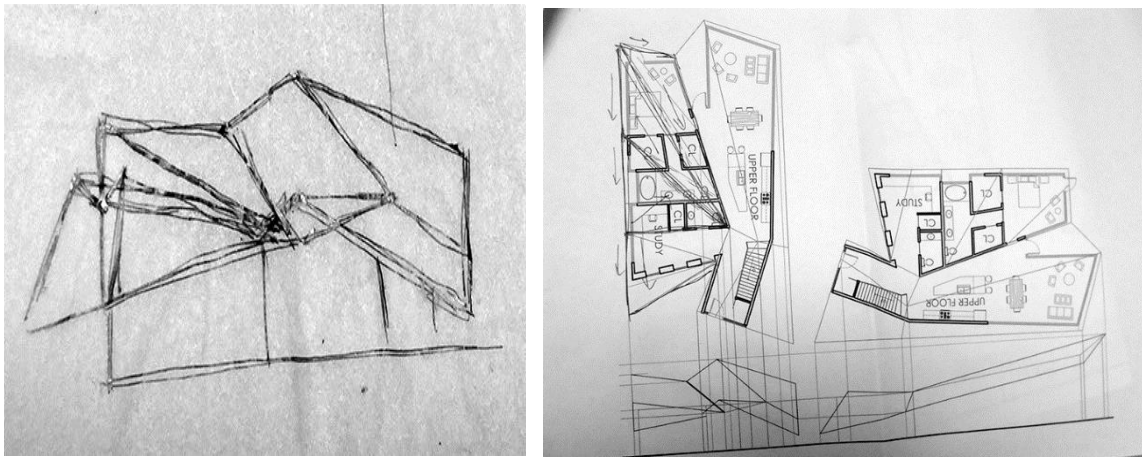

Figure 51: Elevation study on CAD printouts overlay

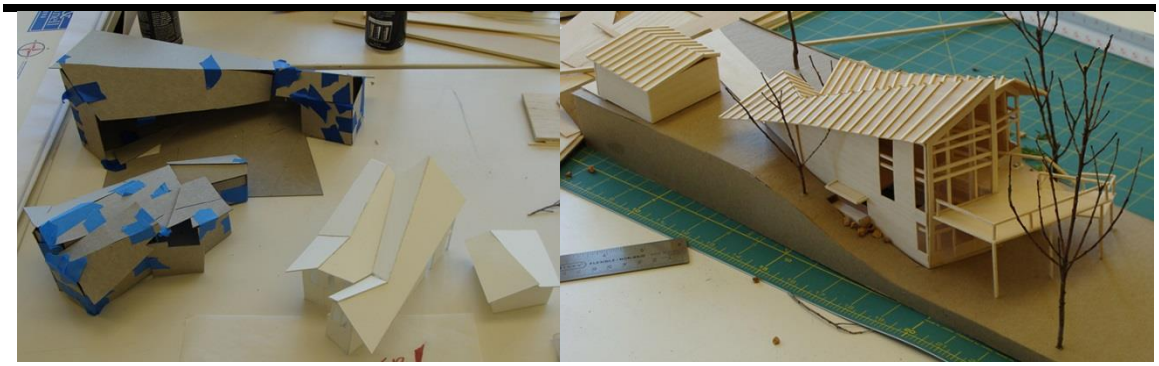

Figure 52: Study and Final scaled model

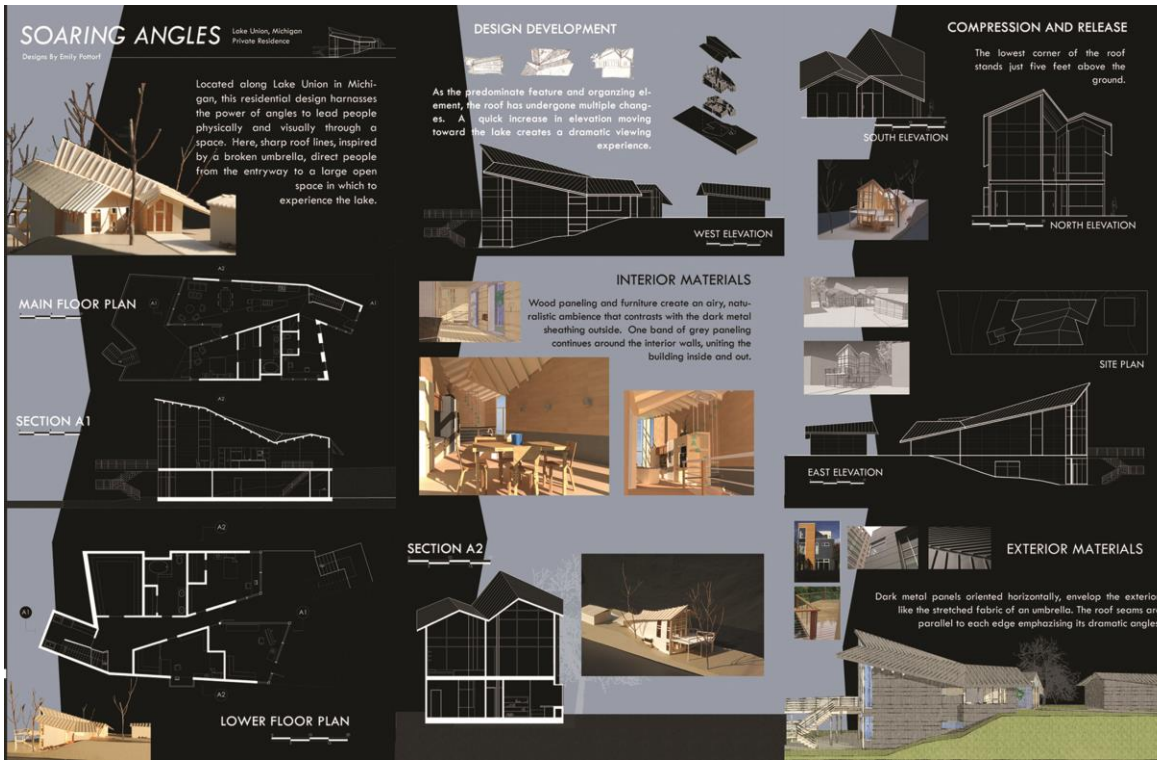

Figure 53: Final presentation board

Through most of her study drawings (Figure 43 to Figure 51) emphasis has given on roof and its formulation. Experimentation has undertaken with mixing different modalities in various combination of free hand sketches, paraline drawings, axonometrics, CAD drawings, printouts and line drawings over it. This iteration of multiple media and drawing type enhanced her design process and formulation of roof's final form. Bermudez (2007) developed a number of hypotheses while exploring media interactions which also support this incident. It is clear from the presented images of the process drawings that – "The media interaction model encourages the idea and practice of process over product, doing over thinking, or better said, of doing as an extension of thinking and not a product of thinking. There is so much fluid movement that designers

do not demonstrate particular attachment to a final product. As a result, the paradigm of operation tends to follow pedagogy of experimentalism, play and constructivism" (Bermudez, 2007 pp 42).

If we look into the students' design process workflow from media interaction, modality shift and mixing point of view- designers form 'Studio A' demonstrated use of wide range of design and drawing tools compare to 'Studio B'. Whereas noticeably higher numbers of digital manipulation of analog representation such as CAD printouts and tracing paper overlay occurred in Studio B. However, in Studio B extensive formal and spatial analysis was conducted using mainly manual modalities that helped students to clarify, develop and get a holistic view of what is being designed. This also generates a superior level of consciousness of their (students) design process. Besides the flexibility manual modalities permit designers to start without having a concrete idea. The (Studio B) assignment of making mass model helped to discover design concepts and to produce spatial layout (see Figure 52) which were essentially executed through manual sketches.

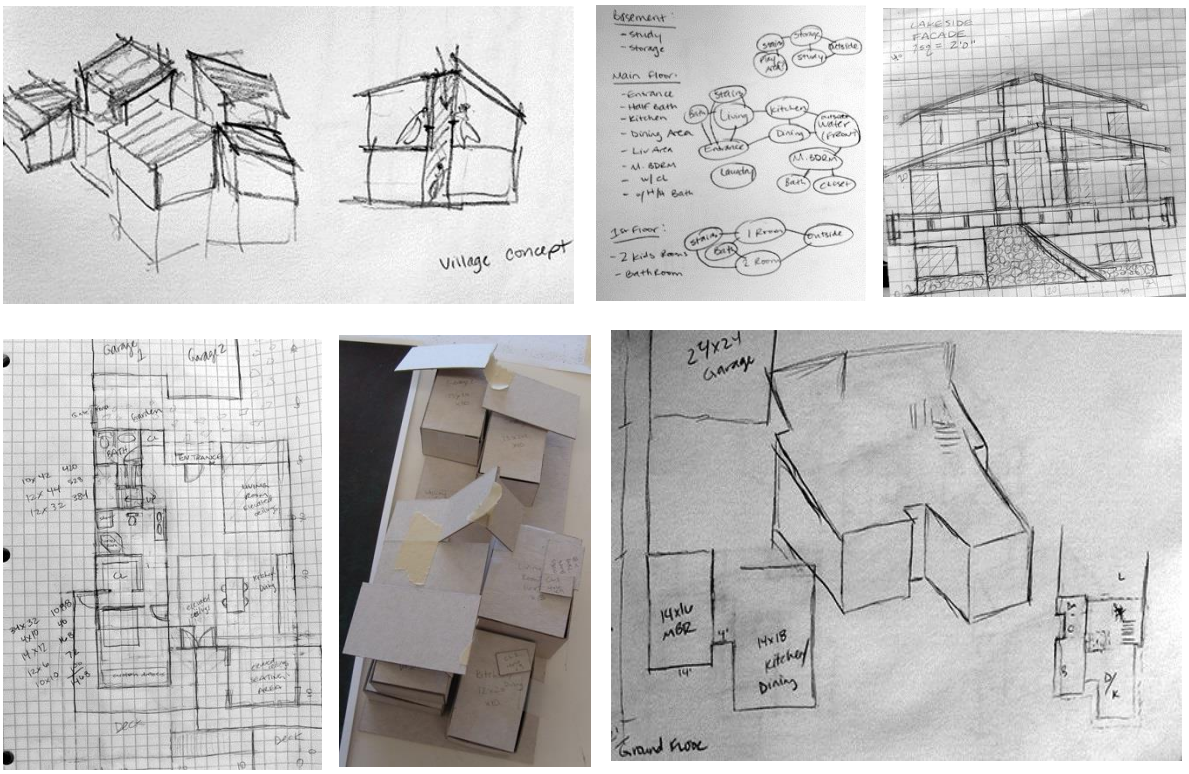

Figure 54: Design development using manual design tools

The progressive but slight refinement of each drawing (for example- plan views) is clearly related to the other type as isometric study drawing, section, massing model and in many cases other mixed modalities. Section studies are being developed in parallel since the instructor conveyed special importance on this type of drawing. Hand drawings and mass (initial) model are used to think and develop architectural ideas.

The digitized or printed image of ‘plan’ is digitally analyzed in graphic editing software, printed, and manually traced / re-interpreted or manipulated in a very lose free hand sketch . First, by manually synthesizing concepts and relationships related to lines and planes, second scanned, and third imported and developed in CAD or 3d modeling applications again. This procedure is clearly documented in the evolution of floor plans.

Often a novel or new insights from this media iteration are transferred to a new digital model. By shifting, mixing or performing movement between modalities (various form of drawings and tools) both manual and digital designers can increases possibilities of having novel design ideas that potentially can impact on design well beyond traditional iterations within manual or digital alone.

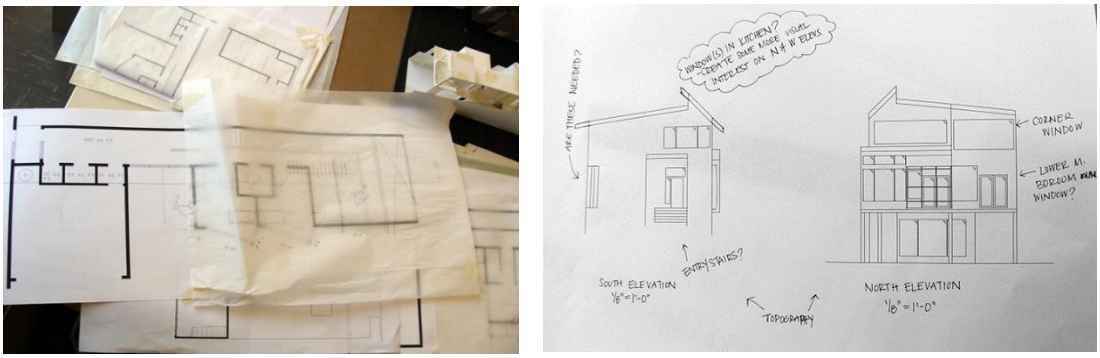

Figure 55: Example of mixing modality.

Figure 55 above shows design developments on CAD printouts. Due to its convenience designers prefer to manipulate and experiment alternatives manually on tracing paper.

In summary, studio B project instructions, requirements and influence of instructor's long teaching, scholarly experience and above all his perception on design, theory, process and methods sets an overall ambience that was reflected on students' architectural design methods and use of media. He wanted students to develop their own idea by realizing the needs and ambitions of the dwellers. Scheduled line up of activities set by the instructor such as - the pin ups of research and detailed presentation on a house, conceptual model, plan –section and sketches, discussions of readings, full

documentation (floor plans, sections, color images, concept statement, etc.) and such external representations facilitated and constrained inference on modality selection as well as problem-solving and its understanding.

4.5 Impact of Studio Setting and Educational Curriculum

Traditionally, architectural design pedagogy is largely dependent on project-based "studio" approach. Students express and explore ideas, generate and evaluate alternatives, make decisions and take actions in design studio. Various external representations and reasoning for these representations as inquire, analyze, and test hypotheses about the designs they represent are conducted in this (studio) environment. This is a complex series of linked acts involving drawing, seeing, inferring alternatives, interpret and explore their consequences. Through various modalities both professional and students identify visual analogies, recall relevant examples, and discover new shapes and geometric configurations. Studio settings and educational curriculum has a profound impact on students' design process and its representation and in design studio they learn meaningful criticism of the design through situational awareness.

In architectural design education, studio setting and its complex socio-physical environment plays an important role in design learning. Competitive and collaborative nature of design studio helps students to learn new ideas, techniques, skills and experiment methods beyond prescriptive course curriculum and syllabus. Besides learning how to design and perform all design tasks simultaneously, they also maintain

personal relationships with instructors and other students. Dana Cuff (1992) called this- ‘the culture of the architectural profession’.

Design is a process of finding solution that shapes up through various stages often cyclic in nature and essentially inherits constraints, blocks and breakdowns (Adams, 2001; Winograd & Flores, 1986). A wide range of difficulties can be identified in design process, CAD, computer and cognition, design conceptualization, ideation, designers’ competency and the character of the context in which they operate—the design studio. Understanding and visualizing space, form, function and their relationships are one of the most difficult tasks that design students learn from the studio. Design education settings teach students to experience the world as an observer and participant, develop awareness on light, form, proportion, scale, color, and texture, as well as their diversified perceptions. Through media students learn to represent and manipulate space throughout the design process that affects their understanding and visualization. Often stylized techniques are copied by students with a high degree of sophistication. Unfortunately, imitating a style can result in a graphic vocabulary that is more concerned with technique than any experiential understanding of space.” (Kalisperis & Pehlivanidou-Liakata, 1998). Early studios are critical in student’s training as it introduces significant knowledge base as well as equip them with, skills regarding media, its proper use and enthusiasm necessary for subsequent studios.

My observation of a senior level design studio (A) and an intermediate level studio (B) to understand how studio settings and curriculum dictates students’ selection and successful use of design and drawings tools for various stages of design. From

literature review, personal experience as an instructor, observation and interview with the students I tried to make sense- how studio culture and their education on various media influence them to select , use and mix various modality and of course reasoning behind it.

Design practice has some common features regardless of its domain as it involves certain activities that must be learned. In architectural education, design is the primarily focus. The department's curriculum offered a comprehensive list of required and optional courses to cover a range of design and drawing tools during the period of observation, namely – architectural drafting and working drawings, visual design, design communication, AutoCAD, computer graphic applications (3d modeling) and such.

Most of the architectural schools that deal with computer literacy and the CAAD integration concept involve mainly two types of computer systems: social and professional. However, depending on the institution's pedagogical approach, extent of offered design communication courses and overall trend and ambiance of the studio environment, a varied combination of design modality is commonly practiced by the students. Learning and teaching of architectural design occurs in design studio where students learn by sharing with each other as well as by receiving comments from the instructors. But a significant amount of knowledge regarding using and mixing modality to effectively express design idea is learned by the students from other sources than formal classes offered by the design schools. As students are becoming more proficient in computer and digitally literate, they are incorporating more of these skills (Bermudez & King, 2000b) and knowledge to the conventional design studio. Studies done by McMillan &Schumacher (2006), Miles &Huberman (1984) and Strauss (1987) described

how the engagement of various media contributes to develop new perspectives and changes in design thinking. Modern architectural studio became a testing ground where computer's role in architecture is continuously being challenged with new innovation and ideas; therefore, such setting for exploring various design media interaction and integration is increasingly being adopted in numbers of architectural schools (e.g. Ataman and Lonnman, 1996; Bermudez and King, 2000; Ataman, 2000; Al-Qawasmi, 2004, 2005; Dokonal et al, 2004). Students have learned and practiced a number of presentation methods in previously taken courses as 'Design Communication' . Knowledge of perspective construction, various manual rendering and physical model building techniques as well as CAD applications helped students to get better understanding of their design. Each representation methods has its distinct characteristics and possess certain attributes and visual cues that others don't. A comprehensive knowledge over multiple modalities often assists designers to act form out of the box. It is safe to assume that knowledge of multiple modalities helped this student to be perceive her design ideas better than before and generate an intriguing method of representing those.

Besides conveying design ideas, students also attempt to 'attract the reviewers' attention and their positive appraisal. Even though many students were familiar with a good number of traditional design tools along with computer-aided 3D software packages, during their studio projects it was observed that the usage of digital tools surpass the traditional means of graphic illustration and scaled models. This is because of digital media appeared to decrease the amount of abstraction between architecture and its

documentation by providing previously unattainable qualities such as motion, texture, shade and shadow, view from all sides and most importantly additional 3D representations. These attributes un-questionably further enhance situational awareness.

Formal and spatial information when delivered through proper tools can stimulate depth perception – often considered as one of the most important components of spatial cognition. For novice designers transforming concepts into form and space is always a challenge. Architecturally related concepts as shadow study, transparent underlays, form morphing and such require some expertise and involvement which often are unavailable through traditional modalities, but easily be represented and understood by students with moderate proficiency with computational tool set. One studio A student's comment also verifies this finding:

> **"**I like working with SketchUp because it has very easy options to make 3D model and play with the form. I can see it from all sides as it works on the design. It also renders shadow on both elevation and perspectives, which is very helpful. Perspective construction on paper is tedious and it takes extra time. I have to finish all my scale drawings to move to develop a 3d perspective of a space and then render it. Where as in SketchUp I start seeing my floor plan (spatial layout and space adjacency) as I draw it straight from my schematic drawings. I know some people (his fellow classmate) who would start working on SketchUP right away. The good part is I can see form, space at the same time and edit (manipulate) 'em (alternative ideas) if I don't like it."(from interview: Studio A student)

Many relevant studies also advocated that 3d visualization techniques can provide students relevant information with higher efficiently and more flexibility resulting lower level of misinterpretation than traditional methods only.

In the questionnaire (see appendix E and F), the students stated that working with multiple medium not only allowed them to communicate with the design ideas (see Figure 56), but also made it a necessary component for representing their design ideas (Figure 57). But, the level of expertise and exposure to digital design/drawing tools were considerably low for most of the beginning design students which lead them to use more conventional design tools as well as studio settings with face-to-face interaction and communication (Kalisperis & Pehlivanidou-Liakata, 1998).

Students also stated that various manual and computational design/ drawing tools and conventions that they have learned earlier helped them to experiment unconventional design method that often results into new forms and arrangements. Nonetheless, general trends of architectural design studios have not advanced much from traditional design methods regardless of the available technologies and innovative design pedagogy.

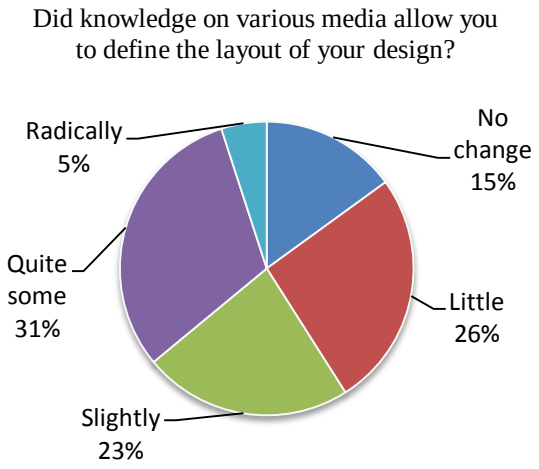

Figure 56: Impact of student's knowledge over multiple design media design layout.

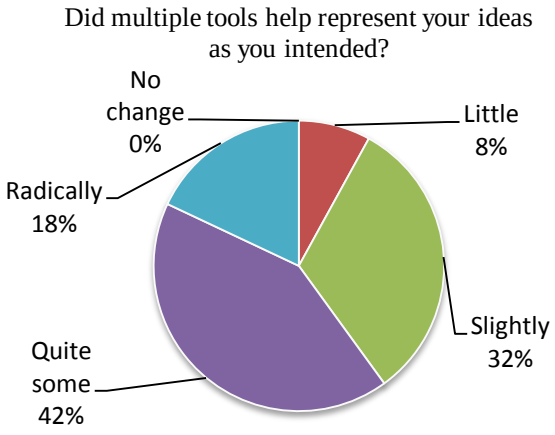

Figure 57: Impact of knowledge over multiple tool on design

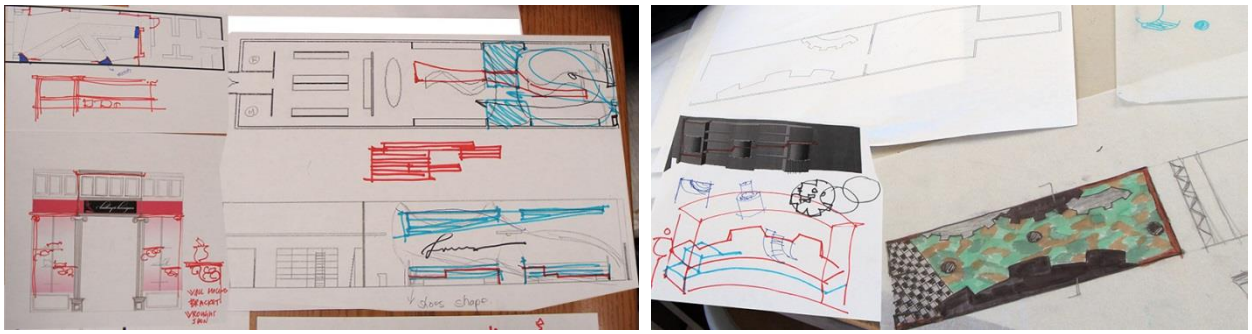

Figure 59: Multimodal approach of design drawings.

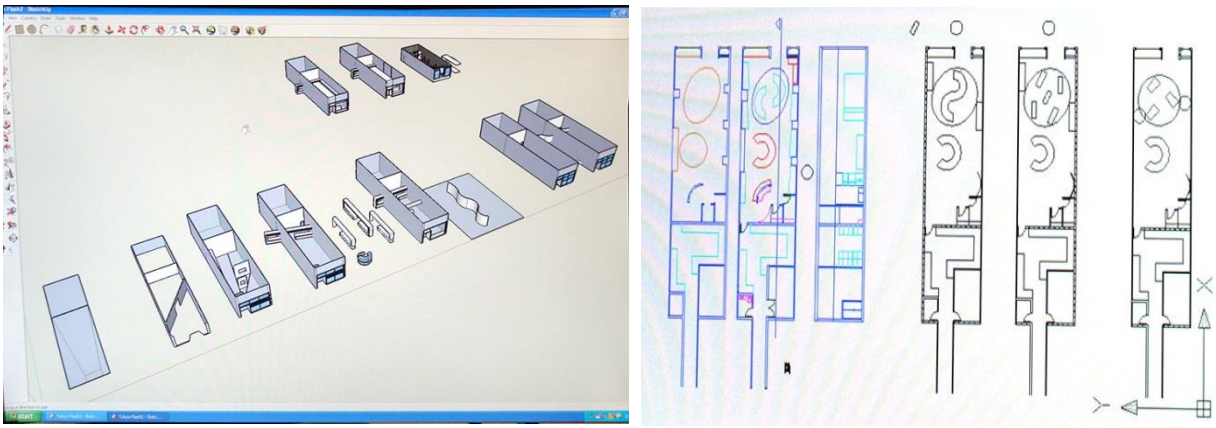

Figure 58: Design development using computational tools only.

By evaluating students' progression through their design process, numbers of produced alternatives and solution-generation strategies- it was observed that students using digital and mixed modalities generated more and various solutions as shown in Figure 59. Each attempt for finding satisfying solution required simultaneous interaction of several domains of knowledge, each by itself is individually complex. Designers require adequate knowledge and practice on various modalities to analyze – synthesize – evaluate and of course to represent and document. In Figure 58, example of studio A student's use of SketchUp (left) and AutoCAD (right) for developing design,

experimenting form and such is represented. These valuable knowledgebase is developed by learning and repetitively practicing in design studios. Example of students' work suggests that computers provide an effective strategy for acquiring and flexibly utilizing design alternatives and options in ill-structured knowledge domains as architectural studio education.

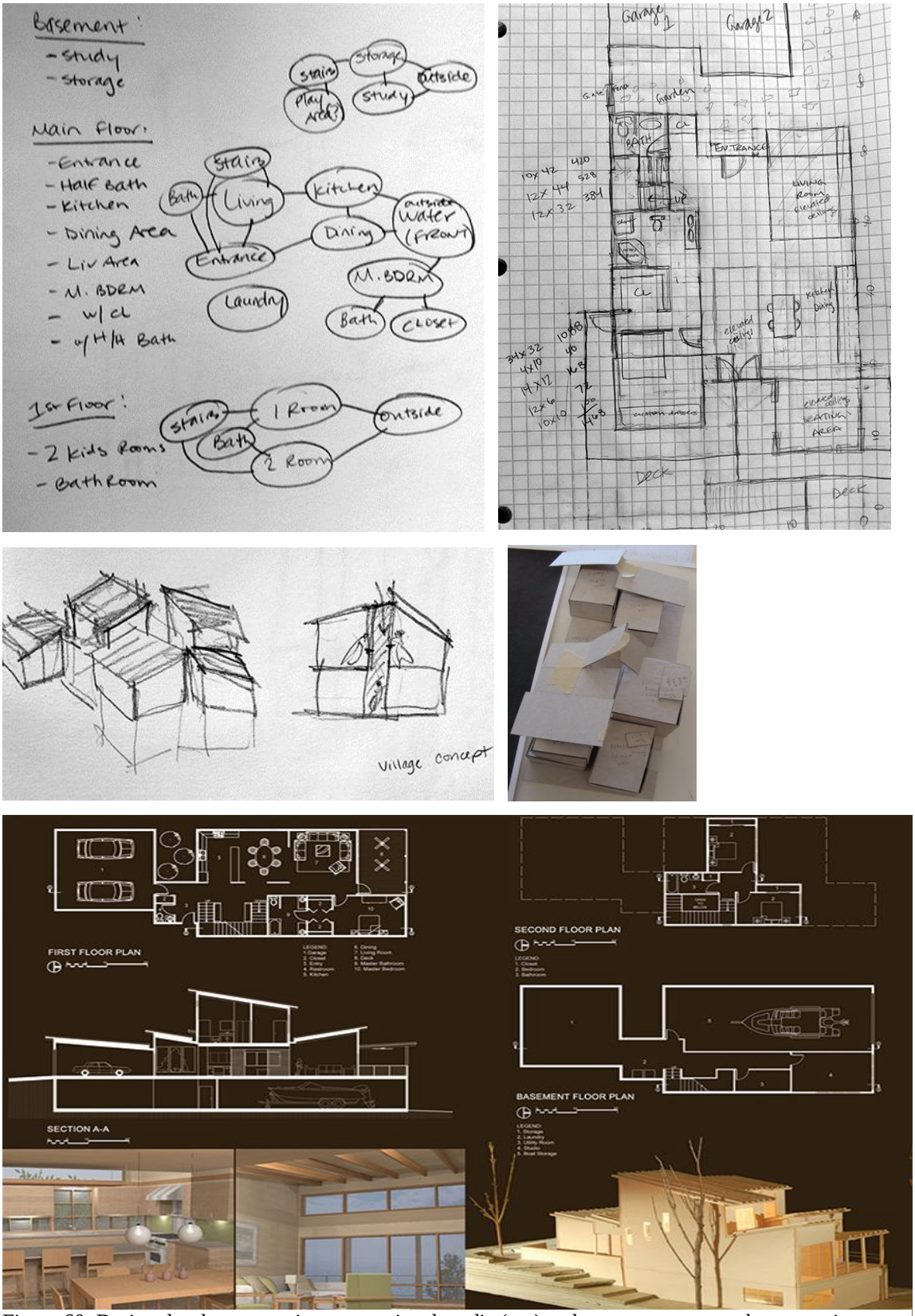

Figure 60: Design development using conventional media (top) and computer generated presentation board (bottom).

Designers often struggle to synthesize design problem from abstract design ideas and construct tangible solutions. The primary objectives of studio setting and education curriculum is to provide design students with knowledge in a flexible manner to produce multiple alternatives to any design problem. This hand on experience is essential to develop students' ability to communicate graphically and model productively in order to produce successful design solutions as example of one studio B student's design process suggests.

Examples from both the studios establish the fact that drawing and modeling with traditional and computational design and drawing tools, constitute the basis of studio performance. Students were encouraged by the instructors to view and execute architectural drawing, including computer-aided drawing, as a valuable process of thought and experimentation. The presented design problems are intended to emphasize analytic and synthetic activities of the design process at all levels, from the contextual inferences to the smallest detail. Language that designers use to demystify tacit, complex and abstract thoughts to substantial and concrete representation is equally important. Therefore, the studio culture and overall pedagogical approach significantly dictates and shows profound effects on designers' selection of modality to exercise their design thinking, its externalization and representations.

Students using digital modalities have consistently produced a greater number of alternative design solutions. However, the repetitive efficiency of computer applications spawn issues affecting design ideation, such as lack of generating completely new alternatives. Some students are tempted to use the computer's ability to create exact

replications of design elements to increase the complexity of their representation. The solution may become more complex visually but does not become a better one. In these cases the computer can actually impede the design process.

Powerful visualization tools do not necessarily secure a better understanding of space or better designs. In fact, they may increase the potential, for students in particular, to become more concerned with creating flashy models and animations than with the experiential qualities of the space that they are designing. Computer-based modeling will allow good students to produce better designs; but it will not turn weak thinker into good designers.

4.6 Impact of CAAD on Design Studio

Project-based studio approach is the traditional mean of learning design where students practice, explore, generate and evaluate alternative ideas to make design decisions. Externalization (of design ideas) in form of two and three dimensional drawings, models and computer generated simulations are prepared to inquire and analyze conceptual transformation and concretization of abstract thoughts. Since through this linked acts of drawings designers propose alternatives, interprets and explore consequences (Mark D Gross & Do, 1997). Selection and use of (appropriate) design modality and drawings also can contribute to the understanding and representation of design ideas. It was observed in all studios that both manual and digital modalities were used in conjunction rather than being considered as separate media.

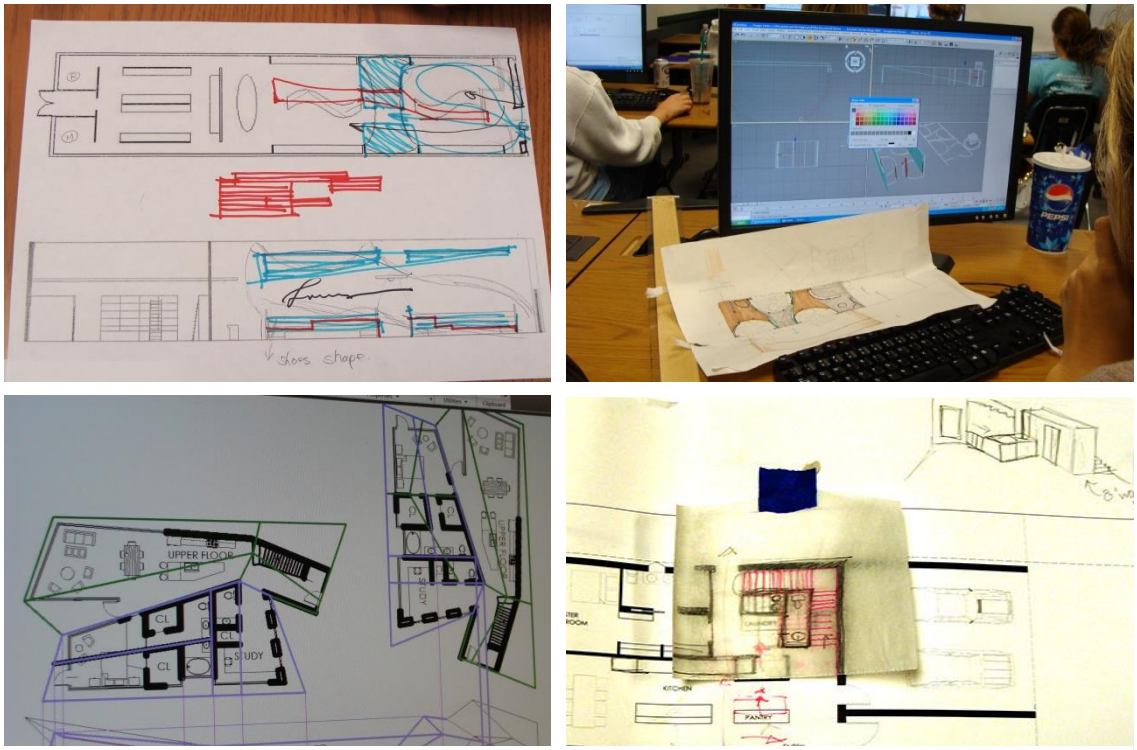

Figure 61*:* Design development in multimodal environment.

Figure 61 demonstrates various combination of multimodal approach to address design issues as (from top-left) students using bright markers over CAD printouts to highlight spatial relationships (digital-manual), experimenting floor materials and testing those in context using 3dStudio Max application (manual-digital), formalizing shape of roof form floor plan in AutoCAD (digital only), design development through paper overlay (manual). This mixed modal approach encompasses various manual drawings and renderings, CAAD drawings, computer generated renderings, simulation of various kind, both physical and virtual models. Since different media 'talk-back' in different ways (Bryan Lawson, 2004; Donald A Schön, 1987), converting directed techniques can contribute to effective understanding and manipulation of design problem as well as documentation. Besides offering designers a rich perception and new means to refine design combining techniques usually make the process more interesting (Ataman, 1999; Osman Ataman & Bruce Lonnman, 1996; Dokonal, *et al.*, 2004; Won, 2001).

The Design Methods Group (Achten, Dijkstra, Oxman and Bax) distinguished four computer systems in education: social systems, professional systems, educational systems and innovative systems (Achten, 1996). Most of the design schools of this century have integrated computer literacy and CAAD concept that involves mainly two types of computer systems: social and professional. According to Glaser &Strauss (2009):

> "*Social systems* are computer tools which all students should be able to use within any higher education curriculum. *Professional systems* are computer tools which are used in architectural practice (e.g. AutoCAD software). Usually these systems

are off-the-shelf software, that is, software developed by standard software companies (e.g. AutoCAD, 3DStudio, Microsoft). Whereas *Educational systems* are modified professional systems to convey specific pedagogical purposes and are developed within or for a specific architectural institution and sometimes are result from research. *Innovative systems* on the other hand are computer systems that reach beyond current state of the art of professional systems (e.g. automated plan recognition, virtual reality design systems) and always are the consequence of research work, hence they are so-called home-made software"(p. 26).

Table 24 exhibits generic computational tools and applications generally used by designers during various design stages.

Table 24: Use of computer tools at different design stages

	Programing/ Research	Concept Generation	Refinement/ Transformation	Development	Presentation	Evaluation
Precedent	X	X				
Online Databases	X	X				
Image Capture	X	X				
Image Editing		X		X	X	
Computer Modeling		X	X	X	X	
Rendering			X		X	
Physical model			X	X	X	X
Simulation					X	X
Virtual Reality						X

Initially CAAD was introduced to the design studio curriculum with strong rejections form studio instructors as it was presumed to have adverse effects on students' design thinking and presentation skills (Bille, 2002). CAAD eventually made its way into the architectural education and got well accepted by the early 1990s through many years

of research (Andia, 2002). Computer literacy and its effective integration and utilization is significantly correlated as identified by Van Dijk (2005) which further confirmed in the conversation with studio one student below as well as in questionnaire responses (Figure 63 and Figure 62) :

> "Since I've started using Revit, I can realize more of what I am doing since it (Revit) creates mass (form) while I am working out my floor plans….. for me this is a huge advantage to see the spatial relation in 3D…. besides, when I have learned how to import CAD drawings into Revit – it lets me experiment and see (visualize) different shapes otherwise challenging for me to design (build)."

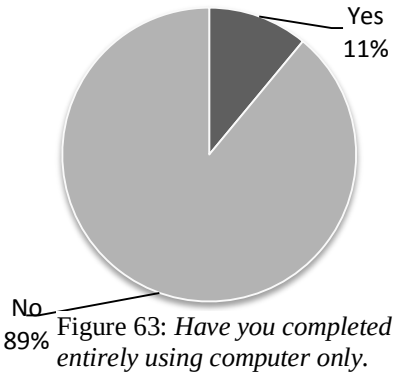

Figure 63: *Have you completed a design entirely using computer only.*

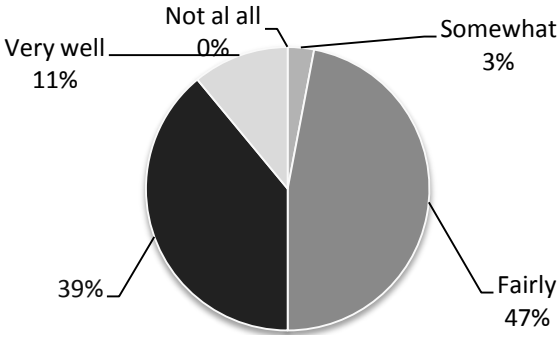

Figure 62: *How well do you relate your design to the program and context?*

A significant correlation (see Table 25) was observed during the inquiry on students' computer literacy and its integration and utilization in design studio. The way CAAD was integrated with design process largely dictates its success. Students' knowledge over digital modalities were calculated based on numbers of application they are familiar with to an acceptable level and the frequency of these computer applications' usage as a design and/or drawings tool.

Table 25: Correlation between computer knowledge and its use as a design tool

Correlations

		Computer knowledge (self-assessment)	Frequency of use during design process
Computer knowledge (self-assessment)	Pearson Correlation	1	.590**
	Sig. (2-tailed)		.000
	N	28	28
Frequency of use during design process	Pearson Correlation	.590**	1
	Sig. (2-tailed)	.000	
	N	28	28

**. Correlation is significant at the 0.01 level (2-tailed).

Technology and digital media is seemingly intertwined with almost every activity this new generation designers perform in and outside of their design studio. Affordability and easy access to computer and other devices as well as early education on various computing program has enriched students' perceptive level and better understanding of a wide range of modality produced by computer. Almost one fourth of the design students were familiar with some sort of CAD program (mostly AutoCAD) before admitting in to the university (Figure 64).

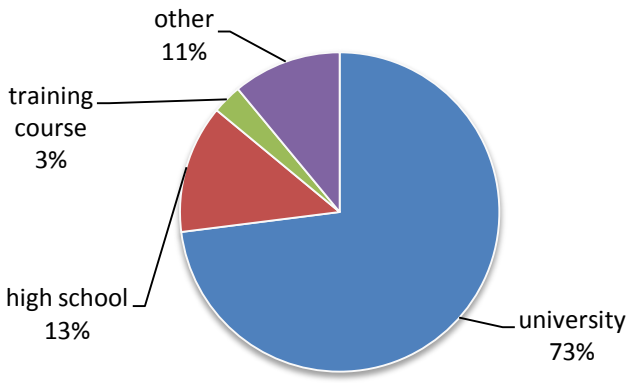

Figure 64: *When have you used any CAD program for the first time?*

The familiarity of using computer for communication, writing, drawing and such – helps design students to facilitate its integration in architectural projects. Bille (2002) argues that this could reflect the students' motivation to use computers in everyday life as a social phenomenon rather than a learning tool. This knowledge indirectly brings new skills and tradition to studio context. New skillset and knowledge are being brought into the traditional context of architectural design studio as these students are gaining more experience with computer and becoming digitally literate. As it was discussed in previous section - the studio culture may affect and get shaped by the changing trend of design media. Visual impact that each individual designer develops by engaging with various media opens up new perspective for design thinking. In recent studies Achten (2003), Al-Qawasmi, (2004, 2005), Breen (2004), Salman et al (2006) and Schenk (2005) also confirmed this view.

On the other hand when I looked at the influence of drawings in digital age and student's attitude toward it, it was found that a large number of the sample believes that they have envisage ideas and communicate those through traditional means of drawing

and designing as one of the studio B student's statement suggests. Figure 65 shows same student's design development drawings.

> It is much easier to start with a pencil then computer. Sometime I wish I could sketch better…. I feel more connected when I draw with a pencil on paper, I can maneuver freely, look farther and deeper into what I'm doing and it keeps me engaged. I can think about my design problems at the same time……. When I think about design alternatives on the floor plan the small freehand sketches that I drew (pointing on conceptual phase drawings) often become a crucial elements for decision-making. I have tried to do this thing on SketchUp and AutoCAD but it was not as intuitive as it is with my drawing book. Probably it is the way I work… As I like to take small notes, draw diagrams and sketches, write down my thoughts and do a lot of bubble diagrams and small sketches. I consider myself fairly good in computer programs as you know I have taken all courses, but I could not manage to formulate design alternatives and decisions in computer alone. (Studio B student interview)

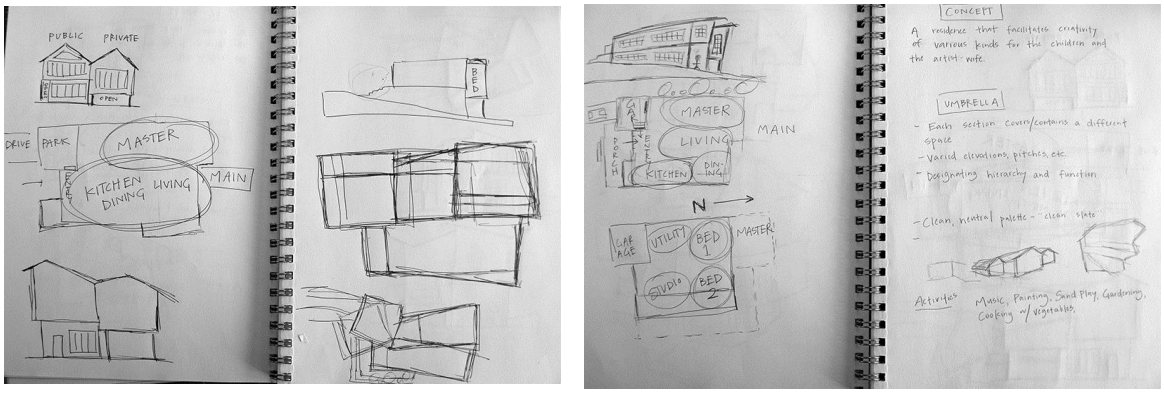

Figure 65: Studio B, student's sketch book showing idea development.

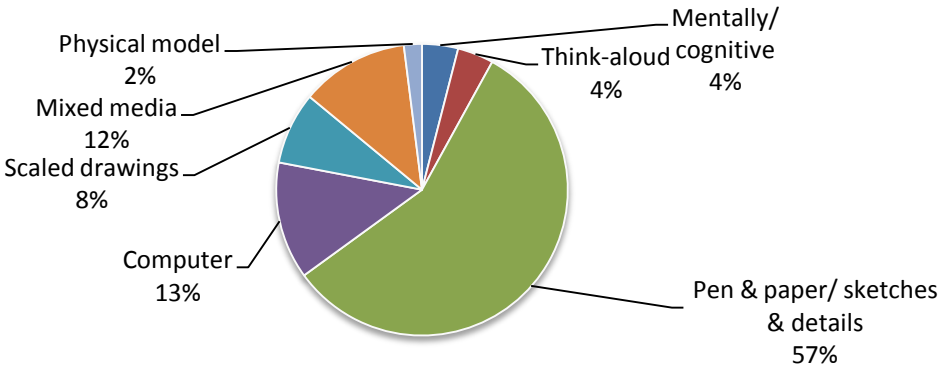

Figure 66: How students usually start designing (after they have an abstract concept)

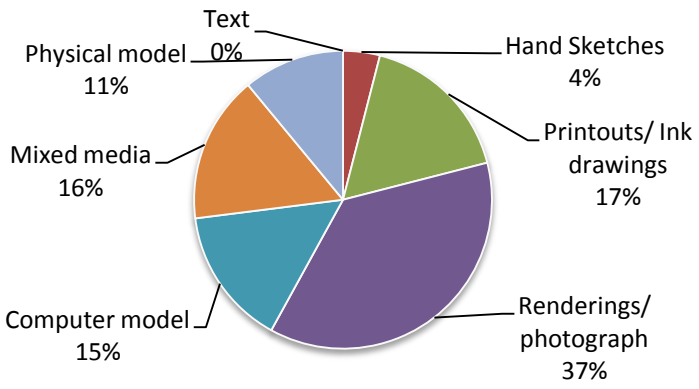

Figure 67: To present design ideas what medium do you prefer?

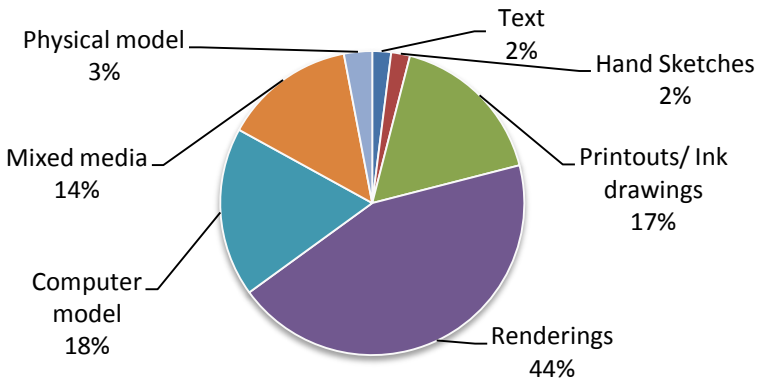

Figure 68: How would you like a design to be presented to you?

More than 57% (Figure 66) of the students started their design process by sketching and detailing with pen and paper while 25% with computer and mixed media. Before moving in to digital media, in most cases, designers try to concretize their imagination and concepts. Knowledge and experience on traditional drawing methods is

considered to be one of the best way to achieve this, which also helps students to develop their own personal approaches (Schenk, 2005). Majority of the students (52%) want to prepare computer generated renderings of 3d model for final presentation (Figure 67) and about 62% of the students perceive presented design ideas better if it is done through some sort of three dimensional drawings as computer renderings, photograph or 3d model (Figure 68).

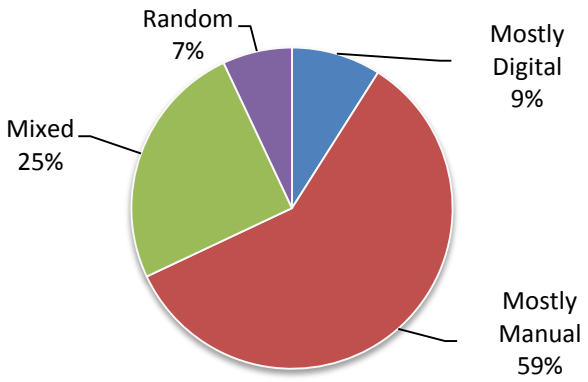

Figure 69: Did the medium stimulates creativity and generates alternatives.

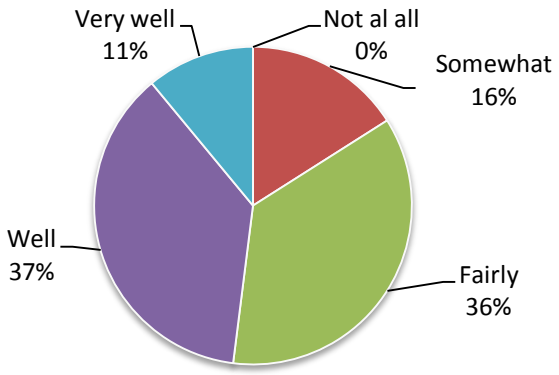

Figure 70: What modality helped you most to stimulate spatial impression of your design?

The act of design is highly visual and the universal language that designers use to conduct dialogues within the design process is drawings. They (designers) learn to associate various sources of information and synthesize design decision by using and mixing various 2d and 3d drawings. These information is more often than not a graphic representation of designer's thought. Using different tool sets are more likely to help designers and selection is made within the context of design process. Almost one third of the students believed that drawing medium stimulated their creativity and problem solving ability to some extent (see Figure 69). It takes years of practical experience, observation and practice to develop one's own methods of design thinking as well as understanding on selecting the best tool set, environment and method that works cohesively with individual's thinking style. It is not surprising that students of this digital age found digital and mixed modality (85%) more convincing and useful for perceiving spatial attributes (Figure 70), evaluating design solutions (Figure 71). Mixing modalities instead of using either alone results in better externalization of ideas (Figure 72) as well as developing more alternatives (Figure 73).

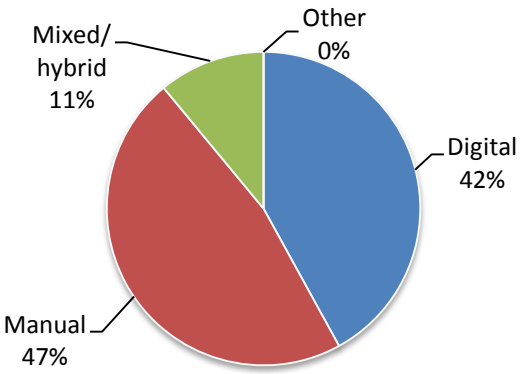

Figure 71: *Which medium allowed you to easily evaluate solution to the design problems?*

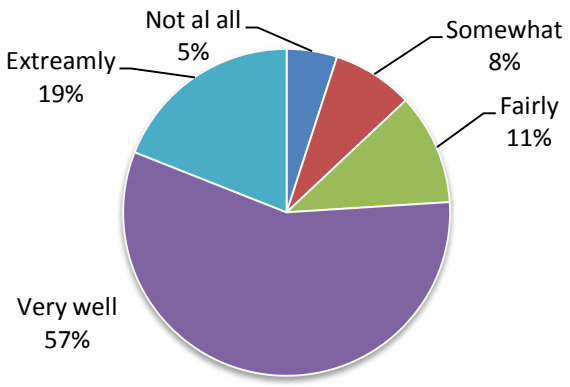

Figure 72: *Do you think mixing design tools affect the way you express or develop new ideas- in comparison to traditional or digital media alone?*

Visual expression is an innate part of the creative design process that provides designer a holistic perspective in solving problems. McKim's (1980) stated "….abstract and concrete imagery are complementary. The flexible visual thinker moves readily back and forth between the two". In both the studios exploration and experimentation of ideas were exercised simultaneously during design. This often produced unexpected results that benefit students by not confining themselves to any preconceived or tightly focused notion.

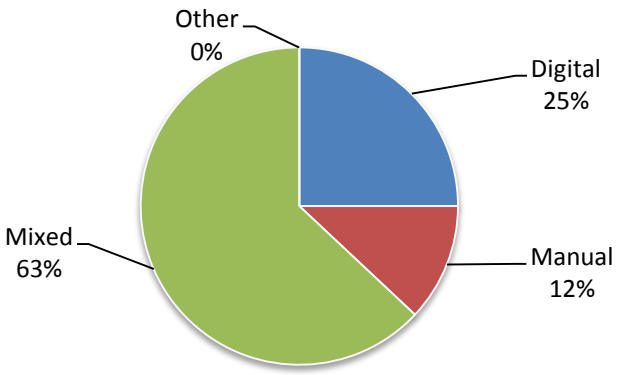

Figure 73: *Which medium allowed you to develop design alternatives?*

Incorporating digital drawings in traditional context brings new beneficial effects as exploring new form of drawing which could provide students and researchers with new insights and opportunities to see their ideas. Computerized representation has proven (Madrazo, 2000) to enhance visual thinking by introducing a change in the traditional studio environment. However, it is my understanding form this study and literature review that- diminishing use of traditional modalities may have a profound effect on development of visual literacy and overall creativity of design students. As a result, a larger proportion of design studios are experiencing predominance of a few particular computer applications (see Figure 74).

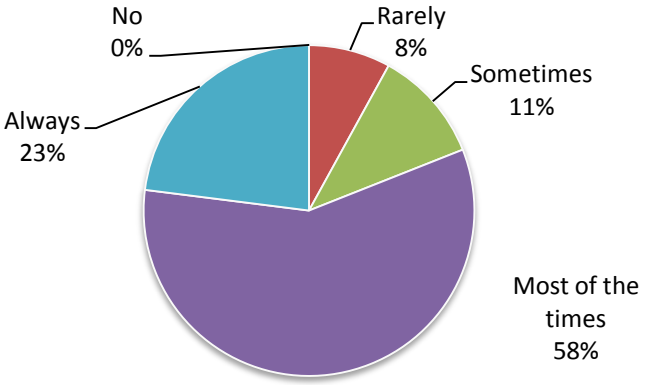

Figure 74: *Do you generally use the same medium for similar design task?*

Arguably, studies from past decade (Do & Gross, 2001; Van Elsas & Vergeest, 1998; Verstijnen et al., 1998) contemplated that sketching and physical model making, manual drafting are the most important media of the idea- generating process. As these researchers argued that digital sketches are not supportive enough to nurture creativity during the conceptual design.

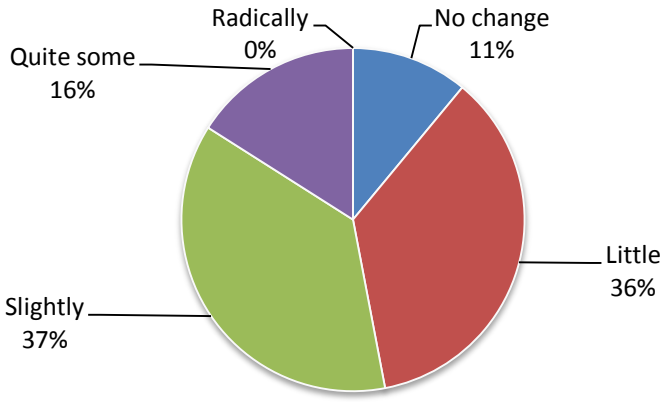

Figure 75: *Did using multiple media stimulate the creation of new ideas?*

However, this study has identified that drawings, within digital or physical platform work as the most elementary medium for design thinking. Students are getting more computer literate and developing numerous skills which a decade earlier was considered 'specialized technical knowledge'(Bermudez & King, 2000b). Studio tradition and teaching methods are arguably adopting this nontraditional culture in various ways. This phenomenon is positively changing design media, process and thus bringing a change in visual impact. But when it comes to generating ideas enough change has not been noticed from what Do &Gross (2001) mentioned decade ago, which is – working with multiple media often do not provide sufficient support for the creation of new ideas (see Figure 75).

Contemporary design studio as ‘Studio A and B’ may seem rather classic, but the engagement of different media and technology elicit design thinking and opens up possibilities of new perspectives. Because students had already taken design communication courses which emphasized various methods and techniques of representing and corroborating design ideas both with digital and manual modalities during the previous semester, it was expected that students are already armed with a decent depth of knowledge on using and mixing a variety of modalities. Each design modalities ‘talked-back’ in different ways (Breen, *et al.*, 2003; Bryan Lawson, 2004; Donald A Schön, 1983) therefore, combining techniques not only made the design process interesting but also provided designers with deeper, richer, insight.

As a concluding remark it is safe to assume that the use of digital modality has potential to affect architectural thinking in number of ways. Contemporary design studio has become an exploration setting for various design media. Integration and of these media extends the challenge and bring new skills to accommodate contemporary design education as well as ever developing CAAD applications.

Proper externalization of design ideas and details facilitate memory by externalizing the basic design elements, uncoupling designer to think about new and emergent properties of the design elements. Sketches, freehand drawings, massing models etc. promotes and serves as spatial display on which various mental operations are performed as calculations, interpretations, and comprehensions of design problem in hand. Perceiving spatial connections, formals relations etc. depends on factors as proximity, grouping, distance, direction, common fate, and continuity. Designers develop

these sense through recurrently working, experimenting, mixing and manipulating various design modalities.

The analyses of designers' retrospective reports of their drawing activity (as observed through their design process) shows that externalization of design ideas and development using multiple modalities have greatly stretched the ingenious palette of early design students besides becoming more productive. Introduction of such tools also helped developing personalized and vivid working methods.

CHAPTER FIVE: DISCUSSION

Finding from the data analysis, their synthesis and interpretation from previous chapter is summarized in this discussion. This study started with the following research questions:

(a) What are the critical reasoning behind modality shift?

(b) What are the factors those trigger modality shift?

(c) How does switching modalities effect design outcome compare to initial design conception?

Data analysis revealed the reasoning of modality shift and students' perception of their action behind the shift. The two studios observed during this study were different in terms of their projects, instructions and approaches. In addition, students' selection of modalities was intertwined with other aspects of design because design externalization methods are not a complete separate element form design itself. Design is a complex process that happens independently in each designer's mind. Besides nature of the design project- studio instructions, designers' background, experience, exposure, overall studio culture and most importantly designers' competency with design and drawing tools are responsible for designer's selections of modality and switching between those.

This chapter interprets and synthesizes the findings from pervious chapter. It is structured based on the following themes: a) studio instructions, studio culture and students' selection of modalities; b) influence of technology and modality interaction on

design process and tools; c) common themes of design modality usage and its effect on design process.

5.1 Studio Instructions and Student's Selection of Modality

In architectural design studio instructor plays a very important role as s/he is the source of primary knowledge, instruction and evaluation. Thus, design outcome of any studio course is largely influenced by the instructor's approach. Students from both the studios expressed their commonalities regarding gaining knowledge and experience from instructors. Both the instructors had strong pedagogical notions that influenced students' design process. Such notions develops over the time through their educations, work and teaching experiences, school environments, background and interests. It was observed that design students also showed tendency to develop similar notions by going through studio phases. For instance studio B students were more methodical users of design tools throughout the whole design process; whereas studio A students preferred using digital modalities for most of the design process. Studio B instructor emphasized developing indigenous concept while approaching a design project. With the example of precedents, text, pinups he created an ambience that shared his own preference and directed ways to translate their concept in to architectural form and space. His ideology of observing built form from exterior led to introducing massing model exercises and drawing three dimensional views as a method of design development. On the other hand studio A instructor gave a branded environment design project that represented few high end

commercial product. Due to the short duration of the project and instructor's experience, interest and background computational media the studio as a whole was more open exercise design development with numbers of digital modalities. He also referred a number of websites and video documentation as precedents and analytics for starting the project.

Both the instructor wanted their students to comprehend fundamental design ideologies, project requirement and develop a process through precedents, pin-ups, class discussions so that they can develop common themes and interpretations leading to inspirations and design solutions. There were differences between the studios regarding the type of the projects, overall ambience of the studio culture and instructor's pedagogical ideology. In researching a relationship between the students and instructors form the studio, a significant influence of instructor's pedagogical approach was observed on students' design process and selection design tools. This result, again had greater impact on comparatively novice designer's selection of design modalities than experienced design students.

Inexperienced designers with media usually do not have the ability to comprehend the benefit of the productive dialog between media hence prefer to work with a single modality. As students gain more competency with their modalities (as seen in Studio B) they frequently move back and forth between those and a new paradigm of this hybrid media.

Alongside studio pedagogy, the influence of digital age and its media on architectural design education and practice is becoming increasingly evident. Designer's

dependency on computer mediated modalities are snowballing as well. Besides providing new externalization and documentation methods, it also expand the abilities to create, explore, manipulate and compose space and form. The competitive nature of contemporary design studio demands new skill sets and approaches to address rather complex nature of design problem. Apart from exploring the medium as a design tool, integration of digital modality encouraged students to rethink the conventional architectural design processes and design products. These issues points toward re-evaluating pedagogical model of design studio that emphasizes inclusive design practice and theory regarding design and drafting tools.

5.2 Influence of (changing role of) technology on design process and tools

As technology and its media is getting sophisticated, it evidently is altering the way designers are producing solutions as well as their products. The fundamental mean of design ideation, process and presentation has also been changed so as designers' aesthetic value and perception of built environment.

Design process and method is directly associated with design tools, its media and their interactions. Interactions between media encourages the process of design development by providing fluid thinking and multiple viewpoints rather than particular specifics of the final design product. Essentially this relationship has a deep impact on how design is conceived, developed and communicated (D. Herbert, 1994). Modality is a more comprehensive term that comprises of not only digital and analogue 'tools' which

designers use to externalize their thoughts but it equally involves ‘media’ where our mind interacts with design issues (DeLaura, 1997; D. M. Herbert, 1994). 4,5,19.20.

From the analysis of collected data it can be argued that multimodal environment enriches design process by encouraging multiple iteration between manual and digital design and drafting tools. But the shift or transition of media and their re-interpretation is very important. Because shifting modality may enhance design process by aiding to cognitive, qualitative and productive aspects of design development or it may hinder the process through loss of information, adding further constraints and relocating focus from the design problem (Bermudez, 1997b; N.Y. Cheng, 1995; Herbert, 1995; Kellett & Ronald, 1996; Matthews & Temple, 1998; Parsons, 1994; Smulevich, 1997).

It was clear that during design process students constantly review their positions, and synthesize alternatives until a suitable solution appears. According to Schön and Wiggins (1992), designing is a kind of dialogue with the design situation. As they described design is “a conversation with materials, conducted in the medium of drawing and crucially dependent on seeing." With digital design modalities students appears to be more engaged in a similar interaction or dialogue with the digital medium. A student constantly reviews his position, reacting to all new information and conditions.

During the observation most of the students tend to design in three dimensions from the beginning of the design process. Apparently, designing with computer mediated 3D environment has some advantages as it provides greater fidelity to reality which permits the student to think more naturally. Digital media are advantageous for design development phases since it can provide with a higher degree of geometric definition and

abstraction as well as greater control over elaboration and coordination of complex form and details(N.Y. Cheng, 1995). They have used abstract paraline drawings (2D plans, sections etc.) to begin exploring, manipulating and to finally articulate planned space in three dimension. For example, student have used modeling and animation software as 3DS Max and Revit Architecture to explore and examine form, space, color, texture, lighting, and shadow, as they explore spatial and temporal movement.

The low correlation between CAAD skills, preferences and modality shift frequency shows that computing knowledge alone is not responsible for switching between modalities. Digital media is not the key to convert a bad design into a good one but a combination of numbers of unorthodox externalization techniques (available in CAD programs) may challenge and feed designer's perception and clarifies their spatial and formal understanding. Knowledge on design process and method is equally important as a greater correlation was identified between experienced design students' performance with conventional design skills (during early design phase). Students with proficiency on multiple modalities were better equipped to systematically explore the medium and to pursue its full potential. In some cases, novice students with limited design knowledge using digital media from the beginning of the design process seem to shift their focus frequently. As a result the final design outcome shows clear offset from the design content in favor of the image and initially conceived concept. Thus, the basic design experience and presentation skills as composition, materials, lighting, and color, tend to make considerable differences in design outcome since these knowledge provides necessary direction to deal with design and modality constraints.

CAAD applications were used by a number of students as design tools (as well as drafting tool) which affected their conceptual cycle sequences. By using these tools effectively few students were able to produce further and alternative decisions. More often than not these digital modalities assisted early designers' understanding of what the concepts of the project were and the significance of it by stimulating perception and offering alternative perspectives. Trying different scenarios by repeating the analysis accurately and quickly, changing drawing appearance with minimal effort (line weight, color, transparency) and doing the same task with variation are among many advantages students have mentioned during interview.

The 'shift' in this study's context includes various changes in design media, visual thinking and design process theory. Similar to Breen's (2004) finding the recurring rapport between design thinking, representation and media provided the means for engaging in design thinking and progressing through various representational media. The observational data reflected that, digital modalities were used at any point of the project when students needed more preciseness and rapidity. This could be related to design 'talk-back' reflection. Moreover, in the digital age its media has become an essential option but its integration into design process need careful attention as that it does not excludes all other modalities. These other media, sketches, scale-models and such address different perspectives that better capture a comprehensive view of the design.

The combination of traditional and digital media and design methods added insights and better means to (re) consider and (re) fine a design. This possibility opens up new opportunities in architectural education as well as in architectural media research

(Bermudez and King, 2000; Breen, 2004). This integration might increase the student's experience of inquiry, discovery and representation (Achten, 2003) and this leads to creativity.

The results of this study also indicates several aspects of students' attitudes toward the use of computers in design. It is found that using digital modalities in early design phase correlates with their alteration of initial design concept in general. However, there is no correlation between students' experience and their attitude selection of modalities. One intriguing finding is- experienced designers showed less tendency of using modalities during early design phases in compare to beginning designers. There also seems to be a gap between the instructions and contemporary studio culture of the digital age. Students had two different views regarding the purpose of externalization of thoughts: *visual reference* and for *spatial experience.* These views were identified from the analysis of the realm of design activity. Drawings are the expression of designers' value and reflection. Unlike many structured and specified aspects of design as structural and building systems, design drawings are highly subjective even though it is usually taught objectively at the very early stage of the design education. As design students get more experience, they develop their own unique style of thinking. This indigenous style differs from person to person. Drawings of various type are the language designers' converse with themselves as well as with others regarding their design thinking. Therefore, beside universal and formal documentation drawings, developing unique drawing style is as important as learning to develop individual design style.

While developing ideas, a number of forms of graphic representation were used by these design students- from ubiquitous conceptual sketches, abstract drawings, notes and doodles to the advent computer aided design. But the media seems to characterize the design process more than any other is conventional types as those graphical devices help designer to generate ideas as well as recording data (Fraser & Henmi, 1994; Herbert, 1993). During early design phase conceptual sketches act as the instrument of (re)interpretation and emergence of new thoughts and form which cannot be anticipated before. Most designers use sketches and various form of manual modalities for this purpose due to its fluidity and hand-eye coordination capability. Evidences from prior researches suggest that interaction with conceptual drawings is one of the key factor for producing design ideas (Goldschmidt, 1991; Kavakli & Gero, 2001; Bryan Lawson, 1994; Edward Robbins & Cullinan, 1994; Masaki Suwa, *et al.*, 2000; M Suwa & Tversky, 1997; Tovey, *et al.*, 2003). In this study however, it was observed that comparatively novice designers have preferred and used digital modalities as their design and drawing tools. Sketching and other form of manual drawings deemed rather helpful for expert designers than novice designers for developing new ideas (Hernan Casakin & Goldschmidt, 1999; Goel, 1995; Goldschmidt, 1991; Bryan Lawson, 1994; M Suwa & Tversky, 1997; Verstijnen et al., 1998). This is because novice designers are more dependent on episodic knowledge than theoretical knowledge for generating design solutions (Bryan Lawson, 2004). On the other hand skilled designers depends largely on precedents and analogical reasoning. Architectural design drawings and images along with their reflections on modality use provide them with most of the information than their experience in reality. Changing modality during this process of idea generation

often help designers to see a challenging ideas from new angle with details never perceived before. Emergence of this novel design idea can occur to both novice and experienced design students regardless of the use of their modalities.

Media used in most modern design studio combine various different applications that were considered individual skills on their own. Computer is single piece of hardware which on media level is used as a platform for various modalities with an option to be combined with another media.

Design is not completely dependent to the early design phase, it rather is a step by step process of going through different phases. Ever since CAD is introduced to the design education, computers got involved as early as from idea generation phase and gradually became a fundamental design instrument that not only acts as a mean of documenting ideas bust also a mean of generating and evaluating concepts. Many students especially early design students worked directly with digital modalities from early stages. This often allowed them to systematically alter and adapt different perspectives of design features. However, the précised nature of CAD lacks a holistic view of the design which restricts students from comprehending any available spatial connotations among design decisions. Students extremely skilled with 3d modeling software (such as 3ds Max, Revit, SketchUp) used these tools frequently in conceptual phase and produced visually appealing conceptual images. The negative side of these type of approach is the tendency of early fixation and biasness on computer generated images and unstructured proposals rather than design content. Nonetheless design students of this digital age more often than not begin working with their digital

modalities from very early stages of their design education. This is because of their familiarity and exposure to similar devices, students' background and contemporary culture.

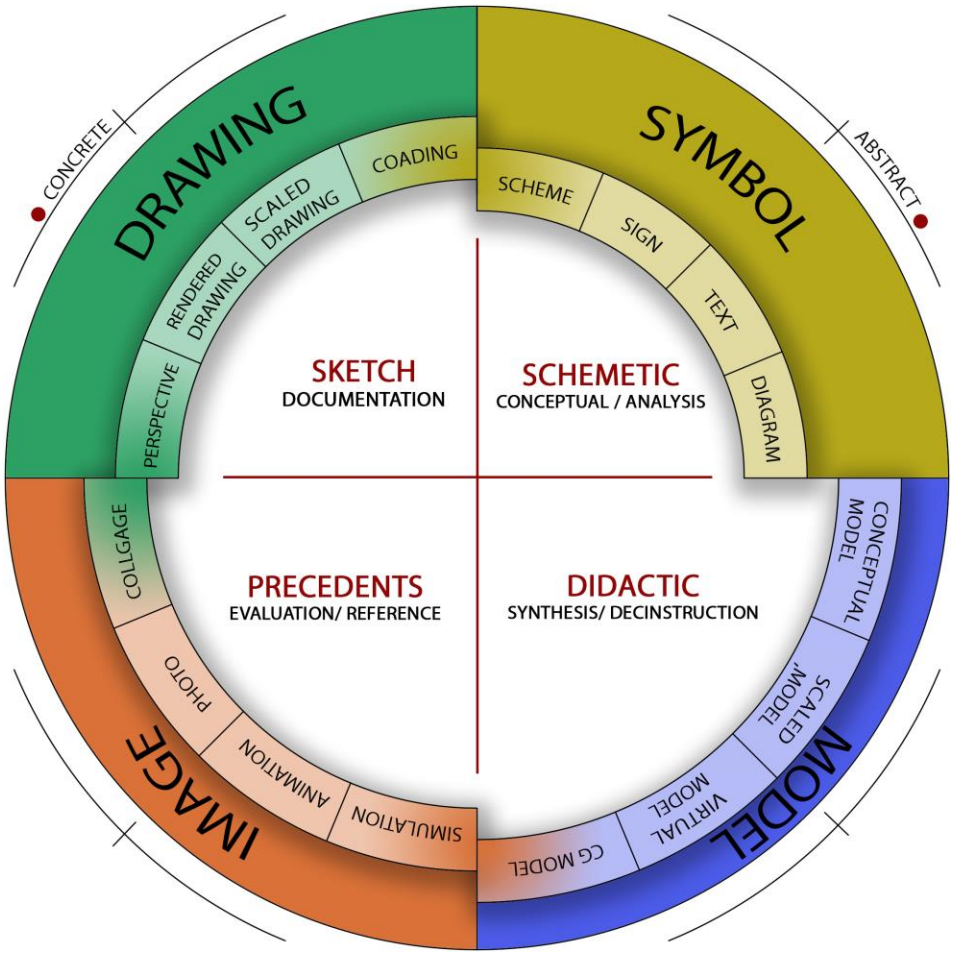

Figure 76: Modality relationship diagram

The diagrammatic system of modalities (see Figure 76) based on (architectural) design presentation module (Breen & Giró, 2003) describes variety of design and (re)presentation media and their relationship. This also portrays direction of changing media conventions in typical design project. New and unique multimedia instrument as

both design and drawings tools potentially emerges where two major types overlaps. Resulting new multimodal design tool extends designers' creative palette to develop new level of information and inspiration. Design studios should accommodate and motivate development of innovative working methods and the instruments of design as a testing ground for new instrument for design inquiry.

5.3 Synergy, synthesis and shift between modalities

Traditionally, designers use an assorted mix of sketches, models, manual and computer generated renderings, often juxtaposed and superimposed to communicate with colleagues and instructors. A synergistic approach between modalities clarifies advantages and disadvantages of each these modalities so that designers can get insight about the synthesis between methods to see how shifting between modalities can enhance design process. The process of design is not modality specific but can benefit from using appropriate design and drafting tool set for internalizing (design thinking) and externalizing (communicating and documenting) ideas, details and other specifics.

Each of the design medium has its own characteristics and idiosyncrasies more like individual musical instrument. Media and contents are deeply related, hence it is more likely that certain ideas will surface and benefit from specific tools. Synergistic approach of multiple modality provides designers with lateral thinking ability. Both digital and manual media has its own distinct characteristics. Synthesizing modalities

often brings contrast due to their distinct inherit properties which designers with competency on multiple modalities can use in their advantage.

For instance, the synergistic development which was achieved by combining two or more modes in studio A students' work demonstrated that using computer to model some of the structural component as free flowing shapes, slopped roof, slanted walls and other such unorthodox forms (see Figure 49 to Figure 53) and then manipulated the geometry to blend the newly found perspective unavailable before on paper.

Since each media imposes its own objectivity of ideation (McLuhan, 1994) using multiple modalities and switching those appears to be crucial for proper transformation of design thoughts into tangible design documents. CAD drawings are precise in defining geometry and need abstract understanding of design organization unlike physical model which is generally less precise but need greater degree of spatial reasoning. Different from painters, artists and artisans who work directly on their media designers are dependent on an intermediator media- pen and paper or paper its digital substitutes. Taking a project from one medium to another can lead to new directions and encourage refinement.

Besides supporting imagination design modalities (design and drawing tools as well as their medium) and the act of switching those provides designers with new reflections and refinements. If this switch occurs through flawed transition further considerations is necessary unless there is symbiotic transition which could be as simple as ink to color pencil or as intricate as freehand sketch from computer generated modeling and rendering. Baffled and hindered thoughts are more than often get enriched

by rearticulating existing facts into new medium because, inclusion of new or different modality initiates a reassessment process which make designers to rethink and re-evaluate the problem that suits constraints of the modality.

5.4 Common themes of design modality usage and its effect on design process

Attributing effects of modality, factors reasoning their shifts and creative manipulation invokes designer's externalization capabilities toward continuation of design ideation and its successful execution. Media theory proposed by Clark (1983) refers media attributes as it is neither necessary nor unique to any particular medium. Clark (1983) stated regarding attributes as- "many different media could present a given attribute so there is no necessary correspondence between attributes and media" (p. 452). However, a distinction can be drawn between capabilities of modalities and the variability of their use within the framework of their effects on carry over of initial design ideas when designers switch modalities.

The aptitudes of a medium is constant and the attributes of that particular medium is its capabilities even is its capabilities even when this capability is not in use. This study shows that designers tend to use a tend to use a combination of modalities for conceptualization and ideation whereas for documentation and documentation and presentation digital modalities appeared to be the primary drawing and presentation and presentation tool. The defining characteristics of one media may be different from the other one or may other one or may have some similarities depending on user's preference and method of usage. Modality usage. Modality overview diagram presented in Figure 78: Overview of modality interaction and its shift

Figure 79 demonstrates contributing factors of modality shift, identified throughout this study as-

1. Studio Culture and Designers' Background and Individual Style.
2. Designers' Competency and Experience over Multiple Modalities.
3. Designers' Experience and Perceptive/Cognitive Ability.
4. Project type, Studio Instructions and Design Context.
5. Designers' Knowledge and Exposure on Design Processes and Methods.
6. Modality Attributes and its Interaction with Design Externalization.

These factors determines how modality is being used, manipulated and mixed as well as the extent of its use. Most importantly appropriate uses of each modality's capabilities may influence design activities and the learning performance.

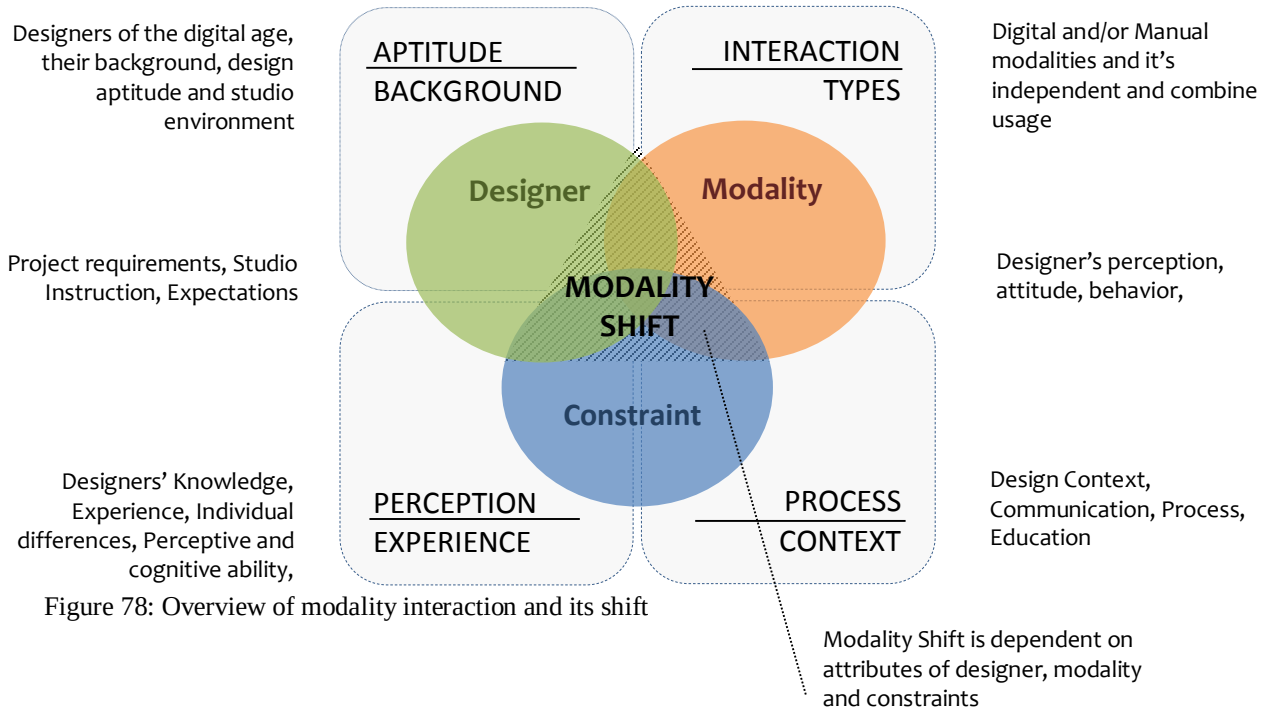

Figure 78: Overview of modality interaction and its shift

Figure 79: Overview of modality interaction and its shift

Modalities and method (of application) should have an integral relationship (Ross & Morrison, 1989; Winn, 1989; Kozma, 1991) for effective analysis and externalization of design thoughts. Capabilities of modalities facilitate methods of externalization that designers can take advantages of. Switching and mixing modalities can provide designer with powerful new methods. Students' competency on both design process and modalities help them selecting appropriate modalities for each phase of design process. However, it was identified in this study that students tend to switch modalities at higher rate when they have less knowledge over modalities (both digital and manual). By selecting suitable modalities that the designer has adequate knowledge on, one can take advantage of that particular medium's full capabilities. Each medium used by designers can be defined and distinguished from others by its delivered characteristics. A particular medium's capabilities can be described to develop specific representations and perform certain design tasks. By adapting and reforming the process of design externalization along with conventional practice of using media a more productive approach would be available to experience the design process as a dynamic, creative interaction. In Schon's term (1987)—factors those shape design and get shaped revolves between the designer, the design problem, and the medium of interaction.

Capabilities, features and constraints of both designers and their media also motivate designers to think and produce creative and indigenous solutions. Modality in this cases provide designers with resources and suggest things that could be done with them. Findings of this study suggest that students were constant in assessing their selection and assimilation of architectural design modality only when they acquire

sufficient knowledge and skill on design process and representational media. It is hard to compare as the capabilities of media is consistently changing and improving with the advancement of technology. At the same time these new modalities are changing the way designers interact with media and eventually enabling arguably more powerful design solutions that often than not emerged from the interactions and overlaps of multiple modalities.

The design process is mostly iterative and conversational between designer's thoughts and various externalizations as drawings and sketches. Designers' individual styles, exposure, interests and influences of the digital age that they are form has an inevitable impact of their thoughts. Many previous studies proved that drawings, sketches and other form of externalizations are invaluable factor in this process. But, the advancement of digital tools and means of creating and visualizing form and spaces as well as various augmented and interactive application attract modern design students to depend heavily on digital modalities. However, much similar to findings form the studies conducted decade earlier a large portion of the students (51% strongly and 37% moderately) in this study agreed that sketching had been very helpful for ideation as well as an important activity to start the design process before moving on to CAAD. Designers develop new ideas as well as verify initial (or previous) ideas using a number of design and drawing tools or modalities which also serves as inspiration for generating new ideas. Designers' knowledge and corresponding functional references- in articulation with design drawings shapes and advances design process. Drawings not only act as a vehicle to externalize concepts but also provide visual feedback.

Constrains on understanding and manipulating modality interactions is another attribute that led designer to switch between modalities inappropriately. It was more than often observed during this study that novice design students started with highly ambitious concepts but failed to transform their abstract thoughts to a tangible from and space only due to their lack of experience and expertise on multiple modalities. Designers' own reasoning behind using various visual elements confirms its functional references that is developed through visual artifacts and drawings. Functional references and (re)interpretation obtained through drawings, sketches and images provide functional and perceptual feedback to move forward the design process. Design drawings developed by these studio students connects initial stage of design to its present stage that let students compare, relate and reflect back to improve the thinking process. Using and mixing different modalities (media, tools and drawings types which are not specific to digital or manual as this study is referring it as modality) help designers to manipulate and perceive various aspects of design- never experienced before, get holistic view or supplemental perspectives of formal and spatial attributes of the design. Sketches and free hand drawings are the media that converse with designers at rudimentary level, scaled orthographic projections are more concretized depictions that register cognitively rich and accurate representation of the design. CAD drawings are much similar to its manually produced counterparts when presentation media is same, for example- paper. However, the way digital media interacts with designers and how the interactions benefit in accumulating design knowledge are different from manual representation so as the visual reasoning process.

Studio instructions, instructor's preferences, peer pressure, predominating trends and styles of a studio environment specifically on presentation and such also plays a crucial role of students' selection of modalities. Successful integration of computer system as a design tool as well as a drawing tool depends largely on how it is being addressed and introduced into architectural design and theory. At the same time a balanced assimilation of traditional means of drawings is equally important. Schenk's (2005) study on teaching design and drawings in the digital age addressed that -- 'students should be able to envisage ideas and communicate through traditional means of drawing'. A panel of senior educators in the same study believed that -- students have to be able to imagine and conceptualize clearly before moving into the digital media and that gaining experience of traditional drawing methods was the best way to achieve this.'

With respect to this claim, it benefited students to develop their own personal approaches, and then learn how to use drawing appropriately for professional practice (Schenk, 2005). Design curricula should apply more attention to the classic forms of drawings with purposeful integration of computing media as an integral part of the drawing curriculum not the opposite (Schenk, 2005).

CHAPTER SIX: CONCLUSION

Concluding remarks based on findings and its interpretation are discussed in this chapter through implications of this research, recommendations, limitations and further research directions.

6.1 Implication of the Study

Design students learn a number of design and drawing tools during their architectural design education. Insufficient integration and interoperability between modalities are identified in this study. Design students, especially at the early stages struggle due to this fragmentation. However, no significant correlation was observed between CAD knowledge and resulting hindrance on administrating design tasks. The process of how and when digital modality is being integrated in design education appears to be more important. Most studio curriculum rarely discuss the issues of media integration in design despite the fact that modality and its integration can contribute to successful ideation, perception, formulation and documentation of successful solution of design problem.

Designers at this digital age are familiar with computer system as it became an integral part of everyday life as social phenomena. Students often improvise and implement various digital tools in studio context which indirectly materializes new skills and tradition for design communication and ideation. As drawings are designer's main visual language or medium to perform any design process; to be efficient- one must be

comfortable with methods or styles those suit his/her own thinking. Design process drawings are comprises of complemented sets of abstract and concrete drawings therefore designer need to be effective visual thinker who is flexible enough to move back and forth within various types of drawings. To envisage ideas and to materialize, then to communicate those properly- most of the samples in this study believed that they have to be competent with multiple modality and hybrid drawing approaches. Before moving into digital media students should have a clear conception about forthcoming steps of design process. Experience of traditional drawing methods are proven to be best mean to achieve this.

Students in both studios have used a number of CAAD software as SketchUp, Photoshop, AutoCAD and Revit Architecture and such. Since project requirements stated only a list of presentation drawings without any specific direction of media to use students have developed various personal working methods on combining modalities. On this regard it was identified that this tendency of mixing is increasing among present design students similar to the study of Breen (2004) which however brings diversity and interactivity. Therefore, the change includes various shifts in design media, visual thinking and design teaching theory. These modality shifts extends beyond the types of computational applications to embrace designers' personal methods of integration and connotation between digital and traditional media, 2d and 3d format or any other combination of media that supports designer in (re)structuring and (re)interpreting concept.

This study identified a theory that explains what causes students to switch between design modalities. A number of factors such as, students' knowledge over design and drafting tools, creativity and ability to improvise, improvisation level of cognition, understanding of design process and methods directed by the design problem (studio project), individual's background and studio environment and culture. Many of these components contributes to the design process independently and with combination of one or more. This theory shows how design modalities are manipulated in the realm of design studio education and outlines the interaction between all those factors and successful execution of design process in design studio.

This study indicates that there are two major perspectives concerning media representation and modality usage. To facilitate unorthodox design methodologies and materialize design decisions appropriate media interaction is necessary. Deliberate interaction and manipulation between modalities offer new perspectives for form and design solutions that necessarily was not available with traditional media alone. Secondly, from representation point of view- in conjunction with analogue representation digital modalities displays strong capabilities to develop tectonic and formal articulations thus produces high level of design development in all areas associated with design. Designers communicate through the language of drawings and drawings are immensely dependent on the modality it is developed with. Hence, it is apparent that design modalities must be considered as an integral part as function, aesthetics, structure and various psychological aspects of human experience.

This study identifies how manual and digital modalities are iterated by experienced and novice design student in studio setting. Media iterations are more frequent during early design stages and become more settled when it is in development phase. In most cases, designers switches their modalities during final stages only for representation needs or if any major discrepancy or flaw is identified.

The study indicates several reasoning for shifting modalities. Every designer has his/her comfort zone. When expectations become high or circumstances get stressful designers tends to lean toward the modalities (digital or manual) they deem comfortable and competent with. Senior students with considerable level of experience with multiple modalities understandably possess more tools in their disposal to switch within and get benefit from it by projecting new perspectives of critical design issues. This also helps them to develop a number of design alternatives regardless of their own creative ability. However, learning new tools alone without putting those in constant practice is not sufficient to generate workable design solutions. In media interaction paradigm experienced or senior students with knowledge on diversified design tools are more likely to improve and strengthen their design solutions by incorporate multiple modalities because each design and drafting tool has its own strength that can balance the weakness of the other.

6.2 Recommendation for educators: Hybrid media approach and related pedagogy.

One of the major focus of design pedagogy is nurturing and developing student's own design techniques and thematic concerns pertaining to visual style appropriate for conducting design process. CAD applications are indispensable and no longer an optional tool for designers. At the same time hand drawings helps to captivate our imagination and provide visual and conceptual purity.

In contemporary design studio a very little instructions is delivered on concepts and procedures about interface and interactions between manual and digital modalities. Unfortunately there are no constituted knowledge regarding modality iteration paradigm in architectural design education and its profession. Lack of knowledge about these connection culminates in superficial, unworthy and weak representation of thoughts and design execution. Multiple iteration and intriguing application of different modalities have shown noticeable improvement on techniques and methodologies of design process.

There is a predisposition among early design students to work within one media or other instead of interpolating media. One of the major reason for this could be novice designers' incompetency and inexperience with design process and modalities which restricts them to realize the useful benefits of media iteration paradigm. Going back and forth between modalities initially requires great deal of guidance and effort from the instructors and students themselves which considerably reduces as designers get accustomed and competent with the process that starts with building skills in multiple

media. Unskilled students with either manual or digital media innately feel comfortable with the one they are most conversant. Without proper instruction these novice designers remain low in confidence and desire to explore their modalities therefore practice low levels of application of interactive design process. Previous studies implied that by providing *i)* step by step instruction, *ii)* introducing media iteration early in curriculum, *iii)* comprehensive pedagogical interaction and *iv)* ensuring competitive yet collaborative studio environment to accelerate learning curve.

Design pedagogy in the realm of modality interaction and communication should focus on knowledge regarding techniques before content. It is proven in several studies that- for activities requiring higher cognitive level and learning skills (such as conducting design process) content independent learning deem pedagogically inappropriate. Further approval of this thought is stated by Bermudez (1997a) ‘‘the architectural practice and education of tomorrow is not ahead in the digital but between the analog and the digital; and not in one medium/approach but in many media/ approaches’’.

6.3 Limitations of the Study

There are some limitation in this study. First of all the number of case study this study observed are only two design studios which rendered some difficulties to generalize common theme from findings. Two design studios were selected based on students’ exposure and experience with design education, process and aptitude on design modalities. The findings could be different if this study included different geographical locations for diverse culture and background, inclusion of more design studios with

different studio environment and curriculum with different focus and pedagogy with different notions. This could bring some different phenomena from those identified in this study.

All-inclusiveness is the second limitation. Unlike protocol studies this study followed extensive observation of design studio for richer and comprehensive understanding of students' design process and their selection and shift of modality along the way. The act of design is highly cognitive and mostly happens in designers' mind, hence it is impossible to completely track every development by observing designers' activity graphically, behaviorally and physically. Cause and intension of many design activity are unknown to designers themselves since design thinking continues without interruption in designer subconscious mind even when they are out of their design studios. This makes a tracing the process utterly difficult. Frequent conversation and personal note were kept to overcome this limitation to some degree.

At the end, the goal of this study was to understand designers' reasoning behind selecting and switching design and drawings tools or media rather than generalizing findings into some conclusions. Even though there are numerous studies those investigated and compared both digital and manual media independently, a little to no theory is available explaining reasons behind modality (design and drafting tools and media) selection, switch and its effect on design process. By identifying factors those motivate selection and trigger shifts, this study contributes by proving knowledge on appropriate selection of modalities during various stages of design process. Also, a comprehensive understanding of synthesizing modality will help students to benefit their

design process by developing alternative and new perspectives of design problem in hand.

6.4 Future Research Directions

First, a study of design process in the realm of multimodal iteration involving both novice and experienced design students as well as graduate students would be beneficial for architectural design education. A critical review of contemporary undergraduate and graduate design studio project focusing use of modality in design process may reveal some unknown facts regarding the effectiveness of multiple modality in design education and practice.

Second, integration of new concepts as Evidence Based, Building Information Modeling and Building Performance Analysis into multimodal design studio may develop new direction toward Informed Design to promote more sustainable and successful design process. By investigating each of these concepts within traditional design studio researcher would be able to understand and identify a mean to develop a sustainable and comprehensive hybrid design process.

Third, an extensive study on relationships among modality preference and individual difference as demographic, cultural, academic, cognitive ability would distinctly identify contributing factors on preference and corresponding shortcomings. By understanding this relationship within the framework of universal design communication method we would be able to examine and conduct design process that may potentially assist cognitively challenged designers.

APPENDIX

APPENDIX A: CONSENT FORM

Consent form for Thesis Design Studio

Researcher‘s name: AKM Zahidul Islam
Researcher‘s contact information: 5735290127, azick4@mizzou.edu

Project title: Modality Shift in Design Process: Understanding the rationale behind modality shift and its effect on architectural design.

Greetings. I am a doctoral candidate at the Department of Architecture Studies at the University of Missouri, Columbia. I would like to ask you to participate in a research study. This study is to understand why, when and how design students change their design and drafting tools during the course of their whole design process in architectural design studio. As your participation will be highly appreciated, you are entitled to know about the procedures that will be used in this research study. You are free to make decision whether or not to participate. The information presented here is an effort to make you better informed so that you may give or withhold your consent to participate in this research study. The focus of this study is to understand why modality (design and drafting tools and its media in different combinations) shift happens and what effects it has on their design process and final design outcome. Your participation in this study will include three areas: first, there will be a questionnaire survey; second, observations of your design studio activity for the whole semester and finally short individual interview. I will observe your design process, decision making and discussions with your instructor in studio regularly without any interference. I will take photograph of your notebook, sketchpad and design sheets as well as screenshots of your CAD works. After analyzing and interpreting your whole design process and survey responses, I will interview you individually regarding any further questions and verification (a 10 to 15 minutes of interview will help me to understand your perspective about switching design modalities, reasons behind your decisions in terms of design process and influence of modalities on your design. Your participation will benefit the development of architectural education by providing fundamental knowledge on design communication and modality use in architectural education. All data collected in this study will be kept confidential to the extent allowed by law. You will be assigned a number which will keep your identity anonymous. There will not be any academic grade points or incentive of any form for your participation.

Your participation in this study is completely voluntary. You do not have to participate in this study. If you decide to participate, you can change your mind and drop out of the study at any time. If you have any questions please call at 573-529-0127 or e-mail to azick4@mizzou.edu. You may also ask questions or state concerns to the University of

Missouri, Columbia Campus Institutional Review Board (IRB), at (573) 882-9585 (http://research.missouri.edu/cirb/). Please note that you may withdraw from the study at any point, without any prejudice.
Thank you very much for your participation.

AKM Zahidul Islam.

_____
Participant's Name

_____
Participant's Signature / Date

APPENDIX B: Category and Code Definition from Student Interview

Category	Code	Definition
Background	Studio experience	Numbers of studios students have taken.
	Frequency of computer use	Discussion related to students' behavior and usage of computers and digital tools
Experience	Known design/ drafting conventions and tools	Discussion related to students' experience with various modalities
	Competency with design methods and processes	Discussion on experience with acts of design, process and methods
	Lack of expertise with design modality	Discussion on how modality incompetency modified design formulation
Studio projects	Project type and duration	Discussion on project type directing students selection of modalities
	Project requirements	Discussion on project requirements directing students selection of modalities
	Presentation requirements	Discussion on presentation requirements directing students selection of modalities
	Emphasis on design modalities	Discussion related to emphasis
Perception	Perception and drawing types	Discussion regarding drawing types and their beneficial features
	Nature of studio instruction	Discussion on students' understanding on studio instructions and design requirements
	Design modality and cognition	Discussion on how selection of modalities aid design cognition
	Preferred visualization techniques	Discussion related to students' favorite visualization methods and techniques
	Modality types	Discussion related to features of multiple modality (manual, digital, combined)
Constraints	Preference	Discussion of students' preferred methods and tools to perform design task
	Conceptual transformation and design formulation	Discussion on hinderness regarding formulating and transforming concepts into tangible form and schematics
	Design ideation and transformation	Discussion regarding issues regarding forming and transforming concepts
Curriculum and studio culture	Courses regarding design and drafting tools	Discussion on courses that provide instruction on design externalization
	Courses taken related to design and drafting	Courses specifics that relating design externalization
	Preferred courses	Courses that student would prefer to take to improve their visualization techniques.
	Overall emphasis on design modalities in curriculum	Discussing regarding emphasis on design formulation, externalization and visualization relating to architectural design education.

APPENDIX C: Category and Code Definition from Observation

Category	Code	Definition
Type of modalities used	Manual	Various traditional, conventional drawing tools as pen, pencil, paper, charcoal, marker and other such media
	Digital	Various computer mediated design tools as Computer aided design applications, Graphics and video editing applications
	Mixed	Combination of manual and digital drawing tools, such as using non digital tools over computer print outs
Nature of modalities	Implicit	Type of modalities designers use to internalize and evaluate ambiguous ideas as a part of design thinking process
	Explicit	Type of modalities designers use to develop unambiguous and concrete from of design drawings
	Spontaneous	Usually a multimodal approach that combines different type of design and drafting tools
Reasons for changing modalities	Studio instructions	Instructor's emphasis on drawing types and use of tool set
	Studio Environment and culture	Overall tendency and studio culture regarding use of manual and digital modalities
	Competency	Student's ability to work with different design and drawings tools
	Cognition/ Focus	Focus of the studio project and students' cognitive level to comply with design problem
	Constraints / limitation	Constraints related to design ideation and transformation
Realm of Modality Shift	Design ideation	(Abstract) Idea generation or conceptual formation
	Conceptual transformation	Conceptual transformation of form and functions
	Form and geometry	Geometry and form of building
	Detail	Architectural details
	Exterior and façade	Outside and details of building elevation
	Interior and finish	Built environment and certain elements of the building
	Circulation, sequence and spatial organization	Sequence of movement and spatial experience in built environment
	Lighting	How lighting is added
	Material	Application of material and details of a specific and whole building
	Scale and proportion	Scale and proportion of built form and environment as a whole
	Presentation	Focus on preparing presentation board for submission and review
Purpose of drawings	Internalization	Expression of reflections, de-abstraction, experimentation and formalization of imagination

	Externalization	Types of design drawings, tangible diagrams and sketches produced to communicate with instructors and self-evaluation
	Documentation	Drawings developed specifically for presentation and documentation purpose
Design stages	Conceptual	Successful formation of abstract ideas to seek solutions for design problems in hand
	Development	Transforming abstract thoughts into tangible design documents to evaluate and communicate and further design improvement
	Presentation	Documenting and producing imagery and drawings using standard drawing conventions
Studio project	Emphasis on Design/ Drawing tools	Degree of emphasis on prescribed design and drafting tools
	Focus on project	Focus of the studio project and design modalities in observed studio
Effects of Modality Shift	Creativity	Achieving creative design solutions by adopting new design modality
	Integrity	Maintaining conceptual integrity throughout the whole design process
	Information loss	Amount of deviation and information loss due to switching between modalities
	Representation	Media, process and type of visual representation mediated by use of modality

APPENDIX D: Final Themes, Categories and Codes

By comparative analysis between two studios data gathered by qualitative (observation, design process photograph analysis and interview) and quantitative (questionnaire survey) data collection methods following final themes, categories and codes were developed.

Category	Sub category	Code
Students' characteristics	Background	Studio experience
		Frequency of computer
		Undergraduate major
	Relevant experience	Work experience
		Exposure and travel experience
Experience	Competency	Known design/ drafting conventions and tools
		Competency with design methods and processes
		Lack of expertise with design modality
	Other experience	Work experience
		Relevant studio experience
Curriculum	Courses	Courses regarding design and drafting tools
		Courses taken related to design and drafting
		Preferred courses
	Emphasis on curriculum (focused on design method, process and drawing)	Overall emphasis on design modalities in curriculum
Studio structure	Studio environment	Studio culture and overall ambience
		Motivation from instructor
	Studio project	Project type and duration
		Project requirements
		Presentation requirements
		Focus on project
		Emphasis on design modality
Perception	Modality types and level of cognition	Perception and drawing types
		Nature of studio instruction
		Design modality and cognition
		Preferred visualization techniques
		Modality types
	Inspirational artifacts	Preferred method of externalization
Modality	Types	Manual
		Digital
		mixed
	Nature	Implicit
		Explicit
		Spontaneous
	Reasons of shift	Studio instruction
		Studio culture and Overall ambiance

		Competency
		Cognition/ Focus
		Constraints / limitation
	Realm of shift	Design ideation
		Conceptual transformation
		Form and geometry
		Detail
		Exterior and façade
		Interior and finish
		Circulation, sequence and spatial organization
		Lighting
		Material
		Scale and proportion
		Presentation
	Effects of shift	Creativity
		Integrity
		Information loss
		Representation
	Purpose of drawings	Internalization
		Externalization
		Documentation
Design process	Design phases	Conceptual
		Development
		Presentation
	Constraints	Preferences
		Conceptual transformation
		Design ideation and representation

APPENDIX E: Questionnaire

Did knowledge on various media allow you to define the layout of your design?					
No change	Little	Slightly	Quite some	Radically	
Did multiple tools help represent your ideas?					
No change	Little	Slightly	Quite some	Radically	
Did using multiple media stimulate the creation of new ideas?					
No change	Little	Slightly	Quite some	Radically	
How do you usually start designing (after you have an abstract concept)?					
Mentally/ cognitive	Think-aloud	Pen & paper/ Sketches	Computer	Scaled drawings	Mixed media
To present design ideas what medium do you prefer?					
Text	Hand Sketches	Printouts/ Ink drawings	Renderings/ photograph	Computer model	Mixed media	Physical model
How would you like a design to be presented to you?					
Text	Hand Sketches	Printouts/ Ink drawings	Renderings/ photograph	Computer model	Mixed media	Physical model
Which manual drawing tool do you frequently use?					
Pencil	Marker	Drafting Pen	Charcoal	Paint & brush	Color Pencil	Other
Have you completed a design entirely using computer only?					
Yes			No		
During design can you perceive the size and scale of the space/form?					
Not at all	Somewhat	Fairly	Well	Very Well	
How well do you relate your design to the program and context?					
Not at all	Somewhat	Fairly	Well	Very Well	
What modality helped you most to stimulate spatial impression of your design?					
Mostly Digital		Mostly Manual		Mixed	Random
Did the medium stimulates creativity and generate alternatives?					
Not at all	Somewhat	Fairly	Well	Very Well	
Did the medium aid/ enhance your idea representation/ visualization?					
Not at all	Somewhat	Fairly	Well	Very Well	
Which medium allowed you to easily evaluate solution to the design problems?					
Digital		Manual		Mixed/ hybrid	Other
Which medium allowed you to develop design alternatives?					
Digital		Manual		Mixed/ hybrid	Other
Do you generally use the same medium for similar design task?					
NO	Rarely	Sometimes	Most of the times		Always
Do you think mixing design tools affect the way you express or develop new ideas- in comparison to traditional or digital media alone?					
Not at all	Somewhat	Fairly	Very well	Extremely	
When have you used any CAD program for the first time?					
University	High school	Training Courses		Other	
How do you evaluate your computer skill?					
Excellent		Moderate		Low	

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