Application of Technology in the Architectural Design Process

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Abstract; Designers draw diagrams for contemplation about architectural ideas and design relationships. On the other hand, scientists and computer engineers are also interested in designing and programming computers for the recognition and interpretation of diagrams and architectural drawings. To this goal, some researchers make empirical studies to see whether designers exchange deign laws and principles or not.
Fast technological developments urge us toward the development of computerized design environments which can also utilize creativity in architectural design and lead to introducing programs that use diagrams and free-hand sketches as sources for designing. In addition, they can revive visual referents for a creative design, causing a revolution in training for architecture. The issue can be of potential architectural research as it is now for some overseas.

Key-words; technology – the process of architectural design– diagrams and sketches– design tools– the empirical study of diagrams and sketches– architecture design software

Introduction

 In recent years, because of the application of information technology, we have witnessed great developments in architecture design. Novel tools enable architects to draw with high precision and speed. Computers have offered huge growth and development to architecture design. Computer Aided Design (CAD) is also another trophy gained. CAD has also been of help to Computer Aided Drafting and map-making. The importance of this software lies in helping the architect with designing empirically with his/her ideas to reach a solution. But actually what happens when the designer is busy doing this? In other words, has the software been able to meet the architects' needs?

The fundamental question is whether computers can ease the dialogue between the architect and his/her ideas.

On the other hand, to convey messages, an architect uses different tools and media when designing conceptually. What proportion of his/her knowledge is lost?

Can technology act as a bridge between image similarities and numerical models? Or even between two-dimensional and three-dimensional designs?
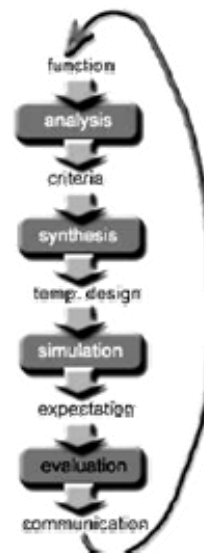
Can new tools increase the efficiency of architecture design? In this article, we have shown that the answer to this question is yes. There exist some potentials in the new technology that can, not only better fulfill the needs of architects through advanced tools in the course of conceptual design, but also improve their designing skills.

The ultimate goal is to improve the designing skills of architects, and to reach it, first we have to understand what relations exist between our goal

and technology, and then to know what projects are being worked on in this regard. Afterwards, we have to know how architects work in the course of conceptual design process.

In the end, we have to realize what new tools and advances can be offered to architects by technology. It goes without saying that it is not going to be possible to answer all those questions, but we can work out a portion of them. The main question of the research may be, "How can technology improve the architects' skills when designing in the conceptual design process?"

Anyway technology is approaching us demanding to be best utilized. The primary models and maps in the design process often depend on the following logical sequence of 1- "analysis and composition", and "assessment." Fig.1 shows the general cycle of designing according to Roozenburg (Roozenburg, N., and Eekels, J., "Product design: fundamentals and methods", 1995). It is to be said that reality is much more complex than it seems and the past research methods for studying architects' design process included the following:

- interview with designers
- observation, note-taking, and case study
- conventional studies (which mostly concern unrealistic projects because of the difficult terms of the contract)
- controlled tests (which are taken under controlled management or in lab conditions and concern a specific case, the pertaining information about which are recorded and analyzed)
- simulation tests (to visualize human thoughts by means of technology)
- theoretical analysis of thoughts (concerning the essence of design thought) (Nigel Cross, N., "Research in design thinking",1991)

These are valuable guidelines aiding us in understanding the nature of designing and extending our research scope concerning new tools to support conceptual designing.

Empirical Studies of Design Diagrams

In initial tests for identifying the relationship between graphics and design thought, 62 designs were managed and led (Do, 1995) and this was done by diagrams and stories (on the basis of aiding program of Archie) (Zimring, 1995, Kolodner, Domeshek, 1992). The designers were asked to:

1. prepare diagrams from the presented stories
2. write down stories from presented diagrams
3. create stories and diagrams from presented topics
4. have some explanation and interpretation of the diagram and story presented on the basis of Archie program.

This test revealed that:

1. designers when confronted by different design topics,

make use of similar conventional drawings (Fig.2 shows symbols designers use for the sun, human, and the theme of light.)

2. designers prefer to use safe and complete images for conveying the concepts of their different designs.

3. the key-words from the stories are used as the most important points in diagrams and the other way round.

4. designer were able to understand other designers' diagrams

Of course, Do's survey just contains the study of the diagrams created from the descriptions of designers in a serious design program. Therefore, this new experience of designing was conducted to make sure that these findings can be closely related to what is really done (Do, 1997).
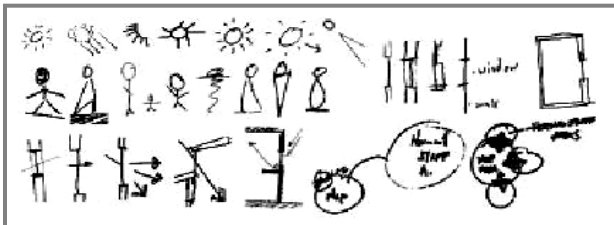

Figure 2- Designers use conventional symbols (concerning architecture concepts) in diagrams.

Three designers (one instructor and two students) participated in the experiment. Do gave the invited designers design planning notebooks and filmed the process of design. A separate individual also jotted down his observations.

The design plan defined the site dimensions and functions (70*25 ft, including a bathroom, kitchen, meeting room, map-making and computer areas, designing area, etc.)

The experiment included four tasks each of which focusing on a specific area. After reading the plan, the designers were asked to present their designs on a white sheet focusing on one of the different themes:

1. presenting the details of different spaces
2. considering lighting and light-related issues
3. visual views, public and private spaces
4. considering an area for a large conference table and designing a space for the designers to work

Drawing Principles and Design Themes

From design experiences, one can understand that designers share the drawing principles with one another, not only when they are drawing the relevant diagrams but also through the design process.

When acquainted with these principles, we can deal with three important findings that affect designing computer software:

* Designers Use Graphic Symbols and Words When Designing

Based on the studies done and past experience, it can be concluded that designers classify the graphic shapes and symbols for creating architectural compositions. Also, they use letters and words for identifying architectural concepts. They use simple geometric shapes like a circle and lines and combine them using fixed principles (For example, they use parallel lines to show walls and windows, or they use an arrow and an "N" to mean "the north.")

We also understood that some irrelevant words are also used (e.g.

labels identifying spaces, or the word "enter" instead of an arrow)

Figure 3- Designers follow some principles in drawings, e.g. shapes and letters

Showing Desires Concerning Architectural Concepts

Designers present their desires in plans, façades, etc., using diagrams to present different concepts, e.g. plan details, lighting, visual views, measuring, etc.

They use plan view to define relationships between different spaces, and sections to show the direction of light and vertical relationships. It is important that they sometimes use circles to show the importance of details, photo-refining or they may present explanations for views.
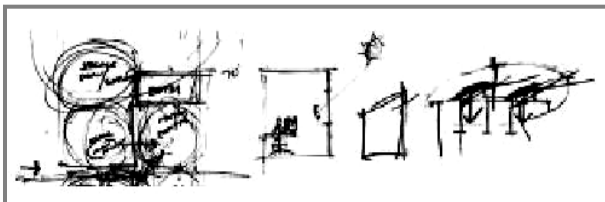
Figure 4- Designers present different concepts through drawing.

Clarifying Design Backgrounds Using Measurements and Furniture

In addition to the above-mentioned points, it is also understood that designers use architecture symbols like measurements and furniture to keep design themes in mind.

When setting furniture and objects in different spaces with specific measurements, designers write measurements around the design to have a picture of areas in mind and

also convey them to or exchange them with others.

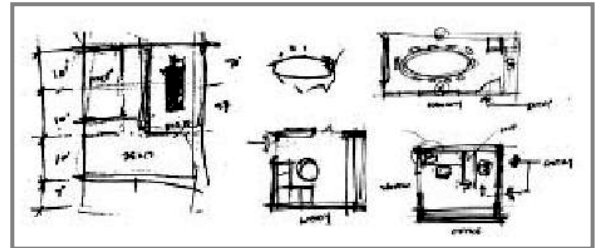In Figure 5, it is seen how the designer has marked his design with numbers to calculate areas.

Fig. 5 – Showing measurements in the design process

When thinking about function spaces, designers show simple shapes as furniture and by the background they design around them, record them in mind.

For example, when defining a space for a conference table, they draw chairs around it to make sure the area is big enough for the purpose. Furthermore, to reach proper spaces, the designer draws doors, windows in walls and sanitary services.

The Presence of Technology in Architecture Practices

Digital technology has also found its way through traditional architecture. It provides the possibility for architects to improve and extend architecture processes. Using them enables architects to attract their clients' attention toward different processes of design by collecting project-related data; architects can use their expertise in digital technology to empower probability and planning managements for controlling the expenses. Designing includes different concepts presenting high values, and has a novel scope with origins in the past. In addition, during the formation of a design, technology can fix the position of the

project by proving its success in controlling the costs, lowering the risks and presenting the visual data. Information, flowing from design to organization, is of critical position; but when controlled effectively, provides the grounds for the related design and implementation of other quick projects by offering methods for the betterment of the procedure.

In 1987, Yannis Bakos and Spiro N. Pollalis in "A framework for the design process," suggested a three-stage model of design stages with the aim of creating viewpoints which make design processes understandable and probably empower the previous technologies. According to this model, design processes include conceptual design, design improvement and structural design. Technology, by offering numerous software solutions, tools, and hardware services, stresses the two stages of design. But we have a long way to go to know about all potentials technology can offer.

Moreover, software companies escape from investing in the improvement of tools and requirements of conceptual design because design in such a dual scope is ambiguous and experimental and it is very difficult to change it to calculated models and imposing principles on it in the process of idea creation when a separating factor should also be involved.

Designing is one of the most neutral and invisible but challenging and admirable efforts of human thought which can also be considered one of the most incomprehensible ones. As mentioned many times, it is not precisely a science nor an art; but a combination of both. The design process is quite unlimited with no specific start or end. One cannot clearly define problems and solutions

or differentiate them. On top of all, because every solution has both positive and negative impacts, no one can offer the correct solution, and only the best one is applied. (Refer to "Design Thought in Architecture" by Dr Yousef Gorji and Mehdi Khakzand, Housing and Revolution Quarterly, Vol. 108, winter 2005.)

Why Do Computers Need to Comprehend Design Diagrams?
Diagrams play an important role in design practices. Designers draw diagrams to discover new ideas and find solutions at the beginning of conceptual designing. They use diagrams as forms of thinking about design themes (Laseau, 1980) and to record ideas (Graves, 1977). Maybe they consider it impossible to think without a pen!(Lawson, 1994). They should be in a back and forth relationship with designing (Herbert, 1993). Many researchers in the field suggest the relationship between design drawings and thought. They believe that design drawings and verbal conventions are inter-related (Eastman, 1968) and are complements (Akins, Lin, 1995). In their drawings, designers see data through which they refine ideas (Suwu, Tversky, 1996).

They start moving after seeing (Schon and Wiggins, 1992), and in this process, they are helped by visual judgments. Many computer aiding systems (by offering samples and suggestions) have come to existence to support our designs. One of the problems with these systems is that they are not capable of recognizing design environments in accordance with offered suggestions and advice. The diagrams used by designers in the first stages of conceptual designing seem to present design themes well and fall into the framework of calculation.

In the following parts which deal with the study of diagrams in brief, we will survey new studies on designing and their relationships with computerized systems.

Computer Calculations Concerning Drawings and Diagrams in Architecture design

What does a computer program need, to support designers to think with diagrams? Based on the studies done, we believe that the following are favorable elements to support the calculations of thought with diagrams in architecture design which a computer system needs:

- A- information concerning free-hand drawings that are related to produced diagrams
- B- creating spatial relationships through different elements and transformation of diagrams
- C- knowing created patterns and their order in diagrams
- D- conducting processes that change one diagram into another one
- E- showing designs and details of diagrams (Cross, 1996) in different levels

Here is an explanation on each:

- A- The most important discussion here is that architects love to use free-hand drawings and they often think with a pencil in hand. Drawing diagrams helps the design to focus on reachable issues and study different parts of design. Taking diagram data into computer programs is not that difficult. After the designer created his/her free-hand and even disorganized diagrams, he/she can draw the complete and beautiful diagram using a pencil, even much more beautifully than a printer does. Paul Laseau(1986) suggests the making of diagrams with an organized drawing plan based on time. He says, "A simple diagram that can be drawn with a pencil in a few seconds, can take a few minutes to be drawn by an organized computer drawing program."
- B- The diagrams a designer draws show elements and spatial relationships. A computer program should show both elements and spatial relationships and those spatial relationships strained to limitations.
- C- One of the characteristics of drawing diagrams that helps reaching the conclusion is helping the architect's eyes to get acquainted with recognizing patterns. These patterns are unknown because they are not drawn either intentionally or for obvious reasons, and are comprehended in the form of diagrams for the first time. A computerized system is to be able to recognize patterns in diagrams drawn by designers. According to Do, 1998, these systems should recognize even unknown patterns.
- D- A computerized system is to be capable of saving graphic changes of a diagram. A change necessarily means the emergence of a new graphic law, which is similar to what happens in syntax (Stiny, 1980). Changes even allow the system to reveal patterns concerning left-handedness and compare them with those of right-handedness.
- E- Sometimes, thinking with diagrams needs the comparison

between them to find similarities and differences; therefore, a computerized system is to be able to recognize the coordinate axes A and B and make one of them (which has fewer members) the sub-set of the other one. It must recognize different diagrams and compare them with one another.

F- In the end, a computerized system, which supports design diagrams, must be able to summarize diagrams at different levels; because diagrams in nature are summarized transcriptions of detailed physical forms. Therefore, any architecture design is summarized at different levels through different diagrams. A computerized system must be able to consider these summarizations and recognize them in diagrams.

Tools Aiding Architects in the Design Process

Architects have different expectations from the tools, media, and methods they use to start designing. Some feel more comfortable to "play" with physical three-dimensional models. Others are interested in general computerized forms. But most of them start with a simple sketch.

In all cases, this process is a creative personal one tolerating no limitation. Architectural sketches are subjective and have different functions, information and appearance. Designers "play" with shapes, architecture elements, forms, three-dimensional shapes, details, diagrams or side and sub-designs to achieve visual feeders and empower creativity.

The proper solutions they reach in this "hunt" are the numerous sketches they produce. Then, studying these sketches, they sometimes make unexpected discoveries, and see new relationships and compositions that suggest ways of correcting their ideas or making them finer (Suwa and Tverskey, 1996). Recent surveys have revealed that computers gradually become capable of gaining control over specific requirements necessary for designing and empower architects with newer and more advanced tools. Cross (Gross M., Yi-Luen Do, E., "Ambiguous intentions: a paper- like interface for creative design", 1996) has changed some of the requirements into the following:

1- necessary tools for designer/user to express subjective designs, ambiguities and emotional stimuli
2- necessary skill for a machine to be able to represent these qualities
3- ability of technology to show them and their interactions in the output

In this article we intend to find a technology which can be suggested for this purpose, to see what technologies are being surveyed in this respect, and where we can find a possibility to improve the situation and offer novel solutions.

Plans under Survey
A- Faculty of Industrial Design, University of Washington: Mark D. Gross , Ellen Yi , Leun Do
1- Digital Clay: extraction of numerical models from free-hand sketches
2- Drawing and Design Intention: surveying free-hand drawing principles
3- The Electronic Cocktail Napkin Project: a program which, by using

a pen and recognizing free-hand sketches, according to design environments, can guide the designer toward his/her goals

4- Gesture Modeling: a review of three-dimensional data guide framework
5- Sketch VR: a program capable of recognizing simple geometric shapes as two-dimensional images, using a pen
6- Space-maker: a program helping designers to touch the three-dimensional space while they are making two-dimensional drawings
7- Right Tool at the Right Time: this program has been created in a free-hand environment in which one can automatically use relevant symbols with simulation tools.

B- MIT University – The Workshop of Computer Science
   1- Sketch understanding: with the help of this program, one can extract the reasons and logic behind designing from sketches.

C- Innerhon University of Technology – The Workshop of Designing Information System
   1- DDDOOLz: this program enables designers to directly design their target spaces in a three-dimensional environment

without the interference of other systems
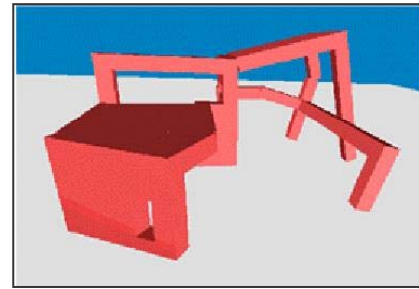
D- Fraunhofer Institute for Computer Graphics (IGD) in Darmstadt
1- ARCADE (Advance Realism CAD Environment): with this program, designers can directly draw three-dimensional shapes by CAD with hand and enter data in the CAD system.

Commercial Products
A- Autodesk Architectural Studio: this program greatly resembles architectural studios/workshops where they can search, experience, criticize and implement their design ideas by numerous manual tools.
B- Sketchup: a simple, fast but powerful program for producing presenting, relating and changing 3D designs
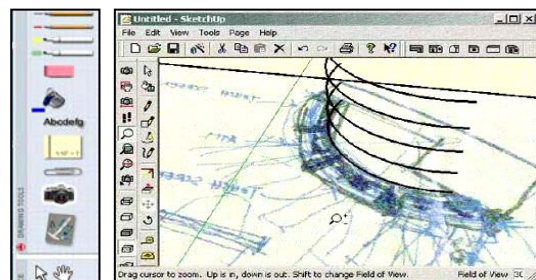
C- D-Board from Nemetschek: this program has separated its software from its hardware with the purpose of helping map-making and drawing. It includes a pen and a sensitive screen on which one can design using different pens and pencils and receive the designs through the software.

Fig.6- Technology: a medium for different patterns

Technology: A Bridge between Distances

Apart from preparing right suitable tools, technology should be able to create relationships between different tools and media and help a designer to stop waste of information. A designer can start his/her hand designs from a piece of paper and then transport them into a 3D modeling program to better see what he/she had in mind.

After imposing changes on images, he/she can again continue designing on paper, and of course again he/she needs the 3D modeling program, previously made images or images related to his/her work.

In any case, in different stages of design, technology can keep distances between 2D and 3D programs, sensory and numeric programs, or precise drawings and free-hand designs.

The Impact of Technology on Design Process

The impact of technology on design can be discussed from two viewpoints:

A- Efficiency: designing can be done faster, more easily and at lower costs. Computers greatly influence this aspect.

B- Betterment of quality: can technology improve the quality of design? The question may not be easily answered and we have to be quite conscious, though wise pondering reveals the fact that technological potentials decrease limitations because technology with the designer's help should make reformations in his/her work. For example, idea generation, improving imagination, inspiring the designer, making the designer feel safe to surf all options, experiencing different complex geometries, enriching the architect with required tools, managing and organizing plans in the design process and exchanging information and data with other designers. Thus, technology can strengthen design.

To prove right the claim that technology can cause the designer to design better, we should make a comparison between two architects with equal skills one of whom makes use of technology because an architect can be so creative that his/her design may seem even better than the other architect's created by the help of technology.

Empirical Studies on the Use of Technology in Designing and Drawing Diagrams

To recognize the relationships between drawing symbols (at different stages) using technology, an experiment was conducted by the writers of this article, with 15 designers and architects all of whom are the faculty members of board in the Faculty of Architecture and Urban Development at the Science and Industry University of Iran. The results are given below in the form of tables.

This experiment was conducted through a questionnaire and the questions are listed at the end of this article. The aim of this questionnaire was to answer questions posed at the beginning of this article. Questions 1 and 2 reveal that the majority of architecture instructors of the science and Industry University of Iran have understood and accepted the effect of computers in increasing the designing skills of architects in today's world. Answerers have also accepted and agree that computers can be effective in the process of conceptual design.

|	Very low	Low	Medium	High	Very high
Question 3	0	1	1	12	1

The table concerning question 3.
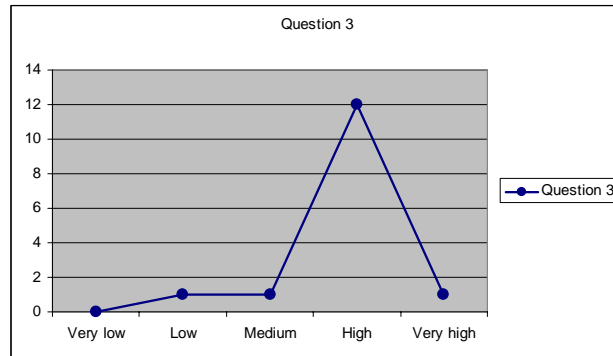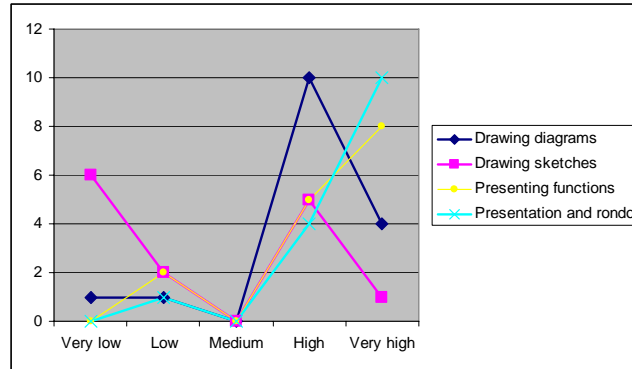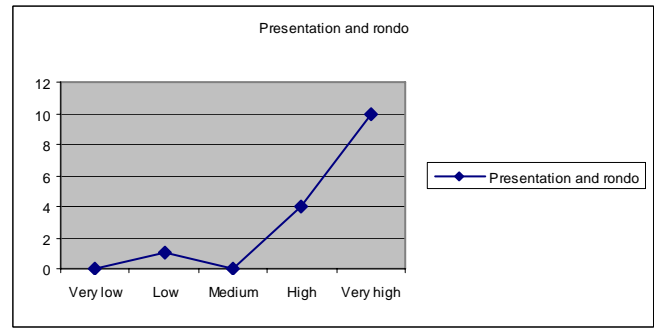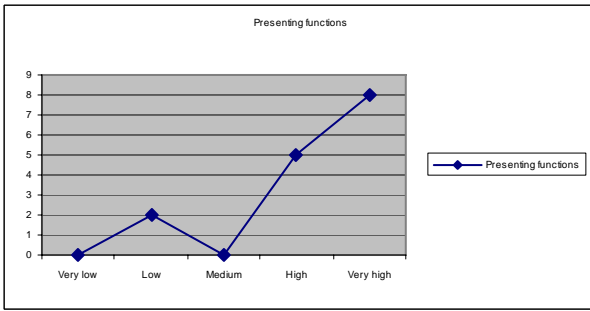

The diagram concerning question 3.

The diagrams concerning the answers provided for question 4 reveal how much architects use computers before entering the main stage of design, i.e. the conceptual design stage. Answerers believed that designers make the most use of computers before starting designing and sketching. So computers play the greatest role at this stage and help architects to present their ideas the best way possible.

In the next stage (i.e. before starting to design), computers can be of great help in showing functions and the instructors have also judged their influence as very high. Answerers believed that the skill of drawing diagrams by computers at the stage of conceptual design is high. It is interesting that they have evaluated the help of computers in drawing sketches as low or even nothing and diagrams show that computers are of little help in drawing sketches.

| Question 4	Very low	Low	Medium	High	Very high
Drawing diagrams	1	1	0	10	4
Drawing sketches	6	2	0	5	1
Presenting functions	0	2	0	5	8
Presentation and rondo	0	1	0	4	10

The table concerning question 4
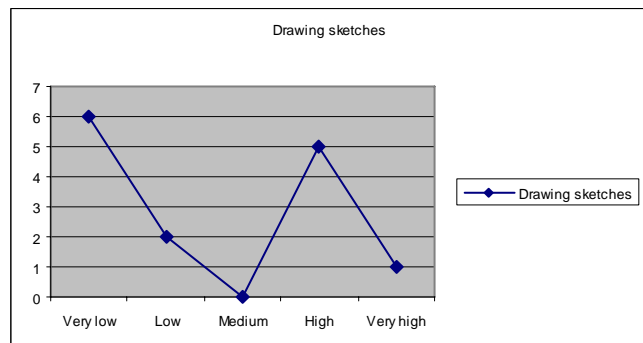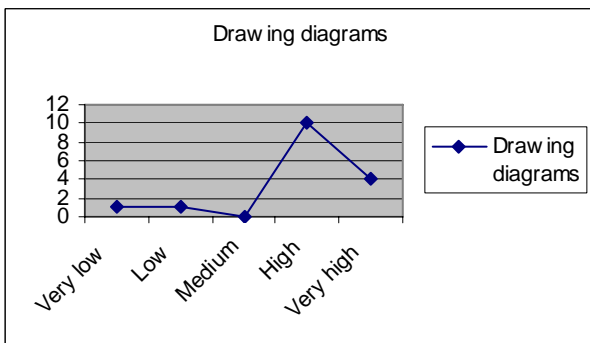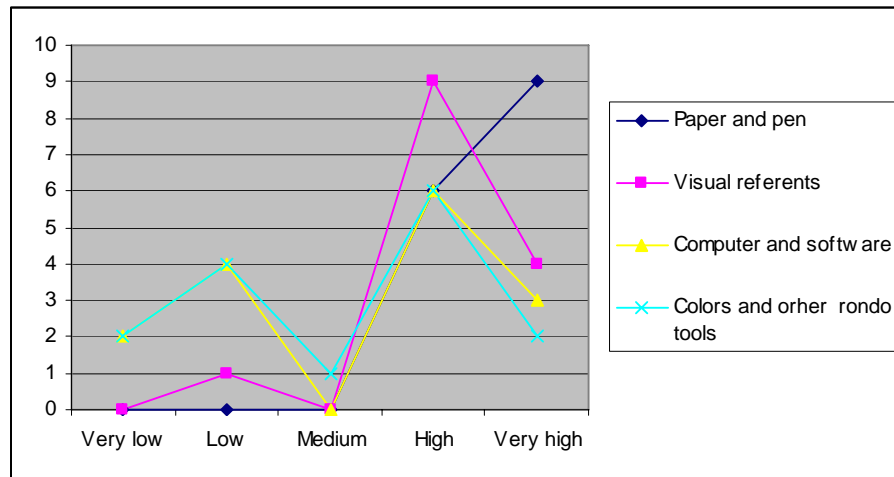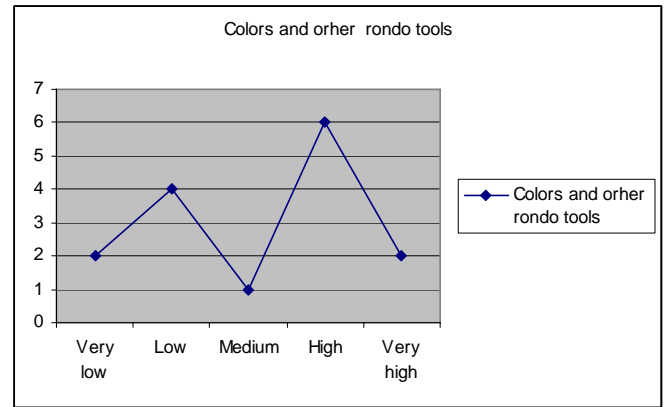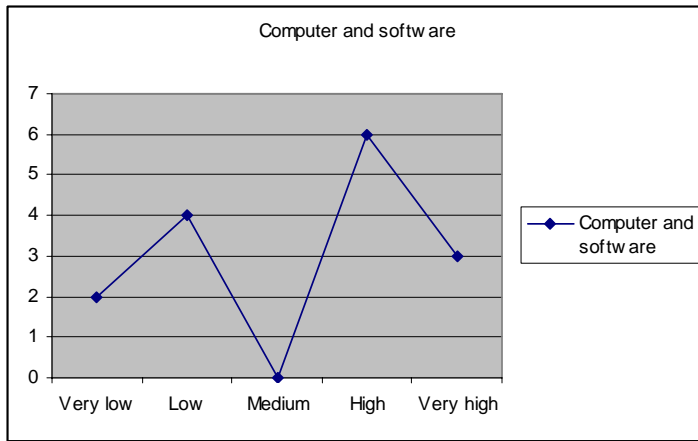
Diagrams concerning question 4

In the answer to question 5, according to the diagrams below, concerning how much designers and architects use tools and media, it can be generally concluded that paper and pencil are still of great importance (which proves Lowson's idea). The use of hand has the highest position in design and architects make the best use of it in conveying concepts and ideas. The results of this experiment showed that architect use paper and pencil quite a lot in the design process. After manual skill (i.e. the use of paper and pencil), the second important tool in media for architects are the "visual referents." Concerning visual referents, it has been proven that architects make a great use of them in making judgments to reach a conclusion. The next important use is of computers and software, colors and sketching tools. The instructors have also judged it high.

| Question 5	Very low	Low	Medium	High	Very high
Paper and pen	0	0	0	6	9
Visual referents	0	1	0	9	4
Computer and software	2	4	0	6	3
Colors and orher rondo tools	2	4	1	6	2

The table concerning question 5
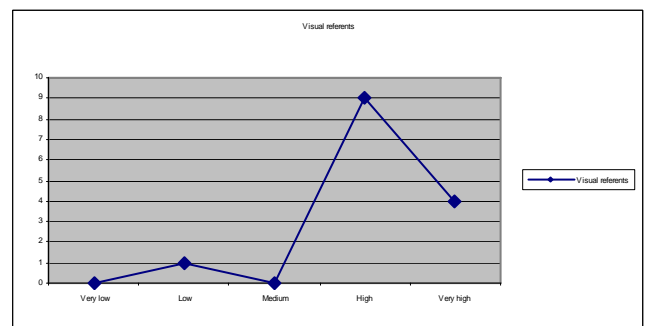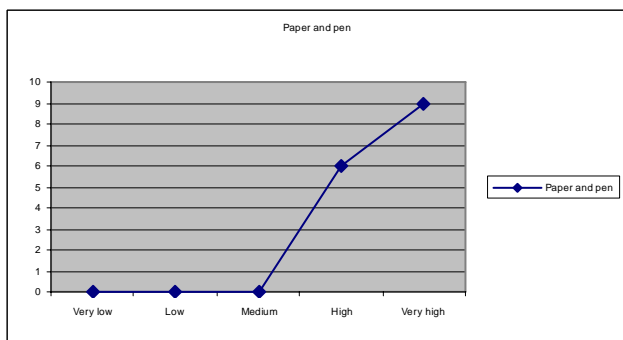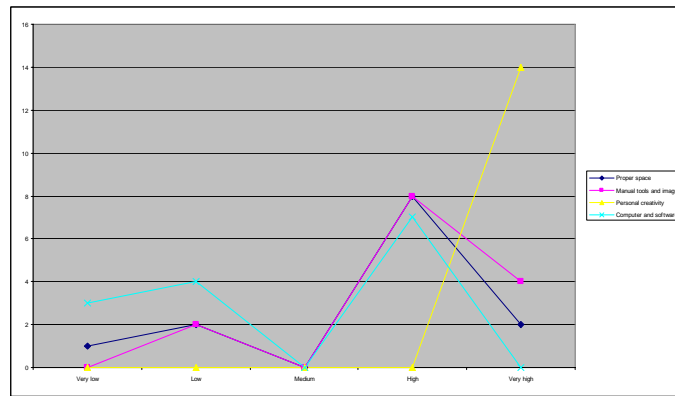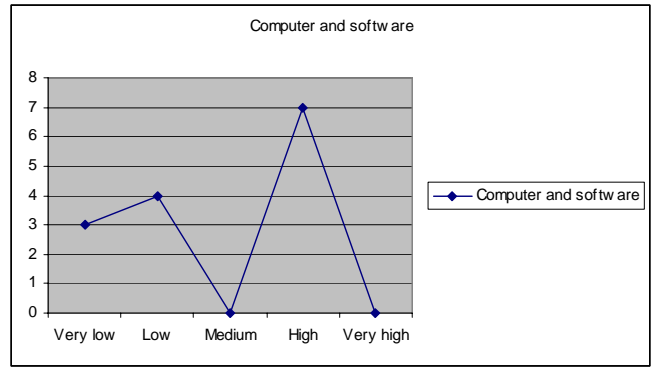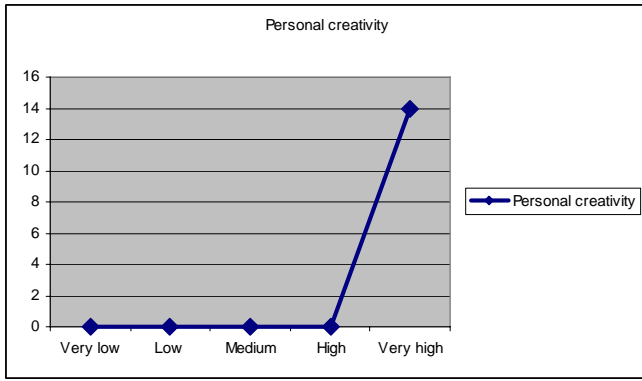
Diagrams concerning question 5

All who answered question 6 agree that one's creativity is the most important tool in increasing designer's power in the architecture design process. After personal creativity, proper spaces and manual and visual tools are great means in increasing the power of designers in architecture design. The instructors of Architecture Faculty have judged their effect as high, and after all this, half of the answerers have judged the effect of computers and software in empowering the designer as high. Other items have received lower points.

| Question 6	Very low	Low	Medium	High	Very high
Proper space	1	2	0	8	2
Manual tools and image	0	2	0	8	4
Personal creativity	0	0	0	0	14
Computer and software	3	4	0	7	0

The table concerning question 6
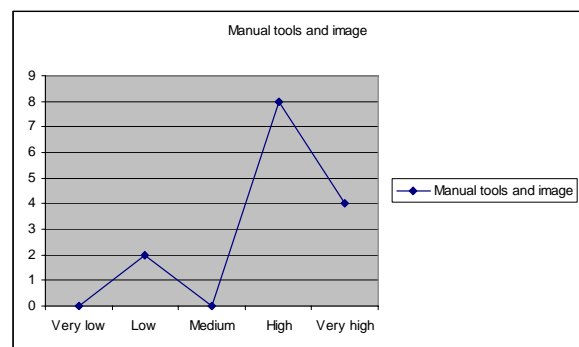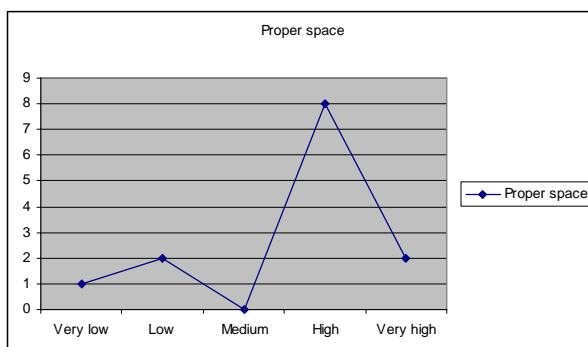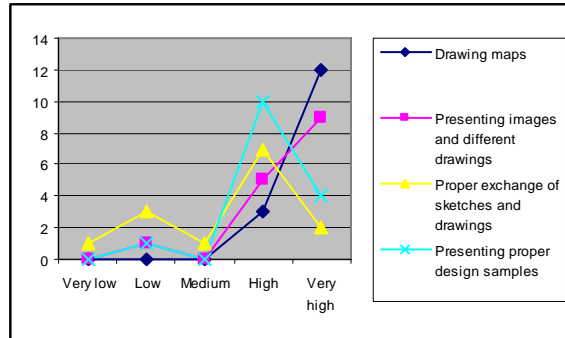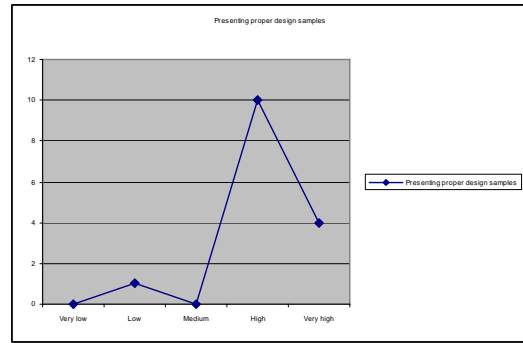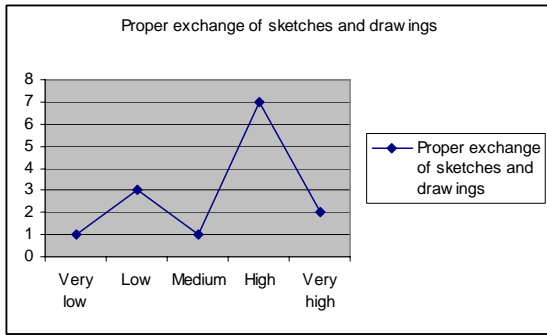
Diagrams concerning question 6

Almost all who have answered question 7 believe that computers give the greatest help in the design process in map-making. The majority of architecture instructors of Science and Industry University believe that computers give architects the greatest help in presenting images and different drawings in the design process. According to the diagrams below, it can be concluded that answerers have considered the greatest help given by computers in map-making, presenting images and different drawings, exchanging sketches and drawings, and finally, presenting design samples consecutively. It can be concluded from the answers that many instructors have not yet been acquainted with all aspects of working with computers and consider them the most important just in map-making.

| Question 7	Very low	Low	Medium	High	Very high
Drawing maps	0	0	0	3	12
Presenting images and different drawings	0	1	0	5	9
Proper exchange of sketches and drawings	1	3	1	7	2
Presenting proper design samples	0	1	0	10	4

The table concerning question 7
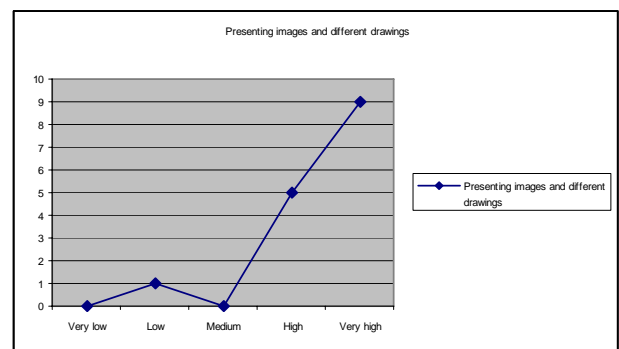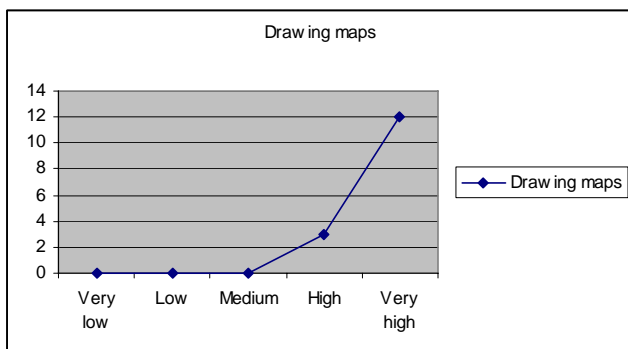
Diagrams concerning question 7

By analyzing the diagrams below which concern the answers to question 8, it can be concluded that all architects participating in the experiment as university instructors of architecture, consider the importance of the presence of computers in map-making, drawing diagrams and sketches consecutively, after the formation of concept design and when collecting ideas. And this means that our designers have not yet considered computers proper tools for collecting ideas or they do not consider computers capable of doing so.

Question 8	Very low	Low	Medium	High	Very high
When collecting ideas	2	4	0	6	2
When drawing maps	0	0	0	5	9
When drawing diagrams and sketches	0	1	1	8	4
Before the formation of concept design	0	1	0	7	6

The table concerning question 8
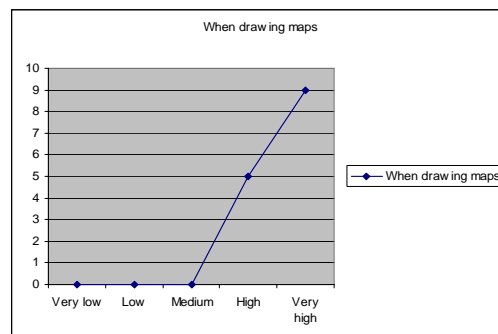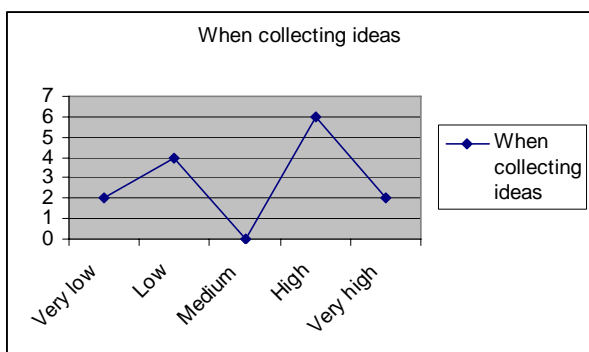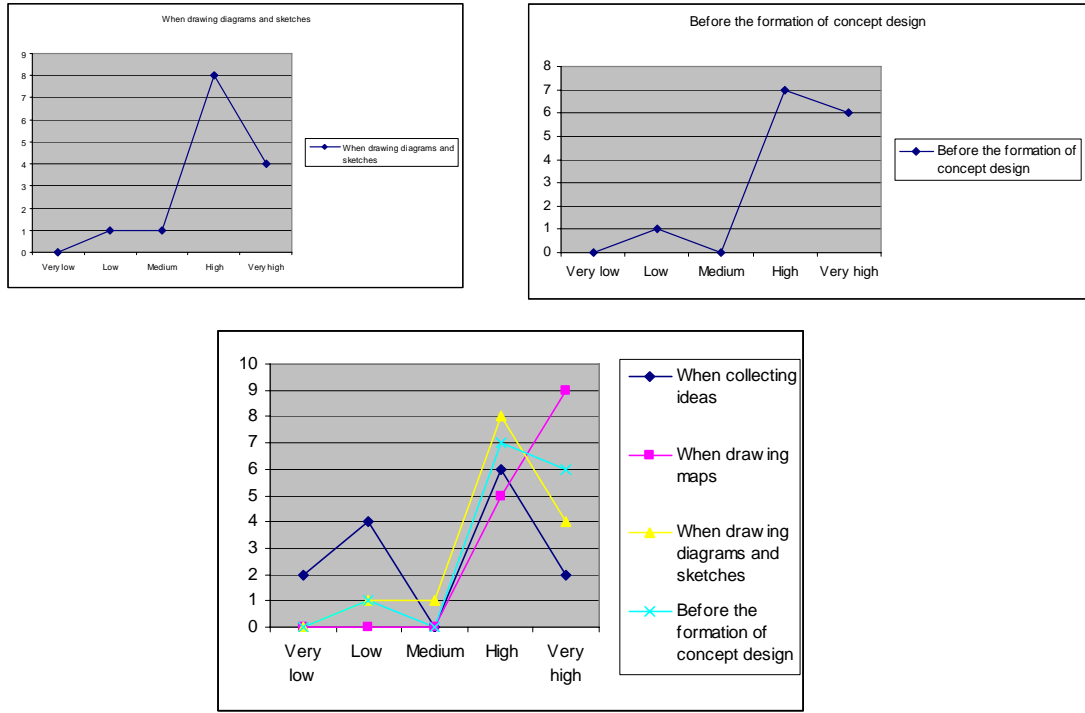
Diagrams concerning question 8

Conclusion and Summery

The local experiment not only reveals points about the present knowledge of our shortages, but also informs us about what is going on in the world concerning architects.

The test given to the faculty members of the Science and Industry University revealed that personal creativity is the most important tool in increasing the design power in the architecture design process which requires attention toward designers' creativity in the design process. It also points out that new software should be created with regard to personal creativity so that an architect can be better able to convey his/her thoughts. But unfortunately, software like CAD are not doing so.

Another point which architect are probably less involved in computer engineers in Iran are not so much interested in designing architecture software which is maybe due to the lack of financial funds. As a result, Iranian architects have only limited source of software at hand and

therefore, are not familiar with new software. Creating conditions in which

computer engineers together with architects can meet the needs with technology can be of great help to architects and designers.

On the other hand, our architects believe that computers provide the best help in drawing maps in the design process, which in turn reveals that paper and pencil, i.e. hands, still have the highest position through which architects convey and exchange ideas and concepts. Although this way may seem the handiest, in recent years, considering the latest theories in designing, architects cannot only depend on their hands, though of great skills, to convey their ideas. Creating many 3D shapes are not as easy as 2D ones and are mostly hard to draw without computers.

A point here is that not only are architects unaware of the present

advances in technology, but they are also unwilling to do so. As mentioned

above, technology is approaching us and we had better welcome it and accept the fact tat our world has enormously changed.

This experiment showed that architects are interested to reveal their ideas by hand. Today, technology helps them to use a pen to draw lines on digital screens and receive their organized results fast and easily. It means that instead of spending hours surfing in books to see samples, hundreds and thousands related images and designs are just the push of a bottom away. But unfortunately, our designers do not consider computers as tools helping them in getting and collecting ideas or they are not aware computers are capable of doing so. However, they have accepted that computers are most effective in conceptual designing or they might be saying so from what they have heard from others.

Many participants in this experiment have also judged the role of computers in increasing the capability of designers in drawing diagrams and sketches and believe that computers are mostly effective in drawing maps.

Among other things worth mentioning in the analysis and evaluation of this experiment, is the designers' approach toward technology. It is not suggested that newly arrived university students be asked to do their projects using computers but they, but from one point ahead, need to know better about computer science and software using them to improve their ideas and creativity and get familiar with new architectural theories in which computers are widely used. Students not using computers not only face a lot of problems during their studies, but

will not be efficient enough in their later careers. It goes without saying that they should primarily improve their manual skills and then work on their computer skills.

Computer should not just turn into tools to be superficially used in offering presentations and designs, which is unfortunately somehow the case in Iran. Maybe for this reason many believe that computers, to some extent decrease creativity. When acquainted with new sciences and software, we can increase our creativity and come up with novel ideas.

Last but not least is the fact that computers can aid architects at different stages. Architecture design, as mentioned before, is closely related to visual deductions, but then again, in many other fields which have found their way into architecture, calculations seem necessary. Therefore, there are times when an architect feels necessary to use computers and software to conduct calculations even to continue designing and drawing. A lot of evaluation is done around architecture with images, but how can the results be presented numerically? Here, technology can be enormously useful.

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Some active groups in new architecture software

- Design Machine Group, Washington University
http://dmg.caup.washington.edu/xmlSiteEngine/browsers/stylin/
http://www2.ds.arch.tue.nl/projects/e3dad/papers.htm
- MIT Project Oxygen, MIT Laboratory for Computer Science
http://oxygen.lcs.mit.edu/
- Virtual Reality - Design Information System, Eindhoven University of Technology
http://www.ds.arch.tue.nl/Research/DDDoolz/
- Fraunhofer Institute for Computer Graphics (IGD) in Darmstadt
http://www.igd.fhg.de/
- Autodesk Architectural Studio
http://usa.autodesk.com/adsk/section/0,,585585-123112,00.html
- Sketchup
http://www.sketchup.com
- Nemetchek D-Board
http://www.nemetschek.com