# Computer Aided Architecture Design Teaching in Architectural Curriculum; a Case-study of UK Schools of Architecture

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In the Name of Allâh, the Most Gracious, the Most Merciful

# The Thesis Abstract

The aim of this research is to examine the impact of the Computer Aided Architectural Dersign (CAAD) on both the design process and architectural curriculum by posing a main research question:

*To what extent can CAAD be integrated into the architectural curriculum?*

The research design included a hypothesis which was culled out of the literature, based on a definition of a problem, and tested through an empirical case study with 36 RIBA recognised schools of architecture using: questionnaire, site visits, and informal interviews.

The main findings of this research are summarised below:

-The way in which CAAD assisted students to produce design ideas and decision during the design process was quicker, easier, and more accurate than with conventional methods (Chapter II).

- The results indicate that CAAD can provide an important aid in both architectural history and urban design areas of study within architectural education (Chapter II).

- The impact of CAAD on the architectural design process was noted to be significant in several areas, for example, transfering, receiving, and manipulating information, 2D drawing, 3D modelling, structural analysis, etc. (Chapter II, III).

-The trend of working in three dimensitional digital modelling proved very useful, as students of architecture were able to explore and test design ideas during the design process (Chapter II, III).

- The research revealed that there are four scenarios for locating CAAD facilities irrelation to studio space within UK Schools of Architecture (Chapter I). The results found that locating a CAAD laboratory within a design studio space is the most preferred place and the most effective way for teaching CAAD (Chapter IV, V).

-With regard to examining the useful effect of virtual design studio (VDS) as a new approach to teach architectural design (Chapter II, III), the results revealed that 63% of UK Schools of Architecture have introdued virtual reality (VR) at some stage of the curriculum (Chapter IV).

-The top two CAAD software programmes found to be most used across UK Schools of Architecture were AutoCAD and ARCHICAD (Chapter IV).

- Making CAAD Teaching relevant to design and integrated with design studio work was found to be the effective way of promoting CAAD within architectural education (Chapter II, III, & IV).

-With regard to choosing a suitable CAAD software for teaching architectural design, this thesis suggested that several key points, described in detail in chapter (I, II, III & V),

should be considered. Two of the most important ones are: the CAAD software programme should be less specific to work with all types of hardware system, and have ability to work with local area networks (LANs) and wide area networks (WANs).
-In addition, the findings of this research suggest some effective directions for a CAAD course framework and a CAAD policy for the Department of Architecture and Urban Planning, Tripoli-Libya (Chapter V).

The research problem, the hypothesis, and the research design were identified, explored, and further developed through an introduction and five chapters, followed by three appendices.

Chapter one is concerned with components of computer systems and with an understanding of the different aspects of CAAD systems, such as their hardware and software as part of answering general educational questions: What do we know?

Chapter two discuss the question: How can computers' capabilities productively be integrated into architectural education in general and into the architectural design process itself?

Chapter three raises question about architectural education policy, curriculum and course content: What is the best way to teach architectural design integrating CAAD?

Chapter four: this chapter reports on the findings of the research design- an empirical investigation into the integration of CAAD within UK Schools of Architecture (by mailed a questionnaire (Appendix I), site visits, and informal interviews). The Statistical Pakage for Social Scienses (SPSS 0.9) was used for data mining and analysis of CAAD tutors returns.

The overall conclusions (Chapter V) will serve as a guideline to the Department of Architecture and Urban Planning, Tripoli-Libya, as a means to improve the current curriculum by adopting the computer culture in general and CAAD in architectural education in specific.

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## Acknowledgements

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# Introduction

The aim of this introduction is to highlight the main parts of the thesis and define its structure and arguments.

In a paper entitled "*Unanswered Questions: Posed by the Devil's Advocate*", presented at the 16th European Conference on eCAADe, Maver & Petric (1998) tried to stimulate debate around the various critical issues facing the CAAD (Computer-Aided Architecture Design) community for more than thirty years up to that time and raised a few fundamental questions, namely, where are we now? Why are we where we are? Where do we want to be? These questions still subsist in the debate on CAAD, and will form the basis of a structure that attempts to draw a clear picture about computer integration within architectural education.

The thesis will begin with these basic questions, with the objective of evaluating two things: the real situation (***Where are we now?***) and the desired aim (***Where do we want to be?***).

Over the past few decades, computer technology has advanced quickly (Scianna, 1996: 391), and Information Technology, as a broad idiom, has had a great impact on our daily life in general (cultural impact) and on architectural practice, education, and research in particular. Phiri (1999: 2) argues "the important point is that IT can save time and makes management more effective, thus giving us better information. IT is the key information knowledge facilitator. One observation is that IT is 'pervading virtually all forms of human endeavour'; work, education and leisure, communication, production and marketing, and the time scheduling of these" and, according to Mckeown (quoted in QaQish (1997: 29)), the use of the computer, as a smart machine, has become an essential feature element of IT.

The computer, as a specific term, has become an ordinary and a daily engagement routine during the last few decades, for "within a short space of time the computer has become a widely accepted feature of architecture, both in the design process and in the everyday operation of buildings and the city, and we are constantly aware that the computer's introduction into architecture will eventually have far-reaching consequences. After all the current revolution is not just about the computer as a tool but about its role in the global telecommunication network" (Bart Lootsma, quoted in Zellner (1999: 7)).

Architecture is part of a network of social activities, as it concerns the built environment (Schmitt, 1999: 5). Like many other social and scientific fields, the field of architecture adapted the computer as a tool in its various processes and phases. As Schmitt argued, “Architecture today consists of a complex process, a complex product and a complex life-cycle. In all phases, the computer is involved. In planning and designing, the machine helps to document, organize, and store information, to visualize design alternatives and to produce working drawings or models for the construction workers. The completed building – the product – is increasingly equipped with sensors, controllers, monitors and computers of all kinds. Once the building is in use, the computer is needed to support maintenance, calculate energy consumption and rent, monitor security and finally keep track of building parts for possible re-use” (Ibid: 5).

The computer has become an important research tool during the design process, to simulate building performance through CAD packages, such as Structural Analysis, Acoustic Analysis, Thermal Analysis, Bio-climatic Analysis, Lighting Analysis (natural lighting, artificial lighting, luminance value, shading, etc.), and Urban Analysis.

As a result of using the computer in architectural practice, drafting and desktop software are replacing parallel rule, changing thereby the nature and the position of labour: “Computers are changing the ways we draw and the ways we use information. These tools have the potential to make the labor of architecture more productive, but, more importantly, they promise to transform the way we design” (Crosley, 1988: 3)

Nowadays many firms prefer to hire recent graduates with computer-aided design (CAD) experience and, accordingly, architectural education policy must respond to changes that are happening in society in order to provide better tools for students’ future careers.

The computer provides a useful aid with its vast application in various purposes (Gero, 1977: 6) (for more on this, see Chapter I, II, and III): Office Management, Project Management and Process (collecting information, survey questionnaire, scheduling, space planning, drawing, 3D Modelling, structural analysis, environmental analysis, cost estimating, specification writing, and bills of quantities.

> “Information Technology is the acquisition, processing, storage and dissemination of vocal, pictorial, textual and numerical information by microelectronics-based combination of computing and telecommunications.” (Ostman C., see Phiri (1999: 1))

Another essential question that schools must find an answer to is: Why are we where we are?, which Maver & Petric (1998) break down into two subsidiary questions, namely, *what do we know?* *and* *what do we not know?*

One can argue that the role of Schools of Architecture is here, as knowledge is passed on to new generations, helping them thereby, to understand facts, through simple and effective ways, and be concerned about the built environment. Part of that is attained by providing them, through teaching and learning, with better skills or IT tools as a strong base for future jobs. Schools can achieve that by a high performance curriculum and a well self-motivated policy. Thus, teaching and learning computer skills should be an essential issue within architectural education nowadays, but at the same time, it requires a high effort from all education components (Schools, Tutors, and Students).

Adopting the computer as a new approach for designing will bring a great challenge to all architectural education components, including education policies, education methodology, curriculum content, organization, tutors and students. One of these challenges lies in how to select the most reliable, accurate, helpful items from the millions of items and choices, which IT can provide now.

For example, with regard to education methodology, adopting CAAD will add an additional load to the undergraduate curriculum (Bridges, 1984: 53), causing difficulty for course content and time. As we can see from (Figure 1), there is a direct relationship between methodology and the course framework within a school's education policy, and any changes in any one area will affect the other.

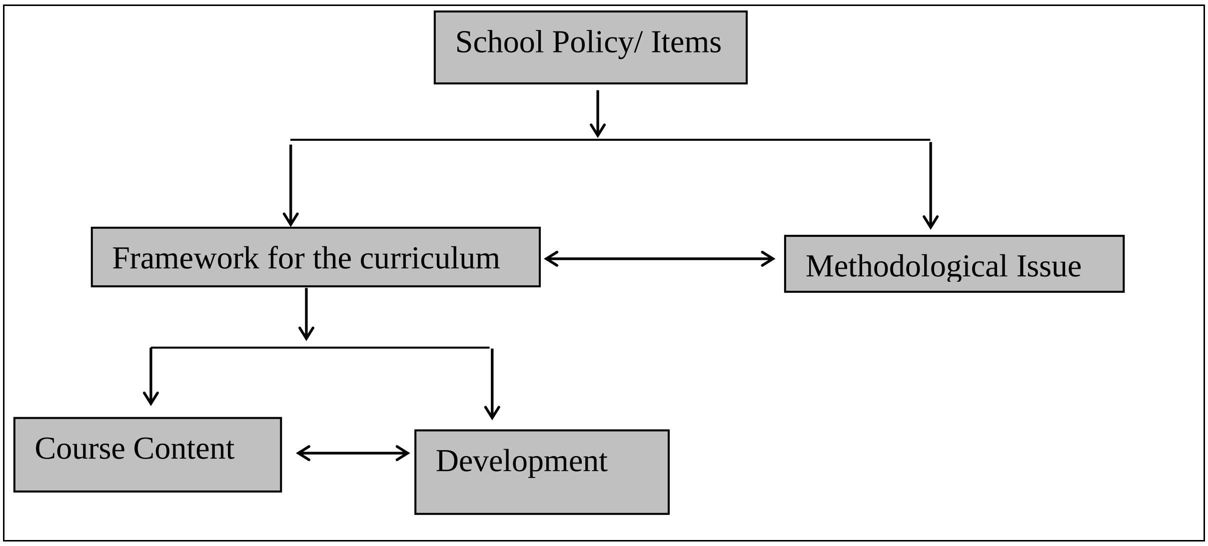


**Figure 1: School scope of work based on 2002 at 20th eCAADe (Mark et al., 2002).**

**How is our future?** Maver & Petric (1998) break down this question into two subsidiary questions: *Where Do We Want To Be?* & *What Do We Need to Know?*

This step is very important if we need to evaluate our situation in regard to what is happening in the society around us. Moreover, a starting point for architectural researchers is the issue of 'How to make computers useful partners in the design process?' in the words of Bryan Lawson (2002: 286).

## I- CAD and CAAD definitions

CAD, an abbreviation for *Computer-Aided Design*, is, according to Kronenberg (1987:2), "a broad term covering a wide variety of techniques" in general, applied from inception to end in the design process.

Phiri (1999: 52) explains CAD as "the use of a computer program to generate designs, normally in the form of dimensional drawings. CAD uses the Cartesian co-ordinate system (X, Y, Z), to allow representation of objects in the 2D and 3D (Three-dimensional Modelling) world. Therefore the system allows lines, arcs and circles to be drawn as geometric 'entities' on the computer screen which can then be scaled to output the appropriate drawing using a pen plotter or similar device".

CAAD is an abbreviation for *Computer-Aided Architectural Design*. In regard to architectural design, it means the emergence of the computer as a tool during the problem-solving process of design. Schmitt (1999: 5) explains CAAD as the intersection area between two worlds: Computer as a feature of IT and Architecture. "Architecture - the word reminds us of buildings, gardens, and cities - the built environment. Computers - we associate the word with technology, precision, networks - the digital word. The term computer-aided architectural design (CAAD) connects the two worlds and points to the original idea behind using computers in architecture: to improve the built, physical environment by providing the best instruments and methods for the creators of architecture".

## II- The CAAD challenge

In recent decades (from the late 1960s), a computing culture and its needs brought a significant challenge to architecture schools, and that challenge, in general, lies in how to integrate computing into the curriculum and improve computing expertise in the student body.

The CAAD trend within architectural education brought a fast and wide challenge to three interconnected entities: ***Institutions***, ***Instructors***, and ***Students***, " In the classroom the computer has the potential to radically change three fundamental ingredients: students, instruction, and instructor, it is obvious that changes of this kind spell out a commensurate change in design pedagogy, if the computer is going to be more than a passive instrument in the design studio, then design pedagogy will have to be changed, fundamentally" said Akin (1990:301).

It obvious to say that this dialogue will bring to readers' minds the following question: What are the challenges in architecture design education (ADE) that may necessitate some degree of attention?

### A- Institutions

The extra dimension to thought and expression that the computer brings to the area of design problems has meant that modification of the overall aims of any school. The curriculum can now integrate CAAD culture while at the same time raising the general level of students' knowledge about what computers can achieve. In the process, education methodology can be transformed as Penttilä argues "If architectural education managers do not react to the evolution of architectural profession and new media, and do not add more architectural information technology and CAAD-courses to the curriculum, someone else will finally take advantage of this field" (1996:353).

At the 20$^{th}$ eCAADe conference, Mark et al. (2002:205) argued that, owing to the changing education policy within Schools of Architecture, the curriculum framework will be changed also from the standpoint of both education methodology and course content (Figure 1), consequent to the adoption of new media in approaching design communication, representation, and the design process. This will also cause a challenge to the theory of architectural design criticism.

On the other hand, Bridges (1986:332) argues that by introducing CAAD in the undergraduate curriculum, the School of Architecture will add an additional load, which concerns one of the most crucial factors affecting the teaching of architectural design in general and teaching CAAD in particular. He talks further about the problem of introducing CAAD in Schools of Architecture, saying that “the volume of information related to architectural education has increased to such an extent that it is no longer realistic to expect that it can all be covered to the same depth in the course of the normal undergraduate training”.

To find the time and the qualified person to teach the subject of CAAD is one of the major challenges facing the schools’ organization of the architectural curriculum (Ibid).

The new way brought a series of questions, the first of which is: *What is the appropriate way to form a computing culture among students?* - A culture knowledgeable about current CAAD systems (Hardware and Software), and incorporating them for the purposes of architectural design and the evaluation of design schemes. “We should aim at a curriculum that goes deeper than computer-aided drafting and that prepares students to design and develop computer applications in architecture and planning,” said Gross (1994: 56)

As a consequence of integrating CAAD within architectural education, additional questions would emerge: How can we teach CAAD within the architectural curriculum? How can we use CAAD systems?

The advent of laptops and wireless communication brings a new challenge to the shape of schools. Design studios could be located anywhere now; and that means an impact on the educational environment and, consequently, an increase in the amount of time obtainable for design attempt. Also, it would create more opportunities for the adoption of distance learning as an alternative form of architectural education.

From a pedagogical point of view, there is evidence the design process by integrated CAAD faces the challenge of change itself, from a bottom-up design strategy into a top-down strategy in many circumstances (Akin, 1990:313) (see Chapter I, II, and III). Consequently, the course content will be affected according to these changes and methodological issues will be brought to the School’s policy.

### B- Instructors - (Architectural Tutors)

Form the theories of teaching point of view; there are two objectives for tutors’ role in architectural education they have to concern about: Firstly, to observe the architectural practice for adopting a suitable way of solving social needs as a continuous resource for improving research knowledge and which tool to use; Secondly, to discover the best way to transfer knowledge from the architectural practice as an experimental field, and how to find a suitable method to transfer knowledge to students.

The introduction of computer technology into the architectural field in general, and in the design process has led to new ways of design thinking, which may be slightly different from conventional methods. In other words, the introduction of the computer in the architectural design process has changed architectural education methodology in general (from teaching method into learning method) and design studio methodology in particular.

In this situation, lecturers/tutors in different positions (teaching or learning) have a difficult responsibility for choosing the appropriate ways to support student’s design idea, and here the direction and trend of teaching will shift away from the traditional approach of lectures towards a less passive approach in which educators perform more of a role of guides and advisors. Roberts, in the same line of thought, contended “ In the future it may be that the lecturer moves away from his traditional role to that of a guide, advising students where the best place to obtain that knowledge, and the best way to use it. For this reason, there is a tendency for educators to move from a passive learning by lecture mode, to an active learning by doing approach, often with the use of specifically written Computer Aided Learning (CAL) packages” (1996: 381).

### C- Students

As the education method changes from teaching to learning, it become obvious that students will perform the highest percentage of education effort.

The challenge here is how the student could maximally benefit from the highest possibilities of the CAAD system without going deeply into the complexity of computer technology. In other words, the student should be aware of other knowledge as well as acquire the basic principles in the use of CAAD his/her studies.

All these needs will require more student time than what was the case previously (three terms per year with a minimum ten weeks per each term).

### *III- Research Problems*

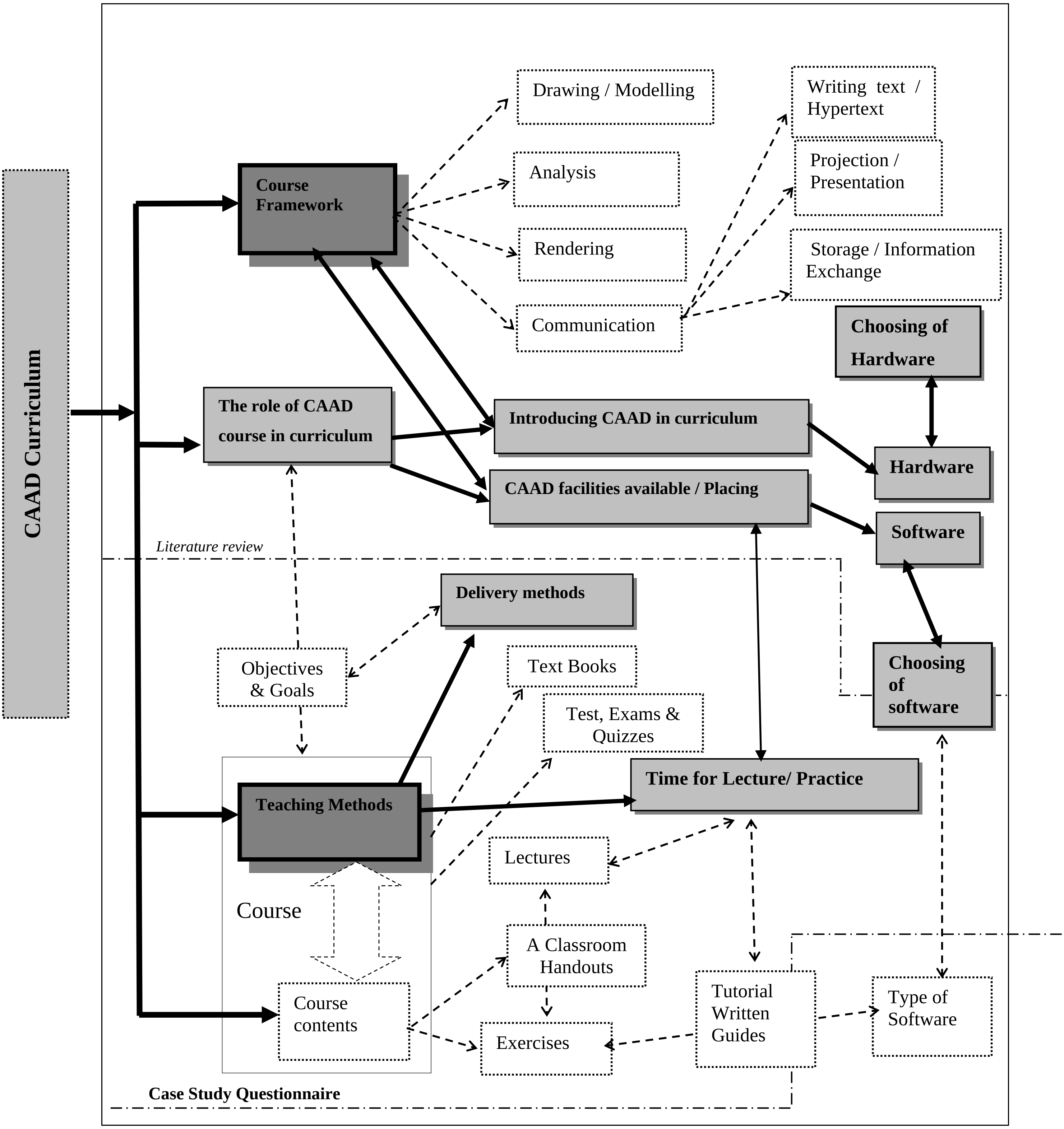


**Figure 2:** The Tree problems of integrating CAAD in architectural education and level of dissertation contributions[i].

It is useful to define what is meant by ‘a problem’ as a first step in discussing the problem-solving process.

Thorndike (quoted in Mitchell, 1977: 27) has given a simple definition of what a "problem" means or implies; "A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever one cannot go from the given situation to the desired situation simply by action, then there must be recourse to thinking. Such thinking has the task of devising some action, which may mediate between the existing, and the desired situations. Thus the solution of a practical problem must fulfil two demands: in the first place, its realization must bring about the goal situation, and in the second place one must be able to arrive at it from the given situation simply through action".

In the light of Thorndike's definition, one can evaluate the situation of the architectural education view within the Department of Architecture and Urban Planning[ii], Tripoli –Libya, as thus: after thirty years of pursuing a traditional curriculum, there is a consensus within the department that a new approach is need. The Goal of this is improvement of the current curriculum CAAD teaching policy, with the Desired Situation being reliance on the use of the computer within architectural education.

The higher education quality council (HEQC, 1995) in UK has set up specific themes that can be used for examining institutions (see QaQish R., 1997: 418) and these are: Management Issues, Curriculum Development, Teaching and Learning, Staff Issues, Student Issues, Assessment and Examination, and Links between Levels.

The process of integrating CAAD within an architectural curriculum will raise a few problems and, based on the HEQC[iii] criteria of curriculum examination, *CAAD teaching and learning* was seen as the vertebral column of these issues.

This research will attempt to address subordinate issues related to *CAAD teaching and learning* as a major educational issue, including methods of delivery, supporting materials, timing and preparation of new policies. In its aim to answer some questions related to these issues, this research will assume a number of useful primitive conclusions as guidelines in its discussions.

## *IV- Objectives*

The aim of this dissertation is to discuss and address the general debate surrounding the use of computers in the field of architecture and the role of computers as a new approach in architectural education throughout UK Schools.

The dissertation will approach this aim by surveying the theoretical background behind the use of the computer.

The results of this research will serve as guidelines to the Architecture Department in Tripoli-Libya in its attempts to improve the current curriculum through the adoption of a computer-based culture in general and CAAD in architectural education, in particular.

## *V- Dissertation Questions*

The current architectural design process and communication in architectural education are being challenged by the evolution of the use of computing techniques. For that we need to understand CAAD and its impact on architectural education and to what depth can we integrate CAAD in architectural education.

In the exploration of the use of the computer as part of IT and its impact on social culture, the study will seek to answer a number of important questions. The main question addressed by this dissertation can be formulated as follows:

*To what extent can CAAD be integrated into the architectural curriculum?*

This question can be broken down into five sub-questions, each to be dealt with in a chapter of its own and each sub-question to be broken down into subsidiary questions:

- *Do computer capabilities assist or hinder students in their study?* **(Chapter One)**
- *What is the right consideration of choosing software packages for different studio course situations?* **(Chapter Two)**
- *How may we teach CAAD with architectural design education (ADE)?* **(Chapter Three)**
    - *How could Schools of Architecture integrate CAAD teaching/ learning into their own curriculum?*
    - *What is the optimum learning process that we should adopt?*
    - *How and when should CAAD be introduced in the curriculum of Schools of Architecture?*

- *How will the architectural curriculum be affected by integrating CAAD?*

- *How will the design process within architectural design studio be affected by the integration of CAAD?*

- *How do they teach architectural design integrating CAAD in the ADE nowadays?* **(Chapter Four)**

- *Is it useful to teach CAAD software in studio? Which way? Integrated with design or as an independent course (pure skills)?*

- *Which future trends should we follow?* **(Chapter Five)**

    - *What new educational policy should be adopted?*

    - *Do future schools need a face-to-face architectural design studio?*

## *VI- Scope, Organisation and Outline of the Dissertation*

From the title of the dissertation - *CAAD Teaching in the Architectural Curriculum* – with subheading - *A Case study of UK Schools of Architecture* - we can extrapolate that this thesis consists of an "Educational" component and a "Computer" component. These components were taken as the fundamental concepts around which each chapter's heading was formulated.

The content's of this dissertation, following this introduction, are organized into five major chapters focussing on: CAAD systems, computer capabilities, CAAD and architectural education, CAAD teaching, and Toward the Future: Conclusions, Recommendations, and Future Research.

*What kind of dissertation is this work?*

This dissertation will focus on the integration of computer technologies within architectural design education (ADE), and on their growing role in this field. We can categorize the dissertation as <u>*Descriptive*</u>, <u>*Explanatory*</u>, <u>*Comparative*</u> and <u>*partly evaluative.*</u>

Owing to time limitation, funding and the breadth of the architectural education domain, the dissertation will not propose to answer all the questions. Assuming there are different levels of research (M. Arch level and Ph.D. level), questions were accordingly classified into two levels, corresponding to two stages of research (Figure 2 and Figure 3).

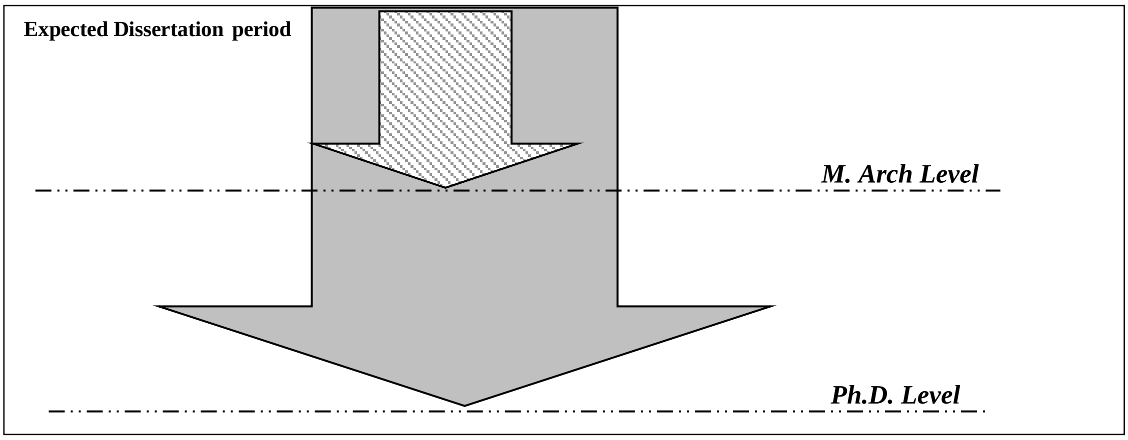


**Figure 3: Organisation for levels was suggested to answer questions of the dissertation.**

The concerns of this work and its discussion bearing on these concerns is organised into four main topics addressed in four main chapters, with each chapter answering a specific question followed by related subsidiary questions. The dissertation also includes three appendices.

***Chapter One:*** **CAAD system**. The opening chapter of this dissertation seeks to give a detailed idea of the computer and its components as a new medium to 'mediate communication' and, ultimately, arrive at an understanding of the meaning of CAAD systems as collaborative tools for architectural design. The discussion in this part of the dissertation will provide a background for the discussion that follows in later chapters.

In line with the chapter's concerns, the discussion will branch off into two directions, hardware and software to answer the general educational question: *What should we know?*

***Chapter Two:*** **CAD Capabilities- as support tools for the design process.** This chapter is concerned with CAD capabilities. It starts by discussing CAD as a support tool (drafting, modelling), then goes on to look at its capabilities as an analysis tool for design work, including the relationship to historical research, and finishes by looking at the capabilities for new architectural education trends, for example, Virtual Reality.

***Chapter Three:*** **The relationship between architectural education and CAAD courses in the curriculum.** This will give a brief explanation on the integration of CAAD with the rest of the architectural curriculum.

***Chapter Four:* A case study of UK Schools of Architecture (the analysis of questionnaire Survey).** This chapter, the part of the dissertation concerned with the case study, provides an analysis of the findings of a questionnaire survey of CAAD teaching in UK Schools of Architecture. There are currently 36 School of Architecture providing architectural courses - all recognised by RIBA (RIBA, 1999) in the UK.

The statistical package for social sciences (SPSS 9.0 for Windows) was used to analyse the results of the questionnaire exploring the institutions' instructor opinion. Furthermore, the summary of the findings is presented as tables and bar charts.

***Chapter Five:* Toward the Future (conclusions, recommendations & future research).** The aim of this chapter is to answer the question: What is the most suitable learning process we should adopt? The conclusion will outline a set of guidelines to the Department of Architecture and Urban Planning, Tripoli –Libya, to improve the current curriculum via an integration and adoption of the computer as a collaborative tool in the field of architecture.

Three appendices and a bibliography are added at the end to provide more information about the main topics and points of the text. The first appendix presents the original questionnaire, which had been sent to CAAD and design studios' instructors in thirty-six UK Schools of Architecture, listed in the third appendix. The second appendix contains a glossary of much-used CAAD terminology,

## *VII- Research Methodology*

Figure 3, outlines methods of data collection used and the type of data and techniques of analysis employed by this research.

I. Compile a bibliography that is related to the area of the research.

II. Define the problem by reviewing and analytically examining different resources (Hard text and Digital text), Libraries resources, eCAADe proceedings, online resources, etc.

III. Perform a case study of 36 different Schools of Architecture in the UK whose courses and examinations are recognised by the RIBA (1999), to investigate different approaches to CAAD teaching within architectural education use questionnaire and design instructors' articles for research design

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# Chapter One: CAAD Systems

## *1.0 Introduction*

Computers and their usage have come in recent times to be seen by many as an important and even as an integral element of modern society. The use of computers and the development of its functions and capabilities are part of, as well as a reflection of humans' attempt to master the available tools offered by human evolution. One of the areas where computers have come to be viewed as even more important and even more integral is that of architecture and architectural education.

Given this, it is the duty of schools to assist students to recognise and appreciate the influence of computers on their future lives (Lawson, 1986:78).

Therefore, understanding computer technology and how computer systems' components work is widely considered as part of an understanding of the influence of computers on students' future careers.

This chapter is divided into two main parts. The first, starting with computer definitions and a brief history of the five generations of computers, seeks to give a brief clarification of the major different types of hardware systems.  The second goes on to look at the diverse categories of software, and their specific features.

The aim of this chapter is to answer in part these questions: What do we know? And, What Should we know? As part of: What do we not know? (Maver & Petric, 1998:3)

*Why this chapter?*

"Today, the creation inside some CAD programs of those little applications that are one of the highest moment of 'learning by doing' method, starts to require more knowledge of some computer science techniques and of the operating systems too" (Scianna, 1996:391). This quotation incorporates two important points of discussion in connection with the computer's development here:

- Computer development as an essential antecedent to CAAD development.

- Technical difficulties are a major problem facing both schools and students while studying. When using computers for study, problems are inevitable. The users' ignorance of computing can turn otherwise minor problems into major hindrances to work progress. The lack of emphasis on computer literacy in schools curricula does nothing to solve this problem.

Here, the student finds himself a slave to his limited knowledge, a concept that was well expressed by Klercker (1999:267): "If you do not master your media you are a slave under its limitation"

- We also cannot ignore the difficulty caused by curriculum time limitations overloading disciplines within the school.

The computer science technologies are employed at three different levels: Hardware level, Base software level, and Application software level (Scianna, 1996:392), without understanding the development of CAAD is a consequence of a simultaneous hardware and software computer science developments, we will never get the overall picture about integrating computers in architecture design education.

*What are computers?*

The computer, as a smart machine, is the key to understanding the effects of the use of technology on architectural education in general. It is important, at this juncture, to give a short explanation about the computer itself to give an overview.

The literature review has shown that there have been numerous definitions throughout the history of computer development, and that there is no one specific definition that can subsume all computer characteristics under it.

In general, computers have been defined "as electronic devices which are capable of storing data in an internal memory, and of following stored sets of instructions (programs) to operate upon the data in order to produce desired results" (Mitchell, 1977:3).

Woodward & Howes (1997:1) have defined computers as "machines which process information automatically and in accordance with given instructions. They do not 'think', but are being programmed to perform increasingly complex operations. They can carry out boring and repetitive tasks with speed and accuracy".

Gero (1977:2) has defined the computer in terms of its common behaviour thus: "The computer is an electrical machine with three distinguishing characteristics: it can store its own instructions, it can execute the instructions at a very high speed, and it is a general-purpose machine”.

Crosley (1988:180) defined the computer in terms of its capabilities and applications as “An electronic machine that can process information according to programmed instructions”. According to Mckeown (see, QaQish, 1997:29) the computer is a ‘smart machine’.

In the booklet prepared for the staff development programme in Robert Gordon’s Institute of Technology, Ellington ([9], 1987:1) characterised computers the same way. He said, “A computer can be defined as a device, which is able to accept information, apply some processing procedure to it, and supply the resulting new information in a form suitable to the user.”

To sum up, the computer has generally been characterised as a smart machine that can store data, operate a specific programme, and produce desired results (Mckeown, 1986). Simply defined, the computer is a machine developed by humans to use as an instrument or tool to help a user (designer, engineer and so on) to carry out a specific task, aiming at getting the higher performance of calculations or processing of data. In the architecture domain, it is also used as assistance and a partner tool throughout a design process.

Its first use is as a user-friendly means of producing 2D project drawings or for modelling and rendering 3D (Three-dimensional), projections, animations and so on. Secondly, it is useful as a partner tool for supporting concepts and for criticising design ideas during the design process by such means as Environmental Analysis, Structural Analysis, cost estimating, etc.

Mckeown (1986) and QaQish (1997:30) have classified the applications according to their impact in different areas as follows: Applications in our personal lives; Applications in Business, Industry, and Public sectors; Multimedia applications; and Applications in Medical, Sports, and Education.

Before addressing the specific capabilities and applications of computers in education, it is worth looking at the nature of the technological evolution itself and the history of computing development relevant to architectural education. In doing so, we will be enquiring into and providing answers to the question: What Do We Not Know? (Maver & Petric, 1998:3) see the introduction.

## 1.1Computer development throughout the ages

To look into the role of computers and their benefits for architecture, it is important to consider the development of computers and the improvements in their capabilities throughout the decades.

Throughout history people have had to become more numerate. As the requirements of their daily lives got more complicated, they have had to develop more sophisticated methods of analysing numbers.

Phiri (1999:6) argues that computational machines, as a term, were well known "as early as the 1800s. Charles Babbage, an English professor of mathematics, developed an idea for an analytical engine that could perform any kind of computation automatically".

However, the second half of the 19th century witnessed the actual founding of advanced information technology with the emergence of the first generation of valve-based electronic computers (Figure 4).

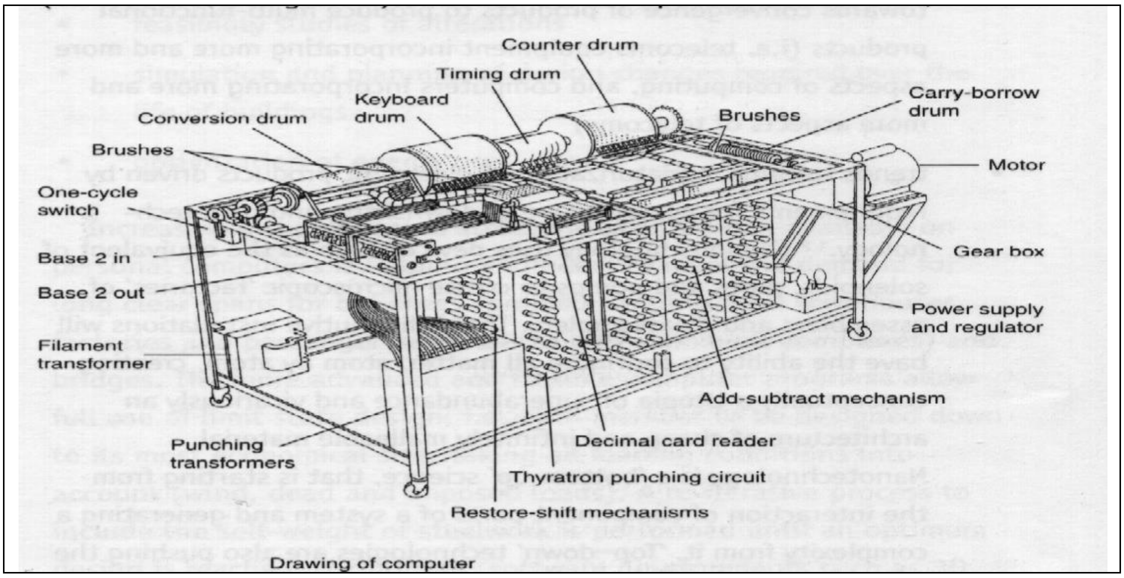


**Figure 4: The first electric computer (Phiri, 1999:6)**

Since then, history has recorded the rise in the development of electronic computers, both hardware and software.

The history of advancements in computing can be considered from several perspectives. This section will summarise and review two of them:

***I-Perspectives of computer development based on computer links with the user***

John Walker argues that the development of the human interface with computers can be divided into five generations. These centre on the notion of the computing links with the user as a base for his taxonomy (See, Zampi & Morgan, 1995:20), instead of the idea of the user-machine as an independent part:

1-The first generation was the switchboard machine, capable of performing a limited set of instructions.

2-The second generation was the punched card computer, with greater data handling abilities and more complex routines.

3-The third generation was the keyboard and screen, in which commands could be directly inputted.

4-The fourth generation was the menu driven program, in which the user becomes closer to the machine and does not need complex orders and routines

5-The fifth generation was the graphic user interface, which is the current state of technology where "a mouse is used to point and click" as Zampi et al. (Ibid: 20) described.

Based on Walker's view, Zampi and Morgan classify *the sixth and current generation* of computer development, so-called Virtual Reality. They define Virtual Reality as an interface "in which user and machine coalesce into a single cyberspace entity" (Ibid: 20-22), with the computer acquiring closer links with the user, since, to quote Walker, "the computer is a tool which has no sense without its operator" (Ibid: 20).

***II-Machine as an independent part***

Howard (1998:10) argues that the earliest thought on the term "computation" goes back to first devices for the calculation or storage of numerical data, such as, the *abacus* in the Far East, *notched tally sticks* in medieval Europe, and *the Inca trails* in South America. He also notes that from the 1940s the computers became electronic, with the development largely owing to military applications.

Phiri (1999:6) classified the history of computer development into four generations. In table (1), Phiri argues that the common feature of the first generation in the period between 1945 and 1955 was the replacement of mechanical components with valves (Vacuum tubes) with small memory capacity. The media used in this generation, either for input or output, was punched cards and magnetic tape. These computers could only run one program at a time (QaQish, 1997:36).

| Generation | ***First*** | ***Second*** | ***Third*** | ***Fourth*** |
|---|---|---|---|---|
| **Year** | 1945-1955 | 1956-1963 | 1964-1981 | 1982- |
| **Computer** | Vacuum tube | Transistor | Integrated circuit | VLSI |
| **Hardware** | Magnetic drum | Magnetic core | Semi-conductor | Optical |
| **Size of system (minimal)** | Very large | Mainframe | Mini | Micro |
| **Processing speed** | 10 KIPS | 200 KIPS | 5 MIPS | 200 MIPS |
| **Memory size** | 2 Kbytes | 32 Kbytes | 2 Mbytes | 250 Mbytes |

**Table 1: The first four generations of computers (Phiri, 1999:6)**

From table 1 it can be seen that the memory capacity increased to 32 KB when the valve was replaced with the transistor. This was the second-generation, in the years between 1956 and 1963. A notable feature of this generation was that computers became smaller and faster, compared with the first once.

Since the early 1960s, the integration of computer circuitry improved processing speeds and vastly increased machine memory size, “thus computers began to support multiprogramming and time sharing. This development led to more reliable and compact computers, combined with low cost and lower power requirements” (QaQish, 1997:37), and that has given the CAD searcher a useful tool for developing new approaches to drawing and design, for example, Ivan E. Sutherland’s Sketchpad System at MIT’s Lincoln Laboratory (Mitchell, 1977:14).

The 1970s witnessed the development of Large Scale Integration (LSI) circuitry, which consisted of thousands of integrated circuits, and led to the fourth generation of computers and yet larger memory capacities. By the end of the 1970s, the microprocessor was smaller due to the reduction of all the circuitry onto a single chip.

Another important improvement with this generation was that data and instructions were entered directly by keyboard - a new input device.

## *1.2 Using Computers*

### 1.2.1 Type of Computers

From the immense amount of available literature, we can classify computers into three kinds, according to (Mitchell, 1977), (Leighton, 1984), (Ellington [9], 1987), (Howes, 1989), (Woodward & Howes, 1997), (QaQish, 1997), (Phiri, 1999) and (White, 2002):

I. Their *Size* and *Computing Power*, viz.: *Supercomputer; Mainframe computer; Minicomputer* and *Personal computer*.

II. The type of logic operated: *Analogue computers* and *Digital computers*.

III. The purpose: special computer design for only *one purpose* and the computer designed for *many applications.*

There are two generic types of computers, *analogue computers* and *digital computers*

### 1.2.1.1 Analogue Computers:

Ellington ([9], 1987:1) had defined analogue computers as "Computers that are designed to handle data which has not been converted into digital form and are mainly used for specialised technical or scientific purposes".

### 1.2.1.2 Digital Computers:

"The information that they handle is converted into digital form (i.e. into a code based on the binary number system, which only uses two symbols 0 and 1) before processing" according to Henry Ellington (Ibid: 1). Woodward and Howes (1997) argue that we can classify or group digital computers by *use, speed* and by *physical size.* Digital computers are subdivided generally into three main types:

*I-Mainframe computers*, large and highly expensive, and need special room and a highly trained team of staff to operate them; normally suitable for large organisations or institutions.

II-*Minicomputers,* simpler and cheaper versions of mainframe computers, suitable for small business or college or for major sections of a larger organisation.

*III-Microcomputers* (*desktop computers*), small, easy to replace and can be used for a wide range of purposes, from simple calculation up to animation. This kind of computers is widely used within schools of architecture nowadays.

The arrival of the laptop (Portable computers) as up-to-date mobile computers with the ability or be taken and used anywhere, was helpful in overcoming limitations of time and place; accordingly, the social environment had changed also.

Natalie Leighton explained that all computers, regardless of their size or sophistication, consist of several fundamental components (Figure 5), and information always flows through these elements in the same sequence: “data enters the computer through an input device, and is stored in the computer’s memory. The control unit directs the information flow and decides what data is needed at any particular time to execute a task. The actual computation work is done in the processor unit, and the results are conveyed to the user by an output device” (Leighton, 1984:9)

- Input devices; part of the computer system responsible for converting the data (e.g. keyboard, mouse, microphone, video cameras, scanners, digital cameras, bar codes, magnetic ink character readers, etc.) into digital form (e.g. data, text, speech, or image).

- A central Processor “in which data is handled and calculation and manipulation of numbers takes place” (Woodward& Howes, 1997:2).

- Memory, the particular space that stores data for use by the processor unit.

- Storage, which is the place where the computer stores information if not in use.

- System software instructions that tell the different devices how to read, how to handle and how to display the data.

- Application software instructions that let the computer carry out specific tasks.

- Output devices, part of the computer system responsible for converting the data into understandable form.

### 1.2.2 The Computer’s System

Woodward & Howes (1997) categorised the computer system into two parts in terms of hardware and software component, based on basic theoretical work.

In general, all computers consist of three basic sub-systems (Ellington [9], 1987:2) (Phiri, 1999:5): the input system; the processing system; and the output system (Figure 5)

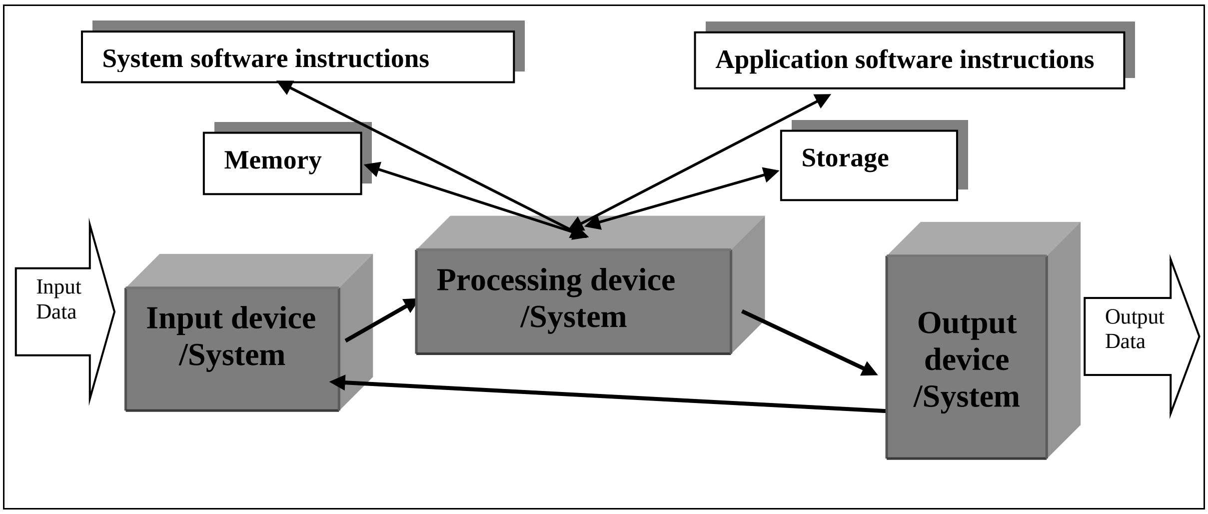


**Figure 5: The direction of relationship between the computer's components system illustrated from (Mitchell, 1977) (Ellington (9) and (Woodward& Howes, 1997).**

-***Input device or system***: the part that is responsible for converting information into digital code that can be handled by the computers (key board Mouse, Touch Screen, Scanners, Digital cameras, Voice recognition).

-***Output device or system***: the part that is responsible for converting code into a form that can be understood by the user (VDU, Projectors, Printers, Plotters, Sound, etc.). This describes the functions of the different components of a computer system.

-***Processing system***: it is the central core of the computer and it is divided into two divisible parts: 1-Hardware and 2-software (Figure 6).

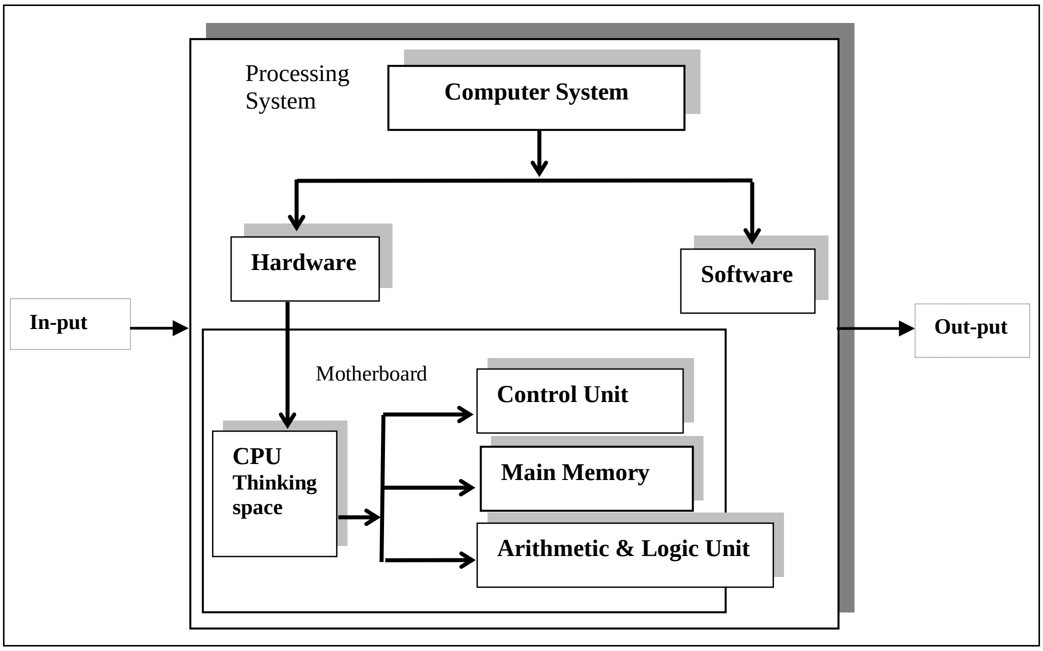


**Figure 6: Diagram for a computer system represented by comprising parts illustrated from (Woodward &Howes, 1997:5) and (Phiri, 1999:5)**

### 1.2.2.1 Hardware

Michael Phiri, in his book "Information Technology in Construction Design", identifies several categories for computer hardware, as shown in (Figure 7).

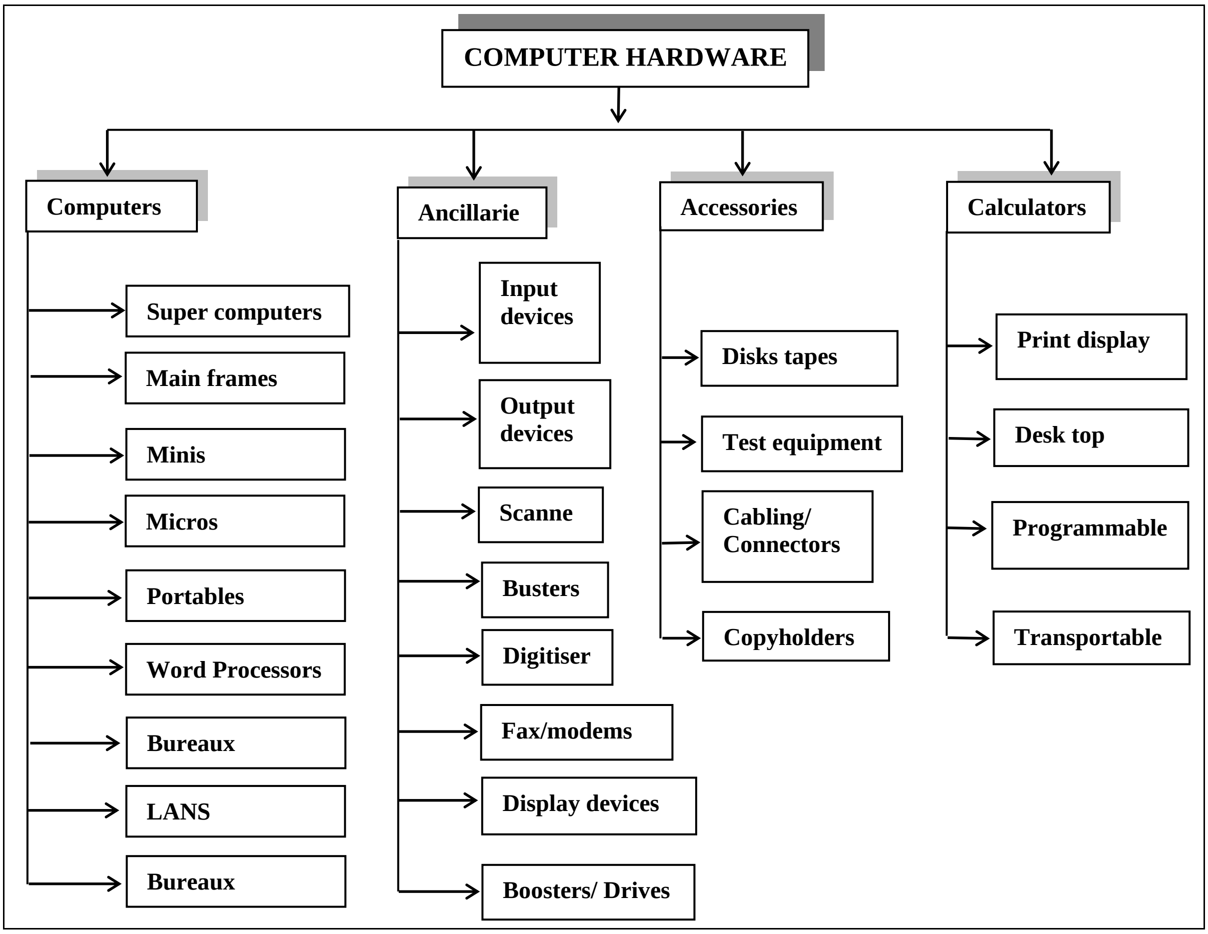


**Figure 7: A schematic diagram describes the categories of computer hardware illustrated by Phiri (1999:11).**

In most cases, the computer hardware is composed of three parts:

I-*Processors*, that metaphor called "thinking space"; also they are known as the microprocessors or central processing units (CPU), "which can handle system software and is controlled by sets of instructions contained in (ROM)" (Woodward & Howes, 1997).

II- *Memory*: "a holding place for instructions and data. One kind of memory is RAM, where the computer's central processing unit stores the operating system and application software in current use. Information kept in memory is more quickly available to the computer than that stored on a hard drive. When the computer is turned off, this kind of memory is emptied" (Cohen, 2000:271); it consists of Read Only Memory (ROM) and Random Access Memory (RAM), which is recognised as the workspace in the computer (Figure 8). CAAD drawing requires large amount of memory for two reasons: storage, and processing power.

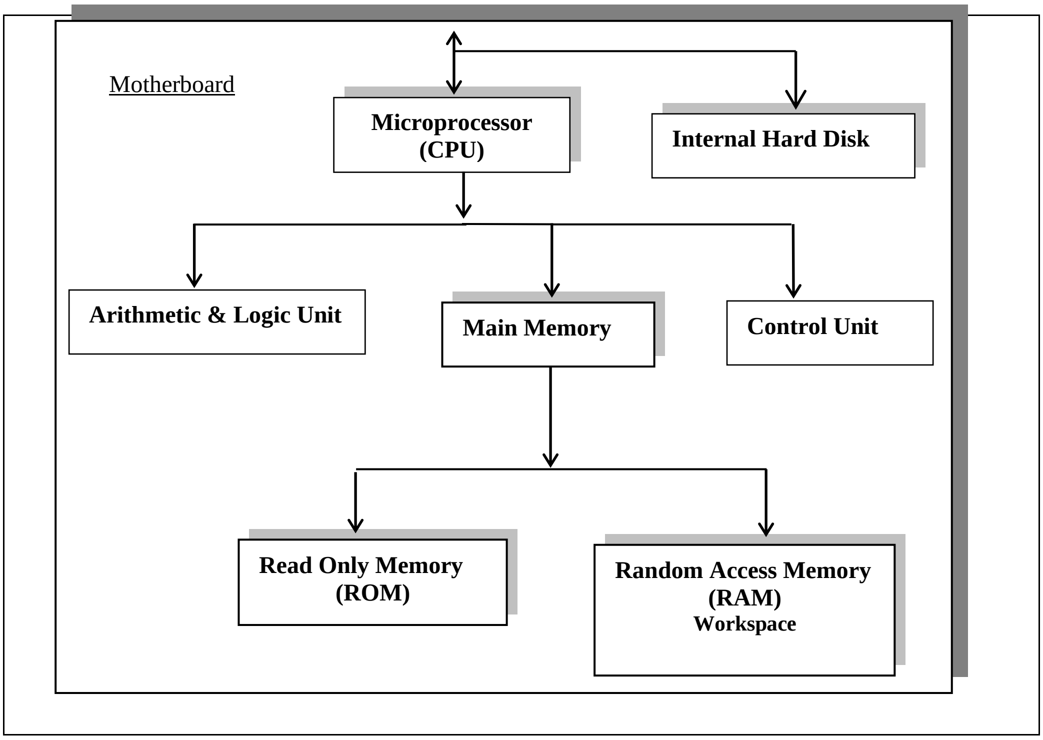


**Figure 8: Diagram Simplifies the hierarchy position of computer's memory within computer system illustrated from (Woodward &Howes, 1997) and (Phiri, 1999).**

III- *Storage* is where programs and data are stored while the computer is switched off. It can be built into the computer case, or used externally such as floppy dick and CDs. Computers advertised nowadays (March2003) typically have hard disk capacities of around 200GB, and RAM of around 256MB.

### 1.2.2.2 Software

There is a vast literature offering a large number of interpretations and explanations of what software is. All these interpretations convey the same meaning.

Longman's dictionary of contemporary English (2000:1367) identifies software as "the set of programs that you put into a computer when you want it to do particular jobs". Crosley defines the software in more scientific words, as "A set of instructions that tells a computer to perform specific tasks. Software is written in special computer languages and is stored on electronic media, such as floppy disks." (Crosley, 1988:186)

Thus, in common usage, software is given to mean computer programmes, which consist of sets of instructions that tell the computer what to do (Woodward, & Howes, 1997:149), or control the computer to carry out particular operations (Campion, 1968:310)

In general the software has been divided into three types (Howes, 1989) and (Phiri, 1999) as shown in detail in (Figure 9):

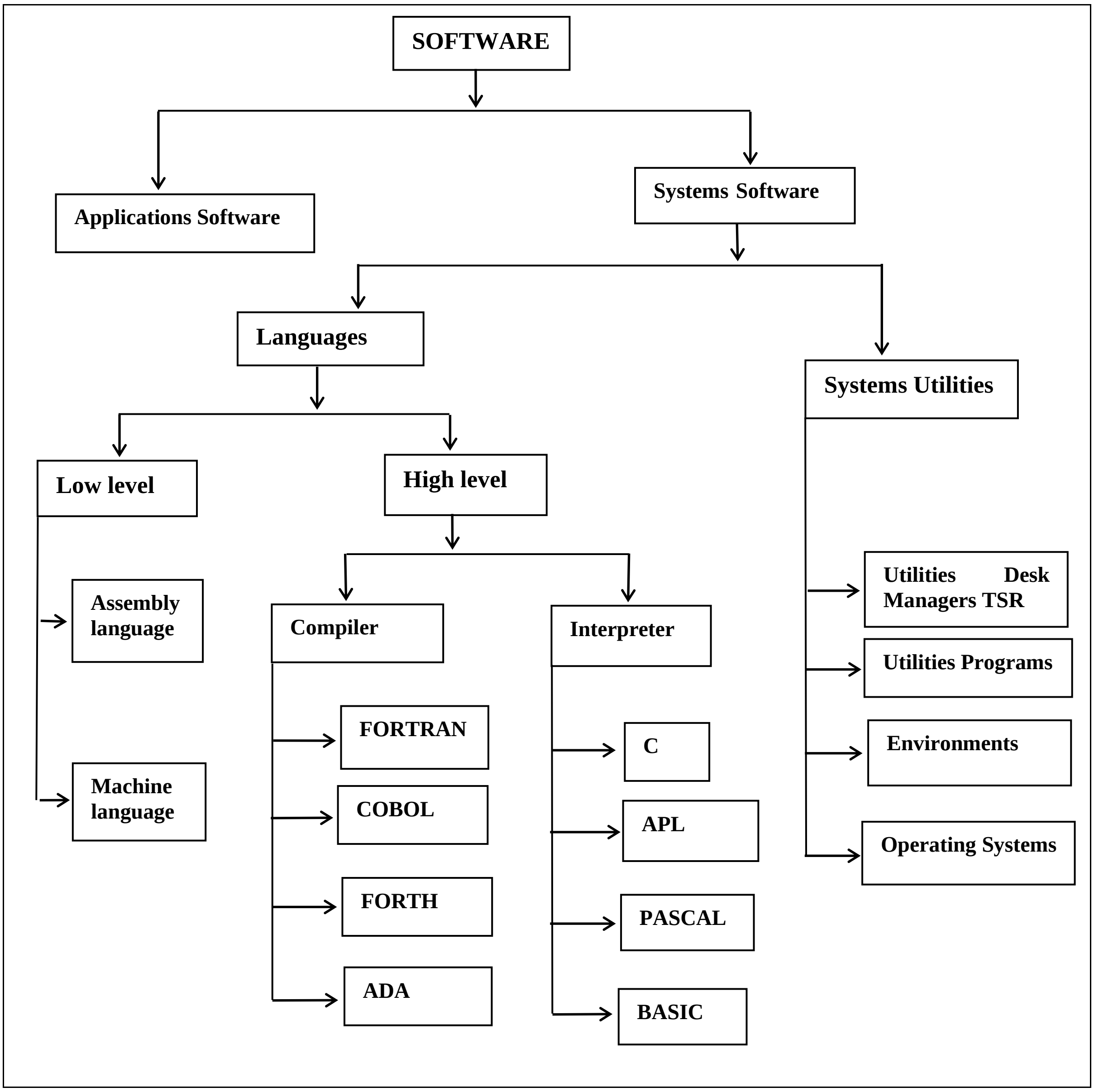


**Figure 9: Diagram shows levels of computer software illustrated from (Howes, 1989) and (Phiri, 1999).**

*I- System Software* or control programs, which are responsible for controlling the hardware "computer function" (Woodward &Howes, 1997); it is typically written and maintained by technical specialists (Mitchell, 1977:8). From the point of view of architectural education, students do not need to know much about it.

*II- Programming Languages* or *Operating systems:* "control how the computer hardware and application software work together" (Woodward &Howes 1997). Operating programs can be categorised into two types: a simple program or low language level, and a complex program or high-level language.

III- *Applications software* (Packages): allows a user to carry out specific tasks. Sanders (1996) call the application programs, *Illustration Software*, and he divides them into four categories: database, word processors, spreadsheets, and CAD systems.

In architectural construction Reynolds (1993:12) divided CAD programs into two categories - the *Generative* and the *Analytical*. "The generative programs actually produce a solution, with or without some human intervention, whereas the analytical programs test or comment on a given design which the user can then modify and re-test".

#### 1.2.2.3 Choosing CAAD systems

> "If the new generation of architects is in need of tools, then we can consider ourselves lucky. On the market there are as many CAD systems as we would be able to learn and use in more than a curriculum of a school of architecture. On the other hand, being able to use the tools does not mean being able to produce good designs." (Cicognani, 1996:88)

The second necessary step after the integration of CAAD into architectural education is that of making a choice as to the appropriate CAAD systems, both the hardware system and software packages.

The difficulties of choosing CAAD systems that will face schools' courses comes from the availability nowadays of dozens of good commercial CAAD systems, "some costing less than £100 with others costing many thousands of pounds. The difference is generally on perceived power, flexibility, customisation and integration abilities" (Phiri, 1999:58)

Numerous decisions have to be made before adapting a specific CAAD system. Woodward & Howes (1997), made a few recommendations to help with the purchase of any kind of CAAD system in general, namely, *the available budget*, *the range of applications to be run*, and *where the computers are going to be located*.

There is such a wide range of architectural software available commercially that choosing the right package for schools of architecture is difficult. Which is the best package has to be determined based on a realistic assessment of the factors influencing the architectural practice "Software is the heart of a CAD system and determines the functions of which a system is capable. Software cannot be chosen in isolation from the hardware, which will be required to run it. It is therefore absolutely essential when choosing software to know which peripherals can be driven by it, and to have some idea of the system configuration which will be required not only at the time of purchase but also in the foreseeable future," argues Kronenberg (1987:20) in his attempt to clarify the priorities for choosing software packages.

Related to these difficulties is the difficulty of writing specialised programs for all architecture proposes. For architects to study computer programming requires more effort, ability and time etc. Accordingly, the current trend is towards ready-made programs, usually called 'package' programs (Reynolds, 1980:38)

In this respect, it is very helpful to give a brief summation of Kronenberg (1987:20), criteria for choosing software:

- The ability to drive a digitiser for mapping existing drawings into the system.
- The system must be capable of accepting a variety of data input formats.
- The ability to convert existing paper drawings into computer format.
- The ability to serve different functional design works such as drawings, presentations, modelling, and so on; moreover, the ability to carry out some drafting needs such as distorting, stretching or moving parts of a drawing.

The first practical step in choosing a program is to find out what is available. There are available, several guides to computers in the construction industry (Reynolds 1980:39), which normally give a brief description of the program. In addition to Kronenberg's criteria, Sinclair (1989) highlighted a few essential points when choosing a program:

The important points were that the package should be:

- Low-priced and well suited to minimum cost computers and printers.
- Provided with excellent support from the supplier.
- Expandable, so that anyone who mastered its use could, if required, upgrade it at reasonable cost.
- Able to produce files that could be read by a desktop publishing package.

Kronenberg (1987: 21) explains that CAAD software in general cannot be chosen in isolation from the hardware, which will be required to run it. Sliwinski (1996:405) argues that "There is no CAAD system suitable for every task, but architect should be versatile", in other word, the architect must find his own way to solve any particular issue during the design process.

An important question is in which year of the undergraduate course and, specifically, which stage of the design work should a CAAD system be introduced? Should it be in the early sketch design stage, for analysis or for the final presentation? It depends on the type of task the programme is required to do. Is it for drafting, for rendering, modelling or communications?

I- Schools of architecture must choose software with a less specific or more general programme to work with all types of hardware system (PCs, Macs) and which can help with time-sharing team work; in other words, the software should have ability to work with LANs and WANs.

II- The software can show three orthographic projections (plan, elevation) together with an axonometric view, all, at the same time, on the same screen, like Rhino SpaceEdit (Cipriani et al., 1990:355).

In general, Reynolds (1980:38) reminds us that manufacturers have put nowhere near as much effort into writing programs specifically for use by architects, as they have for engineering or accountants. He also notes that the majority of programming is an art rather than a science and those views are still prevalent at the moment.

#### 1.2.2.4 The Concept of the workstation.

The introduction of computers into a School of Architecture for the first time will raise several issues about the school's management. It is essential that the school anticipates what these issues will be and prepares for them.

The introduction of computers into a school will interrupt a routine, which has been established for many years; it will also require the school to employ additional staff, which will lead to changes of responsibilities within the school.

A major issue facing schools implementing a CAAD is how to arrange and then manage the workstations. Whatever plan is chosen has to be cost effective. The school must make the best use of its CAAD resources for the least cost.

The concept of workstation should serve different proposes to allow the student to get the maximum benefit from using the computer in ADE as a tool, and one of the proposes, the workstation should be near the design studio or close at hand to the students to allow their ideas to carry naturally from the studio to the workstation without delay. Moreover the students should learn to work with computers in a natural, systematic, hands-on manner rather than in a rote formal manner (Reynolds, 1993)

The author has observed that there are four approaches to the computer workstation space, in the UK Schools of Architecture, all with their own advantages and drawbacks:

1- Place the *computer workstations in the separate space*, which is the first and most common approach. This idea of a designated place for computers as a tool for architecture students still exists in a number of schools of architecture, for example, The Bartlett School of Architecture-London, The South London College (Figure 10, 11).

**Figure 10: The idea of a separate space laboratory at The Bartlett School of Architecture- London [Oct.2002].**

**Figure 11: The idea of a separate space laboratory at School of South Bank University- London [Oct.2002].**

The concept of a separate space laboratory has come to architecture from other disciplines that consider computers to be a distinct and separate laboratory tool, for example, engineering.

Architecture adopted the separate space model but it proved to be problematic because architecture is not like any other disciplines. The architect during the design process needs tools as near as possible to him.

This idea has several advantages; besides the low levels of funding needed to launch the space, this scheme allows larger numbers of students to share the machines at different and unscheduled times.

Another advantage of the separate space is that it is normally built on the LAN (Local Area Network) method, connected with a minicomputer system, so it can be easily extended to cover another workspace.

On the other hand, the school will face the problem of time management between courses. Another disadvantage is that the students will have to deal with overcrowding and delays.

2- The idea of a *Computer workstation within a studio space*, which allows students to interact directly with the computer during design studio time, will reduce the time lost to be better used for the design scheme itself. A number of schools in the UK have adopted this technique to support their architectural courses, for example, Manchester School of Architecture- (Figure 12).

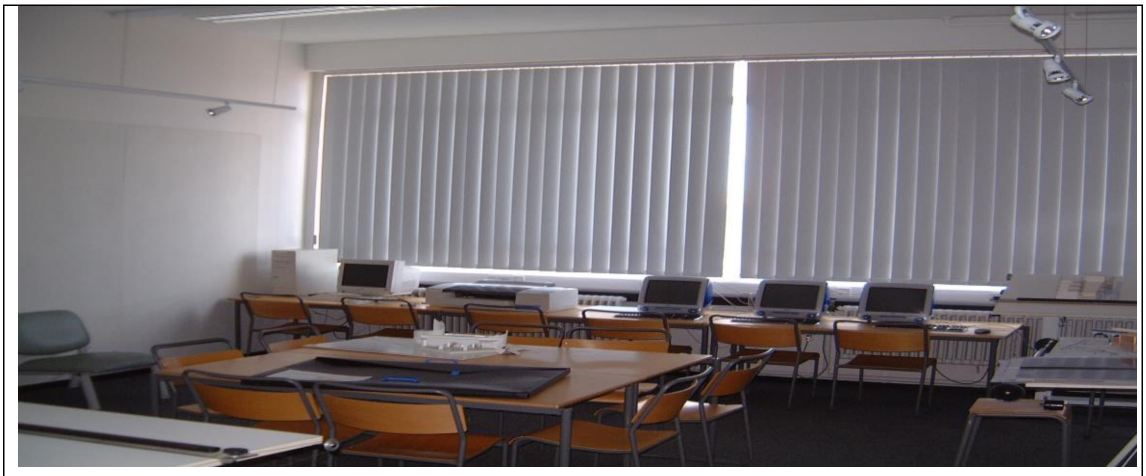

**Figure 12: The idea of a computer workstation within design studio at Manchester School of Architecture-Manchester [Sep.2002].**

It is costly for the school as well as difficult to manage. On the other hand, the students find with this kind of placing of the computer it becomes part of their daily work and little time is lost.

3- The idea of a *Computer workstation space close-by the design studio*. This scheme is half way between the two previous proposals. The consequence of this approach is that the student will reduce the time lost moving between the drawing board and the machine. Another advantage of this scheme is that it allows the student to spend time on design ideas, rather than waste it on moving between spaces. A number of schools follow this scheme, for example, the Mackintosh School of Architecture and Strathclyde School of Architecture (Figure 13 & 14). The problems of this system are overcrowding as well as time delays.

**Figure 13: The idea of a computer workstation close to the design studio at Mackintosh School of Architecture- Glasgow [Dec.2001].**

**Figure 14: The idea of a computer workstation close to the design studio at Strathclyde School of Architecture- Glasgow [Aug.2002].**

4- After several years of familiarity with the computer's culture and knowledge, Schools of Architecture have identified the problem of placing computers effectively. To overcome this problem, they established a new scheme, which is in fact a crossbreed between the two main ones. In other words, they exploit both ideas (inside design studio and separate laboratory) at the same time, for example, Manchester School of Architecture.

## *1.3 Summary*

The literature reveals that computers have developed so fast and become so accurate that most architects and firms will eventually integrate computers into their work.

Although the computer can play several roles within architectural practice, the future of using computers in schools of architecture is still raising a debate due to many problems facing the schools. The lack of understanding the computer, in terms of hardware and software, was considered to be one of those problems.

To understand how CAAD systems can work properly within the architectural design process it is necessary to have a strong background in computing knowledge in general.

This chapter has attempted to present an overview of the computer as a sophisticated separate machine with its essential components, Hardware and Software. It began with systems definitions and the development of the history of computers. Then the chapter intended to discuss the fact that computer software is the central core of any system, and that choosing the right software is one of the most difficult tasks for any school intending to integrate CAAD. This chapter gave brief guidelines for choosing suitable CAAD software.

The introduction of computers into a school of Architecture for the first time will raise several issues about the school's management and how to find the best place for the new tool by re-arranging the school's workspace.

The four schemes for placing computers in schools of architecture were also discussed.

Chapter two will discuss some possible applications related to the main questions: *what do we not know? & What do we need to know?* by answering partially the following questions:

*How will the design process within architectural design education be changed by the integration of CAAD?*

*What are the considerations for choosing the right software for different studio course situations?*

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# Chapter Two: CAD Capabilities- Computers as Support Tools for Design Process.

## *2.0 Introduction*

In the past, the majority of Schools of Architecture all over the world pursued one main objective, namely that of supporting students to master the skill of preparing hand made drawings and models as a main presentation technique in design education (Fuchs &Wrona, 1994:43). The Department of Architecture and Urban Planning, Tripoli- Libya, has been no different in this respect.

The use of computers has had wide implications and effects on every subdivision related to architecture design on account of CAD range of capabilities. It is, thus, worth discussing the general background relating to the benefits gained from the use of computer technology as an assistance tool in both architectural design and architectural education.

According to Fuchs and Wrona (Ibid), “The role of computer models in architectural education is very promising and still not fully recognized”.

This chapter attempts to map and synthesise the different points of view expressed in the literature about current CAD capabilities. It starts by looking at CAD as a support tool (drafting, and modeling), then goes on to look at its capabilities as an analysis tool for design work, and finish by looking at the latest CAD capabilities for new Architectural education trends (Virtual Reality, and Distance Learning). The general application of CAAD capabilities to different architectural education concerns is also discussed.

This chapter tries to deal in part with answering the following questions:

*How will the design process within an architectural design studio be converted by the integration of CAAD?*

*What is the right consideration of choosing software for different studio course situations?*

## *2.1 CAD: as Drafting and Modelling Tool*

A variety of new tools are available to architectural practice and architecture students today and the computer is considered one of those tools.

Since the 1960s, the range of uses of the computer in education in general and architectural education specifically has expanded significantly. At the beginning, the major role of the computer was that of a super-calculator, a role that has now expanded in a variety of different ways. As Phiri (1999:60) argues, we can identify several forms of computer capabilities related to CAD:

- Primitive drawing: points, lines, circles, arcs, and so on.
- Other elements: polygons, ellipses, fillets, traces, Polyline, French curves, and so on.
- Editing capabilities: rotation, deletion, mirroring, and multiple copying.
- Text entry and editing can be carried out in a variety of fonts and font size, moreover there is ability to stretch, compress, slant, rotate, justify and change, edit text characters in different ways according to user need.
- Layering capabilities, one of the major advantages; it allows presentation and logical organization of data more clearly and to be useful, also provides support for users' communication.

From the 1980s, computer science generated more capabilities for architectural practice in terms of improving architectural drawing by the development of drawing programs, which became less expensive and easier to use, synchronous with low-cost microcomputer development.

Advanced computers and software packages are now available to small offices, giving them support for more creativity and production.

According to Crosley (1988:3), "Computers are changing the ways we draw and the ways we use information. These tools have the potential to make the labor of architecture more productive, but, more importantly, they promise to transform the ways we design", and the question here is: *Did that take place or not?*

Before we look into that, we need to be clear about the benefit of using computer-aided drafting (CAD) instead of the traditional pencil-aided drafting (PAD) (Penz, 1992:41), or, in other words, we need to answer the question: *Are there any differences between CAD drawing and traditional methods?*

Architects always use drawing to express, store, and to convey information from the imagination to real stage.

In fact, by adapting a new approach for teaching and learning within architectural education, the computer forced the serious issue of changing the way we draw or we 'think' onto the discussion table. Crosley (1988:4) argued that "When you have spent years learning to do something one way, learning a totally new way can be intimidating, even frightening. You may be concerned that the skills you have accumulated will be rendered obsolete or that you will never learn to use a drawing technique that seems completely alien. ……… Drawing with such a tool, using a typewriter keyboard, or perhaps a plastic 'mouse', is obviously not like drawing with a pencil. In fact it requires a different attitude from those you have acquired through pencil drawing". Part of preparing for this attitude is the necessity of figuring out the differences between both media in terms of their benefit to architecture design.

The literature reveals that CAD packages offer a variety of features, which make them distinct from the traditional methods in the following ways:

I-The CAD package can offer the ability of using the same drawing many times in different places within the same work, for example, we can reiterate the same sample many times like standard building components and fitting (columns, doors) even with the similar plans at different levels within the building itself. Moreover, CAD systems can offer the possibility of changing orientation and mirroring the element without redrawing on demand. Through these advantages the user can save a lot of time especially on a large floor plan besides improving the quality of drawing by drawing the standard component in detail and very accurately (Reynolds, 1980:59).

II-Another practicable capability; on the same drawing, the computer can provide the possibility of adding more information like disruption text to the plan or elevations, dimensions, scales, label points, and so on (Sinclair, 1989:V)

III-Object-based instead of line-based drawing is the second main difference. In the traditional method, we need to place lines, one at a time, until a whole drawing is completed. In the CAD manner, however, the architect wants just for the first time to use lines to create a library of standard elements and after that insert them by clicking the right option. Crosley (1988:6) argues, “As a working method, this can lead to tremendous increases in productivity. Object-based drawing can allow the creation of drawing libraries, sets of parts that can be assembled into drawings. These are comparable to architectural templates, as well as standard details under tracing paper”.

IV-Another main difference is the idea of scale. 2D computer-aided drawing are working on X and Y-axis co-ordinate systems, and add a Z-axis to 3Ddrawing, so, every element or object has a value to a reference point, and that means that the architect’s work is constantly under the invisible control of scale, “Although the CAD display screen is smaller than a typical drawing sheet, it can be used as a telescopic window into a drawing, magnifying it or shrinking it without regard for scale. In fact, the idea of ‘scale’ is almost meaningless when you work on an electronic drawing, since you can move from a view of a whole building to a larger-than-life sized view of a detail in a second. You can work at real-world scale: it is your viewpoint that changes,” said Crosley (Ibid: 10). For a clearer meaning; each dimension on the computer-aided drafting plan corresponds to a dimension in real life that allows the user to work on it as display without having to ‘translate it to another scale (Ibid: 10) (Sinclair, 1989: iv). On other hand, the user can get output at any required scale without any additional effort.

V-The advantage of overlaying facilities was considered one of the useful capabilities offered by CAD packages. It is possible in CAD to look at a room’s drawing with furniture or without, or to copy a roomful of furniture into another room, or print a plan with information such as dimensions, furniture, and so on or without. All this is possible in CAD drawing because the package has the ability to store such information separately from others in different positions known as a layer, and the user can give them a different color or identify, different line weight or styles, which “can be drawn in a single action by selecting the appropriate option, just as a draughtsman selects a pen to give a certain thickness of line”, noted Reynolds (1980:62).

VI-The capability of saving the complete drawing on a separate disk file and return to it as much as users need for more copying, editing or to transfer it to another person, was considered a great distinguishing feature of the transfer of the design information.

## 2.2 CAD capabilities

### 2.2.1 CAD as a Three-dimensional Modelling Tool

Over more than 35 years, and since Ivan Sutherland's *Sketchpad System* at the 1963 Spring Joint Computer Conference[iv], the improvement in graphic capabilities in computer technology has become an important area for CAAD and for computer researchers dealing with computer applications.

The major progress happened in the mid 1970's with the introduction of obtainable desktop computer graphics systems, which brought computer graphic capability within the noticeable range of architectural practice (Mitchell, 1977:22).

Improvement in computer performance (advances in speed and increases in memory capacity in terms of storage and manipulation of large quantities of data), together with the decrease in the cost of computer systems, lead to the production of 2D drawing, perspectives (modelling later) and mapping, becoming typical applications of computer graphics techniques, not only in engineering and architectural drafting but also in various fields such as medical animation.

Howes (1989) noted that, in the past, the designer was slave under limited accessible tools, from drawing on parchment in the medieval age, up to the slow and fastidious drawing methods in the nineteenth and early twentieth century, in so far as manual copying was the only method of reproduction of drawing.

With the advent of the computer as an assistance and practical tool, the architectural work was sped up; less time was needed for more drawings, achieving more flexibility within office responsibilities, and more possibility of voiding mistakes.

Woodward & Howes (1997: 89) expressed and explained a general idea about the role of CAD software packages within architectural production as "CAD packages helping the production of many of the various types of drawing made for the several stages of architectural activity without using paper, drawing board and T-square, scale, pencil and pen. The results may be printed to paper to provide scheme design or production drawings; or they may not: for the purposes of presentation, for example, the drawings may never leave the computer but be displayed on a monitor or projected like slides; and computer files of drawings can be transmitted down telephone lines to another computer anywhere in the world before being printed".

There are a number of sophisticated CAAD systems available today, most of them relating to two main areas (Phiri, 1999:60): 1-As a drafting tool in 2D, 2-As design and representation tools for 3D (Three-dimensional Modelling).

From Woodward and Howes (1997) and Phiri (1999), we can summarize some of the benefits of CAAD systems as follows:

I-The changes can be made easily and quickly by exploitation of drawing and editing capabilities including rotation, mirroring, extending, trimming, multiple coping, extruding, and layering characters.

II-The ability of text entry and editing to be carried out in a variety of fonts, also with the ability to stretch, compress, slant, and rotate, to increase the amount of data with drawing, and, as a result, a single drawing can hold more information than a hand drawing.

II-It can increase the flexibility of drawing by using the capability of switching on or off the different layers.

IV-CAAD systems can provide an automatic dimensioning facility, which can increase productivity and accuracy especially for architectural construction.

V-The capability of easily and quickly sending the files of drawing by phone line (e-mail) would add other advantages instead of using paper.

VI-By mastering CAAD systems, drawings can be continuously edited without the need for scratching or abrasions.

### 2.2.2 Computer Modelling /Digital Model

Modelling is the action of making a copy of something (object) that is usually smaller than the original, real thing, and, traditionally, such a copy can be made from materials such as wood, clay, plastic etc., aiming to process large number of information behind lines to clients, audience, judges etc., as a form of visualization.

The dictionary[v] defines modelling as "The activity of making model ships, planes, figures etc.", Meanwhile, Simovic (1991:100) defined the model and its significance from the design process point of view as "representing of one structure (or process) with another one, under the condition that between 'original' and 'model' exists a definable resemblance {Petrovic 1977}. There is another way of modelling in the design process. It is, also, the evolution from one model to another. The first model is mental, often called 'an idea'. The other one is a product of the first one and only in some cases it happens that it became actualised as an "original". Only few of the designer's ideas become reality. This makes obvious that modeling has a key-role in design process".

Simovic (Ibid: 101) argues, in relation to the status of the model, that "It is much more than just a new toy in our hands. It is powerful and therefore helpful and dangerous at the same time" and that we can not ignore their effect anymore.

Each step of the design process prefers the application of an exacting drawing and a modelling medium, and if the wish is to produce exact documentation during the design phase, then the advantages of computer-aided drawing and digital modeling becomes obvious based on the computer's capability of structuring, storing, automating and fast manipulating (Schmitt, 1999:19).

The idea of generating a perspective image of a building before it is built is a long-standing one in architectural practice, which "often used to show the client how the future building would look. But this need to visualize a building in advance is not merely a device for presenting a project to a client, but a necessary and real part of the creative process of architecture" (Zampi & Morgan, 1995:12).

During the design process construction of the model of proposal was considered one of the important steps to transmit ideas behind the line of the proposal. However, modelling was thought to be the 'back bone' of CAD in terms of its impact on the design process and the final product. This is on account of the fact that by using the influence of Three-dimensional Modelling, imaging capabilities, immerging with collaborative solution, the designer can express and clarify complex ideas.

What is the meaning of a model? Woodward & Howes (1997:105) gave two definitions, both rooted in a computing terminology point of view as: 1-A three-dimensional graphic image, which Alkhoven (1993:50) more accurately described as "a spatial model rather than conceptual framework". 2-A database of all the information required for production and construction. This research will base all the contributions about modelling around the first definitions.

The model function is to describe reality at different levels of idea, and with the model the designer can evaluate the qualities of the design, with the model becoming, therefore, a design instrument (Schmitt, 1999:19).

Within the architectural design process, models were divided into four types of models (Fuchs et al., 1994:44): *scalel*, *assembly*, *conceptual* and *Virtual.* Fuchs and Wrona argue that the new type shares features with all of the three previous ones, with the "ability to contain the most complete design information, of all of the kinds of representation, makes it possible to call it the virtual realisation".

Simovic (1991:101) argues, "Each new technology brings new media. New media brings new types of models. Each of them, again, should bring improvement in the design process. What improvement (if any) and what eventual changes in design process should be invoked by information technology?" As a consequence of living in an IT era, the development of computer technology provides additional tools for constructing model through sophisticated software.

The difference between a physical model (made of cardboard, wood, stone, paper, etc.) and a computer model, as Alkhoven (1993:50) explained, is that the physical one allows the designer to touch the actual forms and assists him to make accurate decisions about the material, which will be used in the reality, also creating the sense of gravity within the designer. Many Schools of Architecture adopt the idea of learning design with the physical model, aiming to create and improve different senses within student skills (Figure 15).

**Figure 15: An experiment of physical model during design studio at Mac. School of Architecture, Mar 2002.**

On the other hand, the digital model consists of virtual lines, surfaces or solids, it can also be given any required scale and can be viewed from any viewpoint; also it can be handheld digitally via telephone line saving wasted time, especially when participants are in different locations, something that is not available in the traditional physical model.

Kadysz (1994: 212) argues, “Real model and virtual model - the medium of presentation is different but ways of using them are similar”, and that nowadays, we can use the modeling system’s ability to convert the digital model back into a traditional model, using *automatic cutting machines* linked to the computer. (Galli & Mühlhoff, 2000)

There are a number of Three-dimensional Modelling packages that can be used for models in drawing, for example: ArchiCAD, FormZ, Rhino, Modelshop, Swivel 3D, etc.

The Modelling programme was categorized into three types (Woodward et al., 1997:29):

1- The *wire-frame* or *wire-line* modeller, which illustrates all the lines of the object, includes lines that are hidden behind the solids in reality (Figure 16). In addition, most systems, which include wire-line representation, have facilities for the removal of hidden lines. From the architectural design process point of view, Woodward and Howes (Ibid: 30) noted that Wire-line models are quick to produce, are helpful in the early stages of design process, and can be used as a basis for freehand drawings.

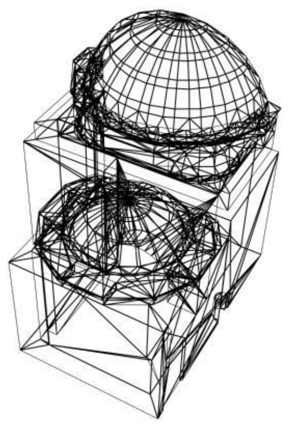

**Figure 16: A wire-line modeller (Boutsioukis, 2002)**[vi]

2- The *surface* modeller, which shows three-dimensional objects from their exterior surfaces, and, if cut, will exhibit the empty interior. More often, it will not allow sections to be cut through the model. From the ability to draw curved lines point of view, the surface modeller systems are most commonly used in engineering applications. On the other hand, the application of the surface modeller is limited to interior and exterior perspectives (Ibid: 30).

3- The *solid* modeller, which, if cut through, will "exhibit a new face on the plane of cut and produce a new solid object" (Ibid: 105) (Figure 17), which can be rotated, sectioned or viewed from any angle. The disadvantage of the solid modeller is that it is laborious, slow in setting up, and needs a large computer's memory to run. The advantage of this kind of modelling from an architectural point of view is that "the building model can be cut through to give a true section" (Woodward & Howes (Ibid: 31), and some systems can provide the facility of take quantities from the solid modeler.

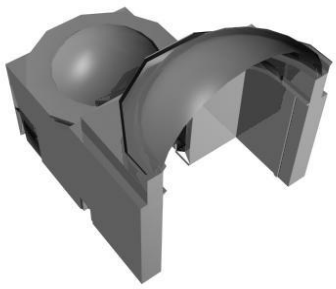

**Figure 17: A solid modeller (Boutsioukis, 2002)**

Woodward & Howes (1997:108) explained that the computer modeling capabilities allow the designer to manipulate the object's model and prepare for representation in several ways: 1- Moving, rotating, and scaling the object as all or any part within. 2- The ability to duplicate the object of the design idea one or more dimensional arrays. 3- The ability of adding to or subtracting from it, or moving some or all without stepping back from the beginning is one of the biggest possessiveness attributes of digital modeling. 4- The ability to be merged with video images or images captured by scanning to look as photo-realistic as required (Alkhoven, 1993:51)

In terms of drafting, 3D (Three-dimensional Modelling) can be analysed to produce plans and elevations, as well as to produce accurate perspectives and rendering of these.

Also, from Three-dimensional Modelling, we can extract volumetric information, to carry out different analyses of thermal, lighting and structure performance.

Pascual & Vicente (1995:26) argue that there are four categories, which the student can take to build a digital model: Geometry; Composition; Texture; and light.

Today, there are various numbers of sophisticated modeling systems, which can be, used for types of investigation of building performances, such as, thermal heating, lighting, and structure performance.

Interacting with digital modeling during design process in recent years caused a controversial debate within architecture education policies; Schools of Architecture must think about digital modeling as a new technique of visualisation and evaluation or, in other words, as a new design tool provided by computer technology.

The joint study program report of 1994[vii] reveals that the tendency of using 3D (Three-dimensional Modelling) as a design tool is broadly accepted in Schools of Architecture (see, QaQish, 1997:89), with digital modeling to drawing on two main reactions: the students' and the instructors' interest and the attitude towards use of CAAD as a design tool within architectural design education.

## *2.3 CAAD: as an Analysis Tool for building Performance of Design Ideas.*

### 2.3.1 CAAD and Visualisation

Kadysz (1994:212) argues that human history saw the development and invention of lots of assistance tools, which seek to extend the possibilities of the human body or intellect, such as the invention of the microscope and telescope to extend human eye or the microphone to extend human voice. In the same sense, the computer (especially by CAAD) seems to be an extension of the architect's intellect and imagination.

The computer's ability to display (to visualize) design ideas during and after the design process was considered one of the great tools accruing from computer development and benefiting the designer.

The literature review has shown that there is a multitude of definitions around the concept of computer visualisation. From the drafting point of view as a broad expression, visualisation is "a graphical presentation of a design idea" (Szalapaj, 2001:225). Whilst, from an architectural representation point of view, Reynolds (1980:80) defines the visualisation as “the methods of generating a representation of a building by computer, techniques known as ‘visualition’ can be used to produce views from any point and from any angle very quickly”. Woodward et al. (1997:151) add, “Modeling (or enhanced drafting) programs … allow models to be viewed from many directions and lighting effects and other physical attributes to be applied”.

There are two kinds of visualisation (Pascual & Vicente, 1995:26): Static, which deals with 2D drawing and 3D (Three-dimensional Modelling), and Dynamic visualisation which deals with 3D (Three-dimensional Modelling), and which incorporates other kinds of effect resources, such as, animation, sound effect, and light effect.

Reynolds (1993) suggests five visualisation methods of model: wire-line method, hidden-line method, hidden-surface method, ray-racing method, and movie method. Woodward and Howes (1997:29-31), on the other hand, categorise CAAD modeling visualisation into five types, namely: wire-line and surface modelers as visualisation aids, solid modelers, animation technique, and virtual reality technique.

#### 2.3.1.1 Rendering

In the last decade, CAAD rendering facilities of computer software have attracted many architects to work with the computer to reach a realistic model, and to attempt to pass information behind design ideas.

There are four kinds of rendering techniques that can be applied to a CAAD model, viz.: Gouraud shading, phong shading, ray tracing, and radiosity technique. All are based on the effects of light on object surface, following the step of selecting texture material.

Most rendering systems today permit the designer to choose the method of rendering. Szalapaj (2001:21) points out that “CAD rendering software allows user to position light sources of various types (for example, point, spotlights, ambient sources), and to define the colors, textures, shininess, and other properties of individual surfaces”.

Moreover, CAAD renderings allow the designer to: 1-change objects, which are constructed as surface into solids, 2 -present the effect of inter-reflection of light between objects, 3- set up accurate viewpoints as ‘cameras’ using the computer ability of numerically defined co-ordinates (Woodward et al., 1997).

#### 2.3.1.2 Animations

An animated picture was defined as "a sequence of two-dimensional images or frames that are displayed in fixed order" (Mitchell & McCullough, 1995:289).

An animated digital model means generating and rendering views from a three-dimensional wire-frame, surface, or solid model. Also there is ability within CAAD software capabilities to animate plan and elevation, axonometric, oblique, and perspective views, which are generated from a three-dimensional model (Ibid: 290)

The development of computer animation techniques (in the sense of perspective) in the early 1960's by the Boeing Company of Seattle[viii] led to sophisticated simulations of movement through an environment to be produced. Later on in the mid-1960s, aircraft firms commissioned research centres to introduce Real-time visual simulation using a colour television screen in aircraft and spacecraft landing and ship docking simulation.

In recent years, the common modeling programs have animation facilities, which can be used to produce a moving picture of the view that would be gained by moving over (fly around) or through (walk through) a model of proposed or existing building. It is made up of individually choosing rendered frames that are then presented sequentially on the screen by a defined time.

The animation program can assist a student to test the effect of environment's components on the model, for example, changing lighting conditions, including: The change of the sun path during a particular day or season. Change in position or intensity of artificial light sources.

From the architectural design point of view, animation techniques can give the designer an assistance tool to understand designs and buildings better, and to see how the building may look in particular space and inspected time (Schmitt, 1999:23).

#### 2.3.1.3 Virtual Reality (VR)

The Longman Dictionary of Contemporary English, (2000:1597) defined Virtual reality in its broad sense as "An image produced by a computer that surrounds the person looking at it and seems almost real".

Virtual reality, as a new dimension of visualisation (QaQish, 1997:82), is a new idiom brought to Architectural practice through the incorporation of CAAD ability within computers, allowing " the user to interact with a computer environment" (Woodward & Howes, 1997:151).

Zellner (1999:10), in addition, defines virtual as a word that derives "from virtus, meaning potential essence or force. The virtual has superseded the real". However, *Virtual Reality,* conventionally abbreviated as *VR,* means "the simulation of real or imagined environment that can be explored interactively on a computer using the mouse or keyboard" (Cohen, 2000: 273).

Similarly, Schmitt (1999:88) states that "virtual reality software systems that allow virtual reality: a computer-created environment, which closely imitates the real world in terms of effects used: it is three-dimensional, it is immersive, it allows things to be picked up and dropped, it gives haptic feedback, for more applications, a special helmet is needed with a display attached to the eyes, to 'disconnect' from the real world".

Woodward & Howes (1997:31) defines VR system as effort to "recreate reality, usually solely visually, and by means of a device such as a data helmet, allow the observer to enter and move within that 'reality' and to interact with it. Desktop 'virtual reality' allows the user to manipulate the screen image of Three-dimensional images by moving the mouse".

The earliest used case of virtual reality as a means of measuring the environment as seen through the human senses was recorded in the 1920s, for aviation practice, which was introduced as a technique of training pilots to land safely with aircraft (Phiri, 1999:63).

Later on, development technology added several functions aiming to improve the performance process of VR, such as motion, shadowgraphs, utilising slides, and films.

The first generation of VR equipment was produced (Zampi & Morgan, 1995:15) & (Phiri, 1999:63) following the addition of sound, the introduction of low cost, high-powered computers, and the invention of specialised graphic chips in the late 1980s.

According to Jason Patterson[ix], " In the early 1990's, the availability of high-powered 3D graphics workstations from vendors such as Silicon Graphics allowed all sorts of interesting uses for interactive 3D graphics to be developed. Computer aided design (CAD) and 3D animation for special effects were two relatively obvious uses, but a more interesting and exciting use was the concept of virtual reality (VR)".

Virtual reality was divided (Phiri, 1999:63) into two types:

First: *Immersive VR.* In this type the participant in the virtual reality event uses headsets, known as a 3Dhead mounted display, or, in some cases, full body armour, with both the headsets and the body armour being, connects to the computer (Figure 18).

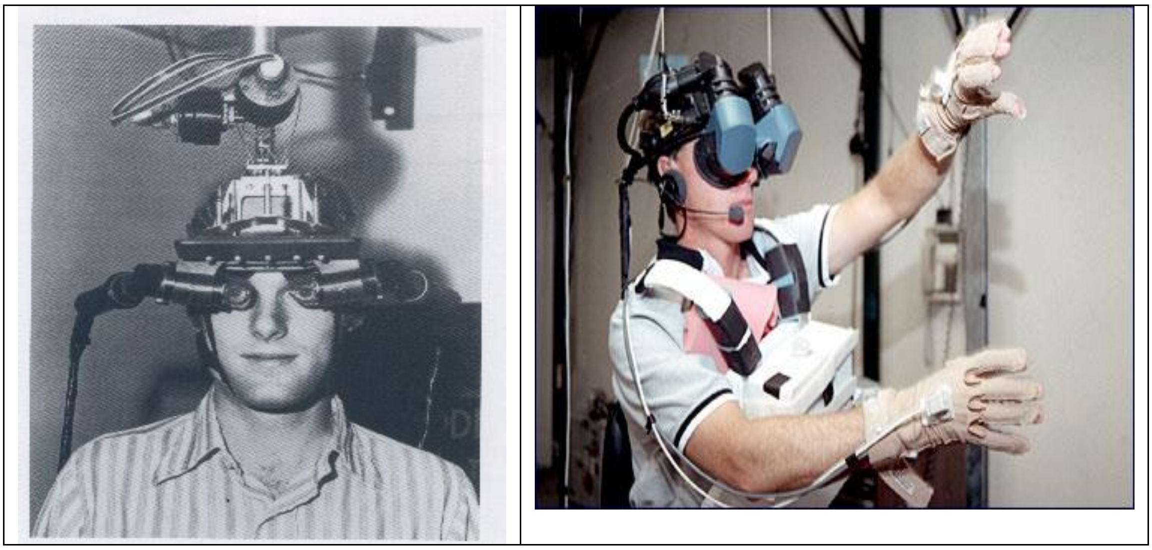

**Figure 18: a- Ivan Sutherland with 3D Head Mounted Display in 1968[x], b- uses immersive VR type to train for space walks.**

Second: *Non-immersive VR.* Or screen-based VR, "where the environment is explored by means of a screen interface or any form of accepted visualisation techniques (Zampi & Morgan, 1995:15) and (Phiri, 1999:63).

Schmitt (1999:26) points out that "Architectural VR is based on a model of physical reality that is stored in the computer as an interactive data set and related operations. Through an interface, the designer or client accesses aspects of reality represented in the model which affect different human senses", therefore, VR from an architectural process point of view, allows the architect (sometimes with client) to see and examine the building before construction work starts, and that is considered the real part of the creative process of architecture (Zampi & Morgan, 1995:15).

The author argues that the introduction of architectural VR in the design studio in ADE will pilot the student towards exploring the potential of the computer as an analysis and assistance design tool rather than as a powerful presentation technique only. In this regard Petric et al. (2002: 73) argue that "The use of VR within the design process provides the designer with an appropriate, quick and practical feed back which facilitates search for design solutions. Moreover, it enables the capture of more information than would be possible to capture with the use of the traditional media and makes the checking of the design solutions more efficient by enhancing simulation capabilities. The use of VR in design broadens the boundaries of traditional perception by providing experiences of worlds not necessarily real or material".

"Although VR is nowadays a quite mature technology, it is seldom used in architecture throughout the design process, but more often it is merely used as a powerful presentation technique" (Petric et al., 2002: 73),

## *2.4 CAAD, Communication and Multimedia*

Maver & Petric (1995:243) define multimedia as an expression showing "the conflation of a wide range of separate media into one suitable computing environment".

In the last decade, especially with the progress in hardware which allows more integration of different media, like video, telecommunication, new input devices or new display devices on the one hand, and the development in software involving multimedia environments with graphical, audio-visual interface, together with the growing ability of integration of different systems for images, video, sound editing, animation, and simulation, architectural education has been moved towards more use of computers.

Hovestadtf & Kohler (1993:391) argue that "Developments in the field of computer science and architecture are leading to new relationships between these two areas, which should influence architectural education".

From the point of view of architectural education purposes, Alkhoven (1993:54) argues that the multimedia environments approach can be very functional on account of the information it can import, manipulate, store, and retrieve in different ways, such as, photographs, text, 2D drawings, digitised maps, computer models, animation, and video. All that will to lead to the establishment of a strong and rich base within the student knowledge.

In regards to teaching architecture, Falk& Carlon (1995) point out that "Multimedia has the potential not only to improve current educational practices but to revolutionise the way that higher education is provided. Multimedia can make lectures more interesting and effective and, more so than books, can provide more varied information to students outside of class. Moreover, having the skills to use multimedia can empower students to learn in new ways and to develop higher-order cognitive skills."

Multimedia was considered one of the most powerful tools for education (Mishima & Szalapaj, 1999) provided by computer improvement in recent years. Moreover, by introducing the multimedia in design work, the student can grasp “the relations and the weight of visual component and acoustical component in the project, giving the student a way to live same sensations as those ones lived if in presence of the real building” (Scianna, 1996:397).

Maver & Petric (1995:243) classified the application of multimedia in architectural and architectural education in general into eight categories as follows: presentation of Design Schemes, explanation of architectural cases, explanation of urban environments, explanation of technical issues, virtual museums of architecture, documentation, interfaces to CAAD, and experimentation.

In terms of presentation of student’s design, Koszewski & Wrona (1995:381-388) observed several aspects of the usage of multimedia:

1- Multimedia can allow the possibility of gathering various kinds and sorts of comprehensive information at one place, which are required for the explanation of a design work: texts, drawings, real-images and sounds. According to Allegra, Fulantelli & Mangiarotti (1995:124), “the hypertext information structure allows the direct intervention on analyzed projects, by pointing out the more important themes and their relationships.”

2- The possibility of easily moving information without the need for rebuilding from scratch.

3- Information being easy to read and to store to computer memory

4- The new advance of technology provides the student with a new tool facilitating the information transfer through access of the global Internet that can “be delivered to any point on the Earth in a manner which is much simpler and more effective than traditional presentation” (Koszewski & Wrona, 1995:385), leading to the possibility of sharing ideas and views around designers’ ideas between different institutions.

## *2.5 CAAD as a support tool for environmental analysis*

When energy saving is not on the top of the design priority, architects (using traditional methods) had to do and organise the majority of design work and the engineer has worked out the details such as lighting fitting, heating and ventilation, needed to aid design ideas.

Since the 1973s, after the Oil crisis, energy in all its forms suddenly became more expensive. That, together with the increase of interest in green issues to reduce carbon dioxide emission (Hanna, 1996: 182), has put great pressure on the architect to design buildings that require less energy and therefore cost less to run (Reynolds, 1993: 163).

The environmental issues and the economic conflict have given rise to energy-saving legislation that affects building design in some countries, and, as a result of such legislation, buildings become more compact, with different shape and different orientation, or less glazing.

Therefore, the would-be designer needs assistance from such bodies to supply him with guides or standards to solve the problems during the design process that is mostly based on complex numerical calculation formula. These can be readily given to a computer, which can be used to test environmental factors. Reynolds (Ibid: 164) argues in regard to this point that “the computer can be used to check on the adequacy of daylighting, specify the amount of artificial lighting required, give the size of the heating plant taking into account all gains and losses, and even print out a comparison between different fuels for the heating plant in terms of installation costs and running costs”.

The advance in the technology of modelling and visualisation software packages, together with the development of computer hardware, offer a new dimension to verify the relationships between the architectural and the environmental components, which is the study of daylighting, sunlight and acoustics.

### 2.5.1 Daylighting

The most important and, equally, one of the complex aspects of the environment performance of a building, lies in the addition comfort element to the living environment. Ka Ming (1997:93) notes that “Daylight phenomena are dynamic, complex and difficult to capture. Students find that they are hard to study and master”. Hanna (1996:181) confirms the point by noting that “daylighting is an extremely important subject in the architectural curriculum”.

Comprehensive architectural criticism theory and attractiveness deem the daylight factor during the design process as having a major effect on the living environment. Hanna (Ibid: 181) argues that “great architects and masters have always placed a great importance on daylighting as the medium through which man communicates with the environment inside and outside buildings”, with the aim of maintaining and improving as much as possible the living environment space.

In current practice, the daylight calculations are generally rarely done at all by hand. Reynolds (1993: 163) argues that the calculation of Daylighting should involve the consideration of the colour and texture of internal surfaces, the amount and nature of external obstructions as well as the shape and size of the window itself (if the benefit of calculating window size is to reduce the amount value of heat loss as necessary, then the use of computers can therefore give a better and more economical design).

In recent years, the advance in virtual space visualisation software and computer ability of analysis bring a new tool that simplifies the technical study of sunlight (De Mesa, Quílez & Regot, 1999: 733)

Design tools for daylight calculation were classified into two groups (Hanna, 1996: 181): Studio-based Tools, which can be divided into five methods (BRE Protractor, BRE Tables, Waldram Diagram, Pepper-pot Diagrams, and Mathematical Formula), and Laboratory-based tools, which consist of two varieties (physical models with natural/ skies, and computerised tools).

On the other hand, Ka Ming (1997: 93) divided the daylighting design tools into three varieties: physical modelling, graphic techniques and computation.

The are so many good lighting software packages available today, such as SPIEL3, MicroLite2, Daylight2, Superlite3, Lumen Micro4, Lumen Micro6, Radiance5, Radiance6, and the 1994 IESNA Software Survey[xi] itself counts up more than 30 lighting design packages that can help the designer and that seem likely to become even more so with time. Given the availability of such a variety of lighting software packages, the question becomes: which software package for daylighting analysis could be taken as teaching tool?

Hanna’s (1996) article, “A Computer-based Approach for Teaching Daylighting at the Early Design Stage”[xii] listed a number of reasons for opting for ‘Lumen Micro 6.0’ software package as a teaching tool for daylighting analysis on the following accounts:

1-The visual information, which can be opted from such a package like Lumen Micro 6.0 in the form of 3D images and perspectives, is very important for the subjective appraisal and that kind of helpful type of performance analysis which will lead students to experience the real life daylighting inside buildings, besides helping to realise the trend education rule of "design by doing".

2- Performance of repeated calculations of sky components gives it an advantage over other ordinary analysis tools and the more expensive physical models experiments.

### 2.5.2 Sun-path and thermal analysis

De Mesa, Quílez & Regot (1999:733) argue that the study of sun-path and linking it with architecture is a traditional idea, but "the use of graphical tools to control sunlight in surroundings or buildings is relatively recent".

Solar gain can affect the internal living space temperature in two ways: 1- Directly by the sun's rays falling on internal surfaces through windows; therefore, the designer needs tools to design windows and their shading devices to control those rays. 2- In an indirect way; the sun's rays may fall on external surfaces and at some later time will appear as a heat gain.

Consequently, the study of solar gain was considered one of the main factors (Reynolds, 1993:166) in thermal analysis especially, when it comes from a clean and constant resource. It is also cheap, from the financial point of view, to maintain comfort zones within living design spaces.

Reynolds (Ibid: 166) argues that thermal analysis is one of the uneasy parts within the design process because "the thermal analysis cannot be performed adequately by non-dynamic analysis; that is by the simple evaluation of formulae. Because the outside temperature will vary throughout the day or night and because the building structure has a thermal 'lag' as it absorbs and gives off heat, the problem is one that requires dynamic analysis and the results will be a graph rather than a simple reading".

In addition to the above, computer capabilities allow for time saving and accurate performance analysis, including the ability to carry out complex automatic formula, in addition to presenting results in the form of diagrams, tables, and the ability to generate highly three-dimensional modelling, perspectives and images, and also the ability to visualise and animate objects.

Brought together, these capabilities make the computer a main and valuable tool for such kind of analysis, such as the SHADOWPACK Package (Ibid: 167), but, as a teaching tool, more research is still needed to provide a suitable tool, useful for architectural education and allowing students to taste the effect of sunrays on design proposals.

### 2.5.3 Acoustical analysis

The acoustic behaviour of spaces was considered (Ibid: 169) one of important aspects of environment performance, especially for large halls in public buildings such as an auditorium.

The importance of acoustic analysis increases with the popularity of open-plan offices and the designer must pay attention to keep a minimum of interference between conversations and other acoustic resources at different points, such as telephone use and the annoyance from photocopiers, the noise level in ducted air-conditioning systems and the spot of fire alarms.

Acoustic analysis aims to provide optimum speech clearness and sound quality without any echo reflections so that listeners can hear them clearly and without distortion, in that case the designer must take the consideration of the echo reflections from surfaces in or around the space, which can distort the sound that reaches the listener by two or more different routes (Szalapaj, 2001:25).

Once more, in this type of complex process, based on different and currently available computer capabilities, the sophisticated computer software can offer more detailed data about the acoustic behaviour of design spaces than it is possible with conventional methods.

The computer programme can calculate the sound and reverberation times and represent it on 3D Models, then import and use them as a basis for acoustic models of space, in the form of a reverberation time (drawing and information tables), and, if it is not satisfactory, there is the ability to change any key parameter, saving time, unlike the case with the traditional method.

At the present, there are a lot of computer software packages which perform acoustic simulation based on two kinds of techniques, namely, Ray Tracing and Pyramid Tracing, such as, IMAGES (Reynolds, 1993:169), and RAMSETE (Ottonello & Dassori, 1998).

## *2.6 CAAD as a tool for Structural analysis*

Structural calculations, one of the earliest practical applications of CAD (Mitchell, 1977:16), which provide great assistance to architectural practice, were explained by Szalapaj (2001:17) thus: “to evaluate the distribution of stress or temperatures in mechanical components undergoing force or heat loading, and vibration analysis of components can also be carried out when they undergo dynamic loading”.

The need of Aircraft and Automobile firms for advanced technology techniques to specifically calculate stresses in design schemes bodies has pushed architectural practice to use those analysis softwares in different design stages, such as Frank O. Gehry, who used CATIA[xiii] software to produce a digital model for design the new Guggenheim Museum in Bilbao, 1991-1997 (Figure 19), by digitising the physical design model[xiv].

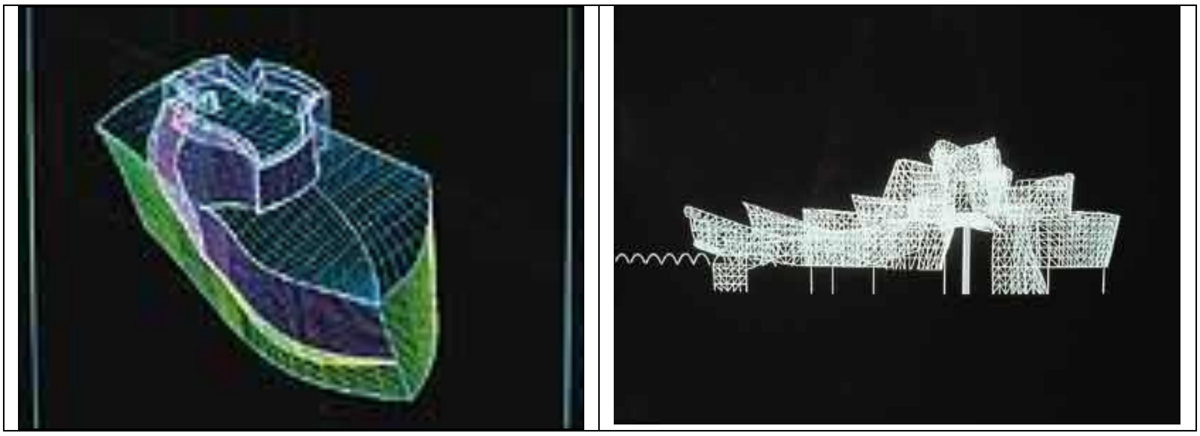

**Figure 19: Using CATIA software to produce digital model and steel frame drawing of Guggenheim Museum in Bilbao[xv].**

And from the point of view of teaching architecture experience, MacCallum and Hanna (1996: 253) state that “the teaching of structures and its integration with design teaching has been seen as one of the major problems in design education in Schools of Architecture world-wide”. They note that in this regard there is a weakness in architecture students’ knowledge about how structures work and that sometimes, they do not even understand basic concepts of structure analysis.

Consequently, the students' creativity within the design process will be affected by the lack of a structures-based knowledge (Pittioni, 1991: 220).

For all that, using computer with CAL packages as an active learning tool will help students understand structural behaviour of building components under different load effects (MacCallum & Hanna, 1996: 253) and that will also help them to generate fluent design solutions (Maher, 1997: 5).

In the 1970s and 1980s, advanced tools to support students in the design process were limited numbers of CAL structural packages as a tool aiding architecture design education. In fact, some of them have not been designed as a tool for the teaching or learning of structure analysis.

As a result, some institutions sought to develop a computer-assisted learning package, for example, DEFLECT[xvi], SAM[xvii], in order to improve the quality of teaching in architectural education and the use of computer as a 'substitute' tutor.

Today, there are many of structural analysis softwares available to architectural design students to explore and use for evaluating schemes at various stages, especially for the analysis of dynamic responses in structural assemblies, and by schools adopting the approach of using computer to teach structure within design education, students can bridge the gap between the way they are taught architectural design and architectural science (Maher, 1997: 5).

Pittioni (1991:220) argues that, in practice, the designing architect could not work without seeking assistance from specialists (heating, plumbing, air-conditioning, water-supply and the structural engineer). On other hand, students of architecture will not have achieved better results if they ignored the advice of experts in structure analysis.

The structure CAL packages are therefore useful to introduce to architectural students in architecture design studios, especially in early design stages to support the design idea.  In Pittioni's opinion (Ibid: 221), Schools of Architecture must think about the contradictory views of CAD and CAL structural advice employed in the design studios.

## *2.7 CAAD and Urban Design*

The design of urban environment, considered one of the most complicated issues facing both architectural practice and architectural education, refers to many factors:

1-Urban environment infrastructure naturally based on difference changeable databases (variables), which are dynamic and directly affected by such diverse factors as economic and demographic changes such as size and gender of the populations.

2- From the point of view of building images within cities and towns, Alkhoven (1993:9) argues that "The image and structure are constantly subject to a dynamic process of change and continuity. Repairs, replacement, rehabilitation, redevelopment, demolition, and urban renewal take place in every town", which, when combined with services, can cause difficulty for urban studies.

Therefore, an urban environmental study encompasses a wider scope of knowledge related to such factors as townscape, architectural landscape, design form, urban history and also architectural planning.

For these reasons, urban environmental studies, as a cross road of different kinds of disciplines, need more organisation and manipulations of database obtained from different principle resources. The important issues in regard to data organisation are how the data is collected, saved and stored without duplication (Grant & Paterson, 1994:138).

From the point of storing, manipulating, visualising, and retrieving the data views, the computer, together with Internet and its abilities, can offer quite new perspectives for architects as well as a new challenge (to clients or residents who can participate via sophisticated visualisation and modelling software packages via the Internet) in solving urban design problems (Rüdiger & Holmgren, 1999:708), and the computer's role within IT becomes clearer if the data is stored at several locations by a variety of bodies.

Grant & Paterson (1994: 137) explain that "The urban visualisation software provides a means of modelling and manipulating the spatial data about the buildings and the urban infrastructure. This allows the display of the massing of the urban fabric, the nature of the skyline and the detailed appearance of the urban spaces". Those urban fabrics were identified as urban physical structures consisting of architectural objects, traffic infrastructure and natural elements (greenery, water areas and streams) (Simovic, 1991:100).

Based on Grant & Paterson's (1994) definition, Danahy (1990:364) identifies three basic elements that the urban design system must support: terrain, built form, and vegetation, especially in architectural landscape.

Danahy (Ibid: 364) further argues that the architectural modelling software is useful for the construction of geometrical forms. Nevertheless, there is little software for the modelling of topography and vegetation, and, in particular, issues of landscape design such as vegetation growth.

In design education, teaching of urban environment, parallel with architectural landscape issues, and its integration with design teaching has been seen as one of the major problems.

Consequently, some institutions in recent years have been interested in the development of a package that would improve students' visual thinking and decision-making skills and examples of such packages include: ABACUS[xviii], TRIM and TUMMS[xix], and URBIS[xx] software packages, and to eliminate, via use of the computer, wasting time in crafting terrain models, that is, in other words, by letting the student concentrate more on the theory than on drafting issues.

Recently, IT and the Internet have offered a new teaching approach to architectural education through the virtual cities that are commonly known as virtual design studios.

Rüdiger & Holmgren (1999:712) point out that by the development of Three-dimensional Modelling, integrated with WWW, form "a tool for presentation to an information system will change the structure of the organisation of the Local Council" and will affect the role of architects and urban designers, and, so, will bring new challenges to architectural education policies.

## *2.8 CAAD as a tool for Historical Research*

Over the past twenty years, architectural practice in general and architectural education in particular has witnessed a massive development in computer technology. Computers have today becomes part of every single work unit.

Koshak & Gross (1998:104) argue that computers provide easier and faster capabilities to deal with available information than traditional tools. By constructing a 3D (Three-dimensional Modelling) of objects, immerging with different kinds of visual sources, such as photographs, text, digitised map, the computer ability to animate objects and video, architectural researchers can make a digital database of the building.

Also, attention can be drawn to the fact that software has been developed to transform a database of measurements into CAAD drawing. Whilst CAAD capabilities can allow the architect to design for the future, they can also be used as drafting tool for drawing existing architectural buildings. Even more, the CAAD software capabilities can provide a useful tool to construct objects that do not exist (ancient cities or building) or were demolished (by earthquake or any natural forces) (Alkhoven, 1993:50).

The computer's ability to construct a digital model and generate rendering can provide realistic representations of building, all of which capabilities can supply a base for walkthroughs, flybys, and virtual reality tours within and around a historic building. Besides, text can be linked with a CAD model to expand a comprehensive database that merges visual and textual information about a building (Koshak & Gross, 1998:104).

In addition, after construction of a Three-dimensional computer model, any type of projection from any angle can be selected.

From the point of view of history of architecture, there is the possibility of getting assistance from computer software capabilities as analysis tools, to help the student to understand what is behind the idea of historical masterpieces, which is the main object of teaching history of architecture. Galli & Mühlhoff (2000:9) argue, in relation to this point that we can carry out analysis of drawing and sketches of historical masterpieces "to make a correct evaluation of architect's work, his composition methods, cultural references and sources of inspiration. It also helps us to understand the design process, from the conception of an idea to its definition on paper and the different variations", and to put forth this kind of computerized analysis will "preserves information for future generations to learn from the past" (Koshak & Gross, 1998:103) and help promote an atmosphere of critical debate within architecture design studios.

Alkhoven (1993:52-53) recorded several advantages of the use of CAAD as an approach of teaching and learning history of architecture:

- CAAD, as an assistance tool, can lead Students of architecture to learn something about the history of architecture, and, especially, to grasp the idea behind lines and forms that cannot be easy to obtain by traditional ways.

- By being able to make a graphical representation in different perspective views and projection, the student will be forced to analyse an architectural idea in terms of its three-dimensional structure as a new and different approach to the design process.

- The research into and study of historical buildings will obtain more accurate results by using the computer's ability to view the building from any possible viewpoint, particularly when the new drawings of that building are compared with old drawings and photographs of a building from the same viewpoint.

- Once more, from the history of architecture point of view (typically, restoration study), this approach, with advanced IT, can give great assistance to comparative studies between exiting building and the architectural treatises on which this building is based.

In recent years, in spite of the fact that historical research has only rarely used the possibilities offered by CAAD techniques (Galli &, Mühlhoff, 2000:10), the trend of using CAAD as an analysis tool has become more obvious especially with postgraduate students (Figure 20 & 21).

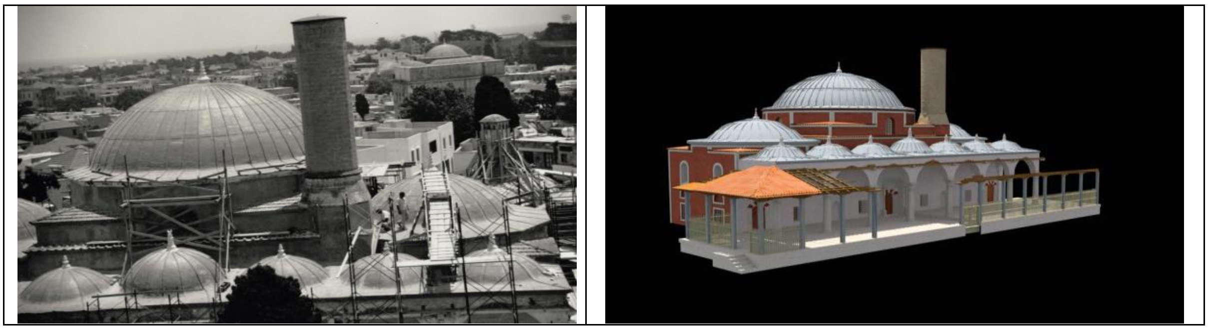

**Figure 20: Using 3D modelling software package to illustrate a historical building (Suleiman Mosque- Medieval City of Rhodes- Greece).**

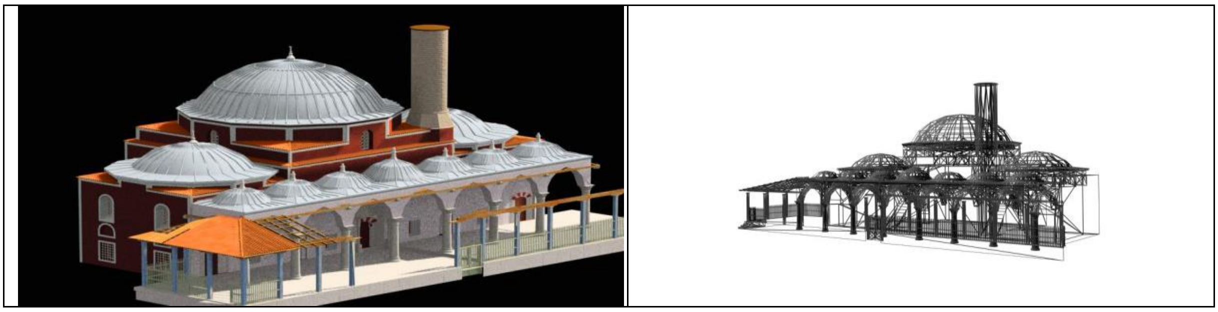

**Figure 21: Another different view of using 3D modelling software package to illustrate a historical building (Suleiman Mosque- Medieval City of Rhodes- Greece).**

## *2.9 Communication, Internet and WWW*

In practice, teams usually carry out all design and construction tasks, with some division of labour and support technicians among the members of the team. Therefore, there is a tendency to spend large amounts of time needed in communicating with each other or organising meeting with consultants, and so on.

Traditionally, the design team members have to cluster themselves in offices or special rooms to carry out their work. But, still, they need access to drawing archives, technical reference, and print machines.

Today, the ability of advanced computers to communicate electronically (digital telecommunication), combined with computer-aided design techniques, can reduce time required for such co-location (Mitchell & McCullough, 1995:441).

Computers can be connected to two different types of networks: 1-A local area network (LANs), which allows computers to be connected within a small geographical area via cables or wires. 2- A wide area network (WANs), which allows connecting computers in a much larger geographical area through telephone line, microwave or radio signals.

Moreover, LANs are mainly private networks; on the other hand, WANs according to Woodward & Howes (1997:113), "require the use of public telecom, and the Internet is a WAN that connects computer all over the world", and world wide web (WWW) can be used as a new way to obtain information from different sources.

The use of LANs and WANs, via a computer modem and the use of sophisticated software as a way of communication, together, can provide several advantages:

- Allow users to share the output resources such as plotters, printers, scanners, etc.
- Quick access and exchange of data information with other users.
- Exchange messages through e-mail.
- Via the network, the team can access and use a single copy of an application programme instead of individual copies.
- Use of the computer-supported collaborative design (CSCD) via network, allowing designers to work together on one task at the same time.

Yeung, et al. (1998:93) argue that "the evolution of the Internet and World Wide Web technologies have significantly enhanced the global communication and collaboration. People, no matter where they are, are virtually getting closer and closer. The barriers that came from time and distance have been partially removed by the use of such technologies. Internet and WWW are not just technology, they are an environment or apace".

The Internet aims at connecting people from the entire world through a telephone network, and "has existed for a long time in other, more primitive forms" (Schmitt, 1999:63). The real development of World Wide Web (WWW) was started by the creation of the Hyper Text Transfer Protocol (HTTP) in 1989, followed by the appearance of the web browser Mosaic, using the point and click paradigm.

Since the middle 1990s, the term Internet has become widely used in education domain. In terms of teaching architecture, many course tutors today around the world are using WWW as an assistance tool in the teaching and learning process. Woodbury & Chang (1997:465) recognised "the majority of these are using the WWW as an electronic substitute for the traditional forms of a syllabus, lectures, tutorial notes and handouts", besides other different usages such as electronic design studios, galleries of student work, distance education, and student collaboration and communication via devices such as bulletin boards that have recently come to be known as Computer-supported collaborative work (CSCW)[xxi].

The use of the Web in teaching architecture should go beyond the delivery of subject material and towards using it as a method for promotion of new forms of communication among students and academics, with the aim of saving time and achieving more accurate and creative production (Woodbury & Chang, 1997: 465-472). In parallel to affecting design teaching, and from the point of view of the tutor's and educational administrator's position, the WWW resources offer both opportunities and fears, which are:

The new form of teaching, using WWW in architecture design studios, is expected to increase the potential efficiency of co-teaching subjects between institutions.

The WWW will offer new forms of communication such as e-mail, video, a common drawing platform (whiteboard), a bulletin board, and a gallery of student work with potential of submitted works or assignment through it, and, so, will be expected to reduce staff contact time.

WWW offers an opportunity to experience directly the changing worlds of architectural practice towards using it as a tool of sending and getting information.

The Web widens opportunities for assisting students to adapt to the theory of self- and peer-directed learning.

Using WWW as a new form of teaching will bring to light the issue of blurring institutional boundaries, thus challenging the conventional regulation policy.

Yeung, C.; Cheung, L.; Yen, J. & Cheng, C. (1998:94), in the same line of thought, pointed out that "the increasing usage of Internet and WWW technology have brought us not only a new way of information assimilation but, also, a change in the social structure of mankind", which, in turn, brought another challenge that will face the existing architectural education by raising a new question: How can Schools of Architecture apply Internet and WWW technologies to support teaching and learning in ADE?

## *2.10 Summary*

This chapter has endeavoured to present the various facts and meanings of CAD and to sift through the enormous and, at times, controversial amount of views and arguments expressed in the relevant literature.

A great deal of attention was paid to the benefits of CAD capability in general to architectural practice, allowing us the opportunity to discus the same benefits to architectural design education.

The development of software systems has caused a recognisable change in trend as well helping with drafting and attracting a wider audience, into giving an additional support tool to the design process by finding more sophisticated 3D (Three-dimensional Modelling) and visualisation packages.

Since late 1973 and after the oil crisis, the design priority has changed, with more attention being paid to environment issues and its features. Consequently, environmental analysis tools (lighting analysis, thermal analysis, sunlight analysis, etc.) have become more vital within the design process.

This chapter has attempted to map and represent the various meanings and natures of computer capabilities, and how architectural education, in general, and the architectural design process, in particular, can take benefit from such capabilities.

The CAD capabilities discussed so far in this chapter have all found their place in architectural education and architectural practice in some way or another, as part of computer applications, with different views and policies.

MacPherson (1985:27) argues that "each school must choose the approach which interfaces most successfully with it is own specific objectives in order to maximize the long term benefits. To achieve this and to minimize the possible risks of an expansive failure, attention must be focussed on the analysis of requirements and available software and not initially on hardware capability. The selection of the wrong system, or approach, can have long term damaging implications."

This chapter also raises challenging questions to architectural education policy, curriculum and course contents. How can these capabilities be productively integrated into architectural education in general and architectural design process itself? And what is the best way available to teach architecture-integrating computing?

At eCAADe2002, Marc Aurel Schnabel, from the University of Hong Kong, argued that "new technologies always shaped the curriculum of architectural studies" (quoted in Mark et al., 2002:209). Assuming the validity of that argument, the question, then, is: to what extent did the computer shape the curriculum of ADE?

Chapter three will seek to discuss some possible applications related to the main and principal question: *How may we teach CAAD within ADE?*

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# Chapter Three: The Relationship between Architectural Design Education and CAAD Courses in the Curriculum.

## *3.0 Introduction*

The aim of this chapter is to discuss the integration of CAAD as an approach for teaching architectural design, within architectural curriculum in some depth.

The effect of using computer technology on our society has been clearly visible during the 1980s and 1990s, during which time there have been dramatic changes in every single aspect of information in society in general and in the construction industry in particular.

A literature review of the period shows great changes recorded in perception and practices in architecture and in the trend towards adopting computers within the architecture design process, which has had its fullest impact on architectural education as a result.

There is no doubt about the importance and potential impact of computers for the knowledge base of architects and engineers today. As a result, Schools of Architecture face the issue of teaching and learning integrating new resources in knowledge (called IT as a general term and CAAD (Computer-Aided Architecture Design or Drafting) as a specific term). Nicol and Pilling (2000:1) argue " Architectural education must respond to these changes: it must enable students to develop the skills, strategies and attitudes needed for professional practice and it must lay the foundation for continuous learning throughout life".

The literature reveals, (for example, Bridges (1983), Neilson & Lee (1993) Moorhouse (1996), Dawson & Burry (1996), Sliwinski (1996)) that introducing CAAD to the architecture design education curriculum will raise a number of educational complications and that it remains an extremely controversial issue.

From the employability point of view, to cope with the practice demand, in the UK "it is a RIBA requirement that all schools teach CAD, although the extent to which it is compulsory, continued or committed varies" (Hales, 1999). Possession of specific CAD skills in students' knowledge base will give them advantage in work placements at the start of their professional career (Neilson & Lee, 1993:189). Similarly, Moorhouse (1996:281) adds "Exploring the possibilities of CAAD designing as an integral part of learning to design will equip the student with the CAAD literacy necessary for working in practice, but more importantly will provide the student with a rich and diverse understanding of design approaches".

By introducing CAAD to the architectural curriculum, schools will be caught between two quite different opinions, should Schools of Architecture teach design integrating CAAD or follow the traditional manner? As Novitski (1999:39) argues, "Professors typically emphasize design and theory, believing that the more practical skills are better conveyed in a professional context. They fear that offering more skills-oriented training might turn the professional institutions into vocational schools. Meanwhile, practitioners complain that recent graduates come to them unprepared for real work".

Because some Schools of Architecture integrate computers based on a theoretical emphasis rather than on a professional based needs approach, and Novitski (Ibid: 39) points out, "Some interns are entering firms with computer-aided design (CAD) skills that far outstrip those of their employers That's because some architecture schools have incorporated new digital technologies in such radical ways that the curriculum is being transformed".

In terms of CAAD integrating with the ADE, Barber & Sharpe (2001:42) argue "There is a move to use computers as an integral part of the studio in architectural education. However, the technology is continually developing, and so there is a process of transition from traditional skills toward computer-based forms of studio teaching. The use of computer modelling may allow different forms of exploration and this will have implications on both design and assessment. Accordingly, studio programmes and briefs need to reflect these opportunities".

The relationship between architectural education and CAAD courses in the curriculum needs to be clarified. This will only happen if we develope an understanding of CAAD applications and their relevance to both the curriculum and education theories.

This chapter is concerned with the issue of integrating CAAD with architectural education. It starts with a general clarification of two main issues: theories of CAD applications and the CAAD view in architectural education, beginning with a brief history of CAAD in architectural education and then going on to look at various forms of debate on introducing CAAD within the schools curriculum.

These issues continue to cover concerns in many articles and conferences, ever since computers were first seen as relevant tool to architecture design education (ADE). They are best discussed by trying to answer the following questions posed as a part of the main question of this work.

- *How and when should CAAD be introduced in the curriculum of architecture design education?*
- *How may we teach CAAD with architecture design education? Or how may we teach design in the computing studio?*
- *What are the main obstacles affecting uses of the computer in architecture design education? Why does CAAD not fully exist in current Schools? (Asanowicz, 1998)*
- *How can we design with CAAD? Or To what extent can CAAD be integrated into the architectural curriculum?*

The aim in seeking answers to the questions is to get a general idea of how to incorporate CAAD in ADE's curriculum, through realising the full potential of the computer in the architectural design process.

## *3.1 CAAD applications*

CAAD applications mean to carry specific tasks. From an architectural knowledge point of view, it means carrying drawing in addition to, word processing, and auto-numerical equation, which can be used in different related analyses such as lighting analysis, acoustic behaviour of spaces, air-flow, etc.

General applications in architecture are described in this part simply to show how the CAAD systems can be used to assist architectural work in the practice of architecture and in turn the architectural student in the same way, during their work within their studies.

Since the first use of computer programmes or 'CAD' programmes, in particular through the late 60s, the number and the range of applications have increased to cover the whole range of architecture practice.

In his important work "Computer-Aided Architectural Design" Mitchell (1977:9-18) put forward eight categories for computer areas of application as follows:

I-*Numerical computation in science, engineering, and operation research.* This is the earliest, fundamental, and most obvious application of computer technology. The purpose is the automation of complex, lengthy, and repetitive numerical functions, for example, the generation of ballistic tables, astronomical tables, and so on.

II-*Statistical analysis and business data processing.* According to Mitchell, this application is the second most important early application. Automated data processing techniques have a long history dating from the late 1880s when Herman Hollerith devised a system for recording census data in the USA (1890) where data was recorded on punch cards and an electric tabulating machine compiled and tabulated the data.

III-*Data analysis***.** The combination of two previous capabilities as a result leads to data analysis and makes it extremely useful for the social, physical, and life sciences.

IV-*Process control.* In this next stage the computer moved out of research laboratories where they were developed, into the everyday environment of factory and offices, into commercial ships and airplanes, and even into the environment of military and space vehicles. Such success was achieved based on computer technology advances in both hardware and software, because the computing machinery generally had become smaller, cheaper, and more robust.

V-*Person-machine systems.* Mitchell traces the concept of person-machine intellectual interaction back to the 1920s by the Pressey teaching machines. The machine function was to present questions to students and the machine gave the correct answer after an answer had been made and checked.

VI-*Computer graphics and image processing.* Computation technology development reached the stage of control of output such as pen plotters for production (engineering, architectural drafting and production of perspectives and mapping technique). Moreover with the advent of cathode ray displays to generate pictures, firms financed computer researches towards producing systems of sophisticated simulations of movement through an environment.

VII-*Artificial intelligence.* By constructing the first modern computers and putting to work numerical computation and data processing around 1950 the opportunity to use computers to solve difficult intellectual problems of a non-numerical character increased, beginning with Alan Turing's[xxii] question can machines think? Posed in his paper "Computing

Machinery and Intelligence". Turing argued correctly as has been shown " I believe that in about fifty years' time it will be possible, to programme computers …to make them play the imitation game so well that an average interrogator will not have more than 70 per cent chance of making the right identification after five minutes of questioning." (Turing, 1950), "Computing Machinery and Intelligence"[xxiii]

Progress in *Artificial intelligence* has been extremely rapid, and Mitchell (1977:13) here lists some main types of Artificial intelligence systems that have been developed: complex games, in the area of natural language (interpretation and translation), performing complex physical manipulation tasks and solving spatial problems such as path finding in a complex physical environment, acting as highly sophisticated and flexible teaching machines, industrial robots, voice-operated supermarket checkout systems, medical monitoring systems, and so on.

VIII-*Computer-aided design.* With the presentation of Ivan Sutherland's *Sketchpad System* (Figure 22) at the 1963 Spring Joint Computer Conference, serious CAD research development started to generate interest among many engineers in the potentials of the computer and the move towards using the computer in engineering drawing. As an aided tool the "Sketchpad system allowed an engineer to generate designs by sitting at an interactive graphic terminal, and manipulating drawings displayed on the screen by use of light-pen and keyboard" (Ibid:14). The general features of that development are as follows:

**Figure 22: Ivan Sutherland and TX-2- Sketchpad Project, MIT's Lincoln Lab., 1963**[xxiv]

- Sketchpad System challenged major companies (automobile firms and aerospace firms) to adapt a new design approach, for example, General Motors commissioned IBM to develop DAC-1 system[xxv] for automobile design this" was to be forerunner of many interactive computer-aided design systems installed by automobile and aerospace firms by the end of the 1960's" (Ibid, 1977:15).

Mitchell argues that the application of CAD in architecture practice came after CAD applications in engineering (mechanical, civil, electrical, chemical, and industrial engineering), and the fundamental reason being economic, in that automobile and aerospace firms are very large and able to invest in expensive equipment, while on the other hand, architectural firms are relatively small and unable to do this.

- During the early 1970's computer applications were in widespread use in architecture practice and interactive computer graphics systems began to appear after costs dropped as a consequence of technology development. Moreover Mitchell argues that a few government, private agencies and private foundations have supported the basic CAD research in USA, which was begun in academic labs.

- In the UK, the development of CAD systems research has been influenced by the public-sector building programs (Mitchell (1977:16), Phiri (1999:54)) for example:

-West Sussex County Council and the *SCOLA-based* system (1968), which was used for design offices in Chichester "to produce descriptions of buildings, cost analyses of designs, environmental and structural evaluations and automatically-generated construction documentation" (Ibid:54).

-*HARNESS* system (1972) sponsored by the DHSS (Department of Health and Social Security) for use in the HARNESS hospital building program " the high level of standardization allowed complete automation of the design process with the computer system performing structural, environmental and cost evaluation, automated generation of layouts, perspectives and production documents" (Ibid:55).

-*OXSYS* system (1972), sponsored by Oxford Area Health Board, used for designing hospitals. The system can help cost estimation from early sketch design in addition to, structural and environmental analysis, semi-automatic design also for detailing along with production of contract documentation.

-The Department of the Environment and the CEDAR, *CEDAR2* systems, (1972) used for Post Office buildings and redeveloped for design of PSA (Property Services Agency) office buildings, which had capabilities for daylight, thermal and acoustic analysis together with documentation.

-The Computer-Aided Design Centre at Liverpool University developed *CARBS* (Computer-Aided Rationalized Building System) in 1973, for design evaluation and documentation.

-The University of Strathclyde made a concerted effort to develop fully CAD systems (*SPACES* (1972), *SPACES1*, *SPACES2*, *SPACES3*, *GOAL* (1978), *PARTIAL*, *PHASE,* and *AIR-Q*).

-CAAD Studies (Ed CAAD) at Edinburgh University developed the *SSHA* system in 1972 for the Scottish Special Housing Association used for house design and site layout.

- The commercial CAD systems saw a breakthrough in the early 1980's with the advent of the personal computer (Schmitt, 1999:7) such as *GABLE* CAD system developed by the University of Sheffield (Phiri, 1999:57).

- The last decade had shown dramatic improvements in IT, Schmitt in "Information Architecture: Basis and Future of CAAD" gave a brief summary of CAD development " The 1990's brought the general affordability of three-dimensional modelling, rendering, animation, and multimedia presentations. The significant development since the mid 1990's has been the growth of acceptance of the WWW and its application" (Schmitt, 1999:7) such as VR, CSCW (Computer-Supported Collaborative Work) as a new kind of teamwork and distance learning trends as a consequence of using WWW technology.

In using CAD applications in an architectural office, software applications fall into four major groups according to Woodward et al. (1997:26):

*Office management***:** include word-processing, desktop publishing, graphics, spreadsheets, accounts, filers, databases, personal organizers, and presentations.

*Design aids:* as in surveying, working drawing, drafting, modelling, visualization, animation, virtual reality (VR), structural and environmental analyses, costing and quantities, also generate specifications.

*Running a job:* job costing, project management, for example, a timetable.

*Communications:* internal and external networks.

Consequently, the computers as a tool from the beginning opened a new way for the researchers through universities for more and more studies since that time, and produce a new movement for the implementation of computer-based techniques through the results of their research.

In an architectural design studio office, Gero (1977:6-7), Table 2 shows in some depth how software application can enrich and assist every single work (from Office Management, Project Management which includes: collecting information, survey questionnaire, Scheduling, etc., up to the stage of cost Estimating, Specification Writing and Preparing bill of quantities).

| | |
|---|---|
| Management and project control | Timetabling and programming, critical path programming, and general management aids. |
| Accounting and cost control | Timesheet analysis, accounting, general job costing, general cost controls aids, and estimating. |
| Information handling | Specification editing, commodity information, general information retrieval, and briefing information. |
| Quantities and schedules | Bills of quantities, schedules, and cost planning. |
| Site and land use studies | Site planning, surveying, cut and fill analysis, town planning, and transportation. |
| Plan layout and analysis | Generation of layouts, particular building layouts, analysis of layout, and briefing. |
| Structural engineering | Frames, and constructional elements. |
| Services engineering-pipe work, ducts | Pipe work and plant, duct design, lifts, and drainage |
| Services engineering-heating and cooling | Cooling loads, Heating loads, Energy consumption, and environmental performance. |
| Services engineering- lighting, sound and electricity | Natural lighting, Artificial lighting, Noise, Electricity |
| Graphics | Two-dimensional graphics, Three-dimensional graphics, Mapping, and General graphics. |
| Integrated systems | |

**Table 2: Gero's list of software application in design office (Gero, 1977:6-7)**

As can we see from Table 2, computers can assist management with design work, for example, to prepare a timetable, and to write, send and save documentations in digital files which are simple to hold, such as bills of quantities, cost estimating tables. Moreover, by using the capability of statistical analysis systems, it can analyse, manipulate and visualise complex data that are collected before and during a design process.

The stage of sophisticated control of output devices that was reached by computation technology development via interactive computer graphic systems allows architects more rapid and accurate production than by conventional manner. Architects, by using computers, are able to draw two-dimensionally and three-dimensionally with different scales from different views, saving more time.

From Gero’s views at that time (1977), it will be seen that the Internet and animation as a way of communication to convey, obtain and handle information within design team collaboration do not appear. On the other hand, Sanders (1996:70) gives another, more clear view of software applications in architectural design studio office, based on task work as shown in Table 3.

| | **Design** | **Drafting** | **Specification** | **Project management** | **Business** | **Estimating** | **Business development** | **Interiors** | **Administrative** | **Personal** | **Contracts** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Word processing** | | | ● | ● | ● | ● | ● | | ● | ● | ● |
| **Spreadsheets** | ● | | | | ● | | | | | ● | ● |
| **Flat file database** | ● | ● | | | | | | ● | | ● | |
| **Relational database** | | ● | | ● | ● | ● | | | | | |
| **Slide preparation** | ● | | | | | | ● | | | | |
| **Project scheduling** | | ● | ● | ● | ● | ● | | ● | | | ● |
| **Contact management** | ● | | | ● | | ● | ● | | | ● | |
| **Calendar** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Multimedia** | ● | | | | | | ● | | | | |
| **e-mail** | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● | ● |
| **Messaging** | | | | ● | | | | | | ● | |
| **Messaging** | | | ● | | | ● | | | | ● | |
| **Internet browsing** | ● | | | | ● | | ● | ● | | | |
| **Two-dimensional CAD** | ● | ● | ● | ● | | ● | | ● | | | |
| **Three-dimensional CAD** | ● | ● | ● | ● | | ● | | ● | | | |
| **Visualization** | ● | | | | | | ● | ● | | | |
| **Animation** | ● | | | | | | ● | ● | | | |
| **Virtual reality** | ● | | | | | | ● | ● | | | |
| **Desktop publishing** | ● | ● | | | ● | | ● | ● | | ● | |

**Table 3: Sandres's Software / task matrix (Sanders, 1996:70)**

From Table 3 one can argue that computer's software assist the design process at different stages, for example, e-mail and calendar facilities provided by computer technology can be used through all stages of the design process. The table also illustrates that two and three-dimensional CAAD systems can assist the architecture design process in the following stages: design, drafting, preparing of specification, project management, to estimate the cost of the design building, and to demonstrate the interior design idea.

With capabilities for visualisation and animation, the computer can be used to present an idea behind lines of the design proposal in three different stages: design stage, business development, and interiors stage of design work.

Mitchell and McCullough (see Sanders, 1996:71) classify the CAAD application by the dimension of the media manipulated as follows: I-One-dimensional media including words, text, and sounds; II-Two-dimensional media including images, drafted lines, polygons, plans and maps; III-Three-dimensional media including lines in space, surfaces, renderings and assemblies of solids; IV-Multidimensional media including motion models, animation and hypermedia.

Johnston, et al. (1989) discusses Computer applications in three general groups: direct instruction, working tools, and information exchange

From the way of using the application in wide-ranging teaching Davis (1993) illustrates the advantages of using the computer by assembling the application through two categories:

I. Tutors can use the Word Processing with presentation software to prepare lecture notes, syllabi, tests and exams and class handouts. The computer can enable tutors to make revisions quickly, update the information available and add new material, and to move or combine topics from one set of notes to another.

II. Computer applications in both hardware and software provide a new tool in the area of communication, for example, using Web for e-mail.

Through the potential of e-mail, the tutor as well as design members in collaborative work can send and receive information messages at any time, day or night. They can be used to set coursework or to comment on work, used to communicate important class information. Student can post homework assignments through e-mail and submit homework and papers through the network. e-mail also allows users to forward entire memos or papers to others and to file away particularly interesting communications for later review or editing.

By introducing e-mail within architectural education (both in teaching and learning), schools of architecture can extend classroom discussions outside the classroom. Davis (Ibid) finds that electronic discussions avoid the common classroom problem of one or two students always dominating the discussion.

With such a broad history of software application, and given time limitation, and the core objectives of this dissertation, it would be impossible to describe in detail every single application of software in architecture content with the main and general application. Thus the research, to be satisfactory, will summarise the history of CAAD software applications to give general idea.

## *3.2 The status of computer and CAAD teaching*

The computer as an aid or tool in architectural education has occasioned much debate, is a controversial issue, and provides scope for argument in many conferences and journals.

Scianna (1996:392): in his article “What software for instruction in architecture?” argues that, computer science is progressing very fast in three different directions: hardware level, base software level, and application software level. Consequently, the computer technology development makes available more powerful and easy to use instruments. Architecture practice and architectural education are concerned in taking part in the computer development.

### 3.2.1 Computers in teaching and learning generally

Since the first realisation of the usefulness of the computer as a supercomputer, the variety of uses of computers in education has extended enormously. Ellington ([09], 1987:3) in his booklet about how computers can be used in tertiary education, classifies the handling of computers within education into five main categories according to direct functional use:

1-Use of the computer as a super-calculator for carrying out complicated calculations with great speed and accuracy for academic research. For some time this was the only role. Today, the majority of statistic software packages are based on this common role, for example, Mini Tab and SPSS packages.

2-Use of the computer to teach about computers and computer programming.

3-Use of the computer in an administrative or managerial role. Ellington argues that the computer can be a helping tool for management of the teaching and learning process (CML) such as timetable planning. Moreover, the computer can help to generate, mark and analyse tests, and the school can use that data for preparing reports on the progress of the (each student, the course tutors, course plan etc.).

The computer could be used to give guidance for each student about the course structure before and during the study via school Web sites on the Internet.

4- Use of the computer as a database directory, this feature is one of the most important uses of the computer in modern society during the last two decades, also as one of the earliest features of information technology, which differs from conventional forms of reference, such as libraries. " The information they contain is stored electronically, and can be accessed from virtually any distance using a remote computer terminal connected to the central computer by telephone link" Ellington Ibid:10).

Every educational system trying to integrate computer with curriculum will find that there are some factors affecting the use of computers: technical factors, the availability of suitable software, and attitude.

5- Use of the computer as direct aids to the teaching/learning process (CAL), as Ellington explains, "The computer is normally used in one of two distinct modes".

First, ***Substitute Tutor Mode***, "The student interacts directly with the computer, which is programmed to react to student responses to the questions which it sets. The computer may then ask supplementary questions, or provide additional learning information, before requiring the student to respond once more" This method is useful for teaching history of architecture and some parts of science in architecture knowledge such as environmental studies, for example, heat transfer.

Second, *Simulated Laboratory Mode*, The computer in this mode is more of a learning resource than a direct instructional device.

In some cases, the combination of the two modes was used.

As Ellington ([18], 1987:1-3) states in each of a series of three booklets published by CICED[xxvi], the School of Architecture can be educating students into three available teaching and learning ways by adapting computer in the curriculum, these are: *Individual learning techniques, Mass instruction techniques,* and *Group learning techniques* (See Ellington [3], [4], and [5])

Yeung et al. (1998) note that there are three modes of learning activities in architecture design education as follows: *Self-paced learning, collaborative project team*, and *teleconferencing*. Based on this theory of teaching and learning approaches, it can be seen that the concept of long distance learning approach can bring together all that at the same time.

### 3.2.2 CAAD in Architectural Education

Throughout the literature review there was found to be agreement in categorizing the history of CAAD development related to architectural education, and from the important works of Penttilä (1996), Maver &Petric (1998), and Lee (1999) it can now be appreciated that the history of CAAD development related to architectural education can be divided into three periods, although this observation does not indicate the developments of computing technology itself.

1-From early 1960 until the mid 1980s, CAAD was introduced to architecture education mainly as a drafting or visualizing tool (under CAD title, shearing the same features of content with other disciplines, such as civil engineering with undefined border), which appear as characteristic of CAD education in the format of short support courses, based in general on learning the programming language of system operation.

From the CAAD research point of view Maver &Petric (1998) argue, “In the late 60s and the early 70s, effort was focused on the development of computational methods for generating design layouts in relation to the measurable parameters of design performance [heat loss/gain, lighting…] and cost. In the late 70s a breakthrough was achieved with the advent of Direct View Storage Tube Technology to allow the graphic representation of plans, elevation, and the representation of wire-line perspective geometry [it was possible to model]".

2- From 1985 until the mid 1990s, the advent of increasingly advanced computer hardware and software during this period offered more benefit to the CAAD user, for example, it brought the 3-D colour modelling software package, and accordingly architectural institutions started to deal with CAD as an architectural design medium, in other words, as an architectural tool rather than just a general computing machine.

The most important feature of this period is the appearance of CAAD-teachers and professionals, and CAD- oriented research and development activities, which played an important role in several architectural CAAD-departments by connecting to commercial business-life, for example, the Department of Architecture and Building Science at the University of Strathclyde-Glasgow. Penttilä (1996) argues that the CAD education usage within Schools of Architecture in this period has a clear configuration as CAD-curriculum, which consists of oriented courses such as: the basics of architectural computing, drawing with CAD, modelling with CAD, and CAD-based design projects.

3- From the mid 1990s until the present the CAAD software industry has continued to increase, and thus important drawing with representing tools appeared in increasingly sophisticated form and at shorter intervals. Meanwhile, compared to the remarkable commercial achievement of graphic design applications, intelligent design systems have proved to be a much more difficult and elusive undertaking than anticipated.

The main feature of this period is the attempt of CAAD researchers to take advantage of integrated multimedia for new architectural education.

The advent of Laptops with wireless connection as mobile computers seems to promise a change in the education environment through transforming or reshaping the place of the design studio. It can be taken anywhere and we can say the architectural education studio becomes a 'mobile studio'.

The broad literature classifies the CAAD domains relevant to curriculum of architectural education into four main categories (Zutphen, 1990, QaQish, 1997) as follows: I-Management in CAD: CMLinCAD (Computer-managed Learning); II-Administration in CAD: CLAinCAD (Computer-Learning Administration); III-Learning in CAD: CALinCAD (Computer-Assisted Learning); IV-Teaching in CAD.

The dissertation will now concern itself with the two last aspects within the architecture design education framework in some depth.

**Teaching and Learning in CAD: CALinCAD or Computer-Assisted Learning.**

QaQish (1997:106) argues that the term CAL "refers specifically to the computer as a learning resource or media", while Zutphen (1990:274) gives a broader definition of CALinCAD as "a computer-aided learning system intended to inform and excite students in Schools of Architecture and those in architectural practice about computer-aided architectural design. CALinCAD involves integrating CAAD, CAL, and system design and development into one system. This demands knowledge not only about CAAD, but also about teaching methods and software engineering".

CALinCAD means the common area between three related disciplines: architecture, education, and computer science, as powerful learning aids in architecture design education as shown in Figure 23.

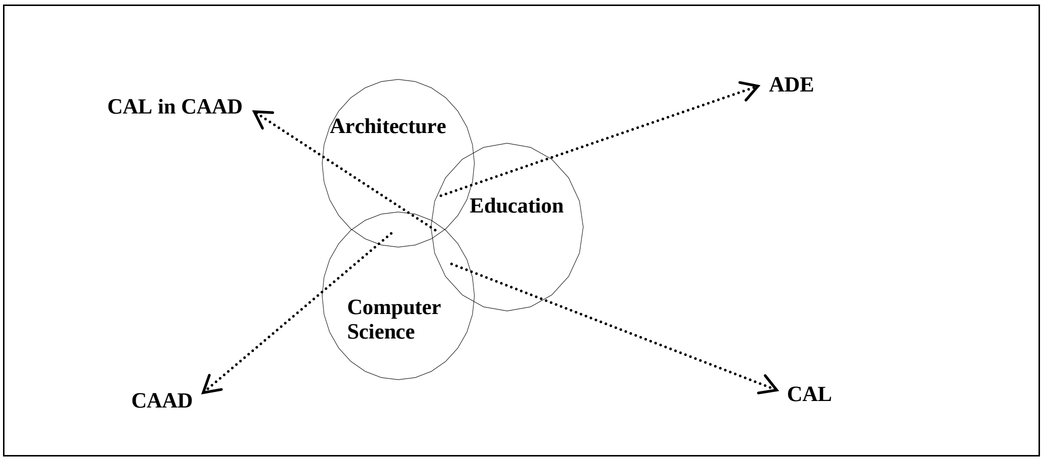


**Figure 23: Illustrate of the three component of architecture education domain based on Zutphen's diagram of CALinCAD (Zutphen, 1990:274)**

CALinCAD is divided into two categories: I-CATinCAD (Computer-Assisted teaching). II- CALinCAD: (Computer-Assisted Instruction), which was divided by Zutphen (Ibid: 275) into five main types of CAIinCAD as follows: Tutorials, Drills, Simulations, Games, and Tests. Each one has its own advantages and drawbacks.

Zutphen identified certain advantages in using CAL in ADE: I-CAL that can encourage students for adapted self-study or individual teaching trend through the education program. II- by adopting CAL within ADE it can increase students' confidence by providing a student with correct answers through special design software system (useful for a history of architecture course). III-CAL considers useful presentation tools to instructors from a time efficiency point of view. By CAL the instructor can treat any previous lecture, or add any new material.

Meanwhile, there is another argument that the integration of computer technology will sometimes raise the issue of isolation and lessen direct interaction with tutors in the architecture design education environment.

To achieve high incorporation of computing in any School of Architecture, the curriculum "must satisfy varying student objectives and must encompass a range of computing roles" (Gross, 1994:56-64). In general he suggests students can use the computer for:

*Documentation*. Use computer capabilities for Structuring, storage and retrieval of information data: writing documents, quantity of material and cost estimates.

*Drafting and Representation*. Use computer capabilities to draw general dimensions of buildings' parts and components. Gross argues that CAD as computer-assisted drafting has revolutionized the working production drawings by making it possible to edit and revise without redrawing; by this means the CAD can save students' effort, time, and money.

*Image Making, Simulation, Modelling and Information Analysis*. The exploitation of these is one role for computing in schools by means of exploitation of three-dimensional modelling, (structural, lighting, acoustic, thermal and bio-climatic) for analysis to support the idea during the design process and decision making of building performance.

Today, the capabilities of CAAD systems and the ability of interface between CAAD packages allow a student to use diagrams, tables, digital picture, 3D (Three-dimensional Modelling), and maps at the same time with drawings to represent real situations and to explore and document design proposals.  Moreover, the student, by using a digital camera and a digital camcorder with high picture value, can insert a rendered image into photographs and movies of real sites to his proposals.

*Communication*.  Computer technology during the last two decades has revolutionized the way to transfer and receive information data via web and thus the world has become a global village. It becomes easy to chat, and send mail; as a result the technology has revolutionized education methodology itself by introducing virtual reality, cyberspace and adopts distance learning concept. Moreover, the research tool is changing by adopting the Internet as new tool for research in general.

Gross also argues that the computer technology now allows the display of data that are inherently nonvisual, such as, the acoustic behaviour of any proposed material or the traffic flow in a city plan.

#### 3.2.2.1 View of adopted CAAD in architectural educations' curriculum

"It has been widely suggested that computers may be thought of as a design medium. Those who are unfamiliar with this idea tend to view CAAD as an automated drafting and visualisation tool, whose application is somewhat post-design" (Moorhouse, 1996:281). Another enthusiastic trend views CAAD as an instrument for hall design process, which embodies the first view (the main aim is the skilled use of commercial software as a drafting tool), and the second trend within architectural education is clear development of designers rather than training of expert technician, which is the core of ADE.

Maver and Schijf (1983)[xxvii] (quoted in Bridges, 1986:335) divide the application for the criteria of introducing computing in architectural education into two phases of policy, each with its own realistic step objective, summarised by the author in Table 4:

| **The policy of education study level** | **Levels of integrating CAAD with the curriculum of architectural education** |
|---|---|
| Prepare students for CAAD use, by given them general idea and right approach of using computer in different situation of design level | <u>Exposition</u>: the concepts underlying CAAD, survey of the state of art, demonstrations. Aiming to bridge the gap of misleading of the common computer culture, which students brought with them from society. This level needs intensive effort and advice from instructors. |
| | <u>Preparation</u>: in this level students need to experience range of programs in terms of discover best way of explore the idea of form, content and interface |
| | <u>Application</u>: using one or more programs in a studio project |
| Prepare students for CAAD expertise. | <u>Instruction</u>: students in this level are asking to go deep in knowledge to grasp the idea of programming skills and knowledge of hardware and software systems. |
| | <u>Development</u>: specifying, implementing and maintaining hardware and software systems. This level is concerns to obtain a high level of the computer technology within architectural curriculum and the School of Architecture need to pay attention to the controversial issue of teaching of computer science instead of teaching how to use computer as assistance tool in architecture design |

**Table 4: Maver and Schijf's criteria for using computing in the curriculum of architectural education (illustrated in Bridges (1986:335)).**

In 1986, an attempt was made by CBEC[xxviii] for National Academic Awards (Bridges, 1986:335) to set up more precise criteria for an architectural education curriculum, which concerns CAAD in an architectural design courses. This is divided into three main areas with five performances as illustrated in Table 5:

| **The area of using computer in architectural education** | **The activity** |
|---|---|
| Use computer in general facility | Word-processing, spreadsheets, office and job administration, etc. |
| Computer Aided Architectural Design | Education in computing and CAAD techniques |
| | Using CAAD as assistance tools in the design studio. |
| Research | Use of computers for research. |
| | Research into computer use and application |

**Table 5: CBEC's criteria for using computing in the curriculum of architectural curriculum (illustrated in Bridges (1986:335))**

Moreover, the CBEC is concerned to create acceptable standards for computer literacy within the curriculum of architectural education. Bridges (1986) summarized these as:

I- A basic understanding of: computers and computing, hardware and software, and programming.
II-Practical experience of: word-processing, information storage and retrieval, and draughting beside 3D (Three-dimensional Modelling).
III- An awareness of: the opportunities that computing offers, and the likelihood of change and development.
IV- An understanding of the implications of computing for: the design of buildings, the organisation of architectural practice, and the architectural profession.

To sum up, the CAAD content in architectural education should have three main elements (Ibid: 336) as follows: the technology of computing, the computer application in architecture and architecture design, and the use of computer as an assistance resource in teaching of architecture.

#### 3.2.2.2The benefits of using the computer in an education course

The literature provides many instances of how an institution and instructors can gain benefits from incorporating computers with architectural education (Reynolds, 1993:7) (Davis, 1993:335).

The instructor can use the computer to increase the amount of material in the course: for example, providing more illustrations or more in-depth descriptions of some topics, or adding material not previously attempted because the material requires complex calculations.

Also, it can be used to treat course content in a different way: for example, instead of lecturing on the architecture movement, by showing a multimedia program of some architecture critics' speeches. Moreover, clips and a text about masterpieces relating to that movement can be added. The computer can be used to present demonstrations that cannot be done with traditional instructional tools such as simulating the dangers of over loaded structure, daylighting performance within a building or costly lab experiments.

Kaplan-Neher (see, Davis, 1993:335) argues that the computer can assist in improving course content by presenting hypothetical scenarios; for example, the computer can help urban study students to model or illustrate the growth of population within the city at different times of the year.

The computer can help students to speed up most parts of the design process and this saving in time can be spent on other parts; for example, the computer can speed up the production documentation or the initial studies stages and the time saved can be spent on sketch design and detail design. According to Reynolds' distribution (1993) of an architect's work (Figure 24), which is based on studies by the American Institute of Architects and the Royal Institute of British Architects, it can reduce the percentage of the production documentation stage from 38% to 25% of total design work time, and the initial studies stage from15% to 10% of total design work time. It can then add the remaining time to the sketch design and detail design. Thus the time for this stage will represent more than 50% of total design work time.

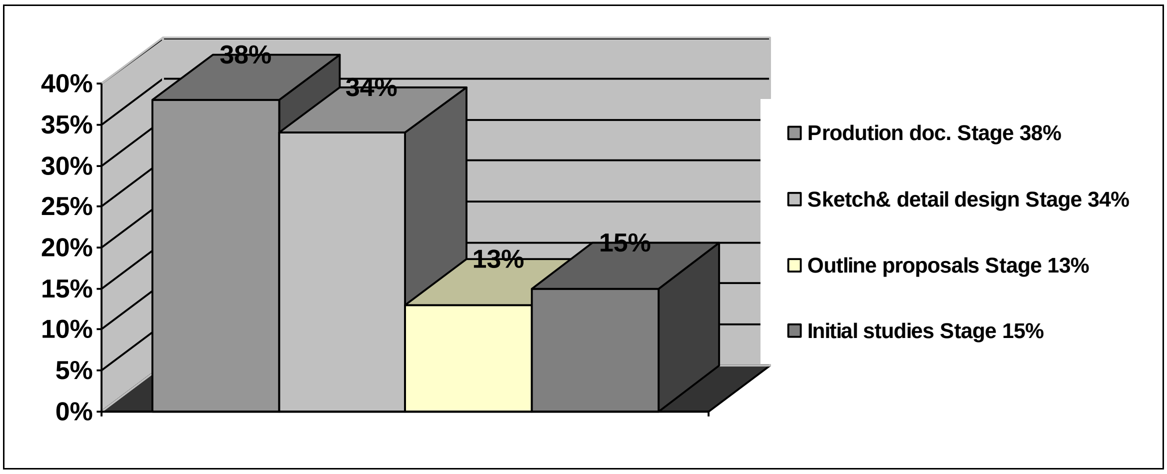


**Figure 24: Reynolds distribution of an architect's work (1993).**

Incorporating CAAD in the architecture curriculum and using the high speed of calculation provided, it could be used to shorten the design period by speeding up the design process. The sense of reducing a design budget issue will rise within students' knowledge by teaching them that the high level of investment project needs fast construction and the computer can offer the best tool for preparing documentations, to organize the work and estimate costs especially in periods of high inflation (Reynolds, 1993:6)

By using computers the design course can demonstrate the issue of communication between individuals of large teams known as "the time sharing collaborative work", the computer via web can keep the team small and cohesive, furthermore the new technology brings new methodology to schools of architecture. The computers can provide easy access to different sources of information databases and knowledge through its ability to connect with local (LANs) and international networks (WANs) (see Chapter II).

On the other hand, Davis (1993:335) argues that the strategies of using the computer in courses of architecture raise different obstacles, which schools of architecture must take into consideration, for example:

I. To equip the school with effective computer workstations requires a large budget to install computers and to keep them up-to-date.

II. Copyright issues again bring in matters of finance, posing problems for improving course content.

III. Preparing both workstation and CAAD course is what is called a "time-consuming issue".

IV. There may be an issue of computing devices being incompatible when related to course promises.

In an attempt to provide a better description about ways of incorporating the computer with architecture design education, Akin (1990:302), categorizes computational design instruction in Schools of Architecture into three main paradigms for use (Figure 25):

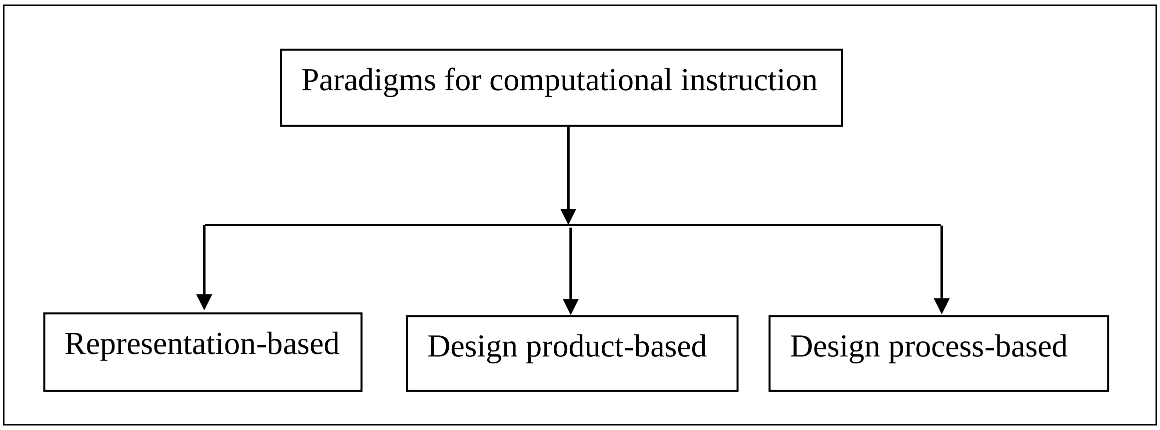


**Figure 25: The three main paradigms for computational design instruction illustrated from Akin (1990:301-316).**

I- *Representation-based concept*. In this approach, a learner begins by understanding the basic ideas of computing, algorithms, and data structures. The student is trained, through the use of these, to generate the fundamental graphic of design language such as points, lines, and curves as a base for standard two-dimensional design computation. A three-dimensional design incorporating colours and textures can be learned using the same theory.

II-*Design Product-based concept*. This concept for design approach is based on allowing students to evaluate their design ideas once they have been generated, by necessity on the computer, through providing different analysis tools, such as to analyse heating and cooling load, structural feasibility, etc.

Flemming and Schmitt first postulated this approach in 1986, and it has subsequently become known as “Flemming’s approach[xxix]”. However, Akin (1990:303) argues that this approach is generative rather than evaluative and “the computational advantages of the medium are used to understand design in terms of the design object” .

III-*Design process-based concept*. Akin explains the aim of this approach “is to consider the qualities of the design process and how the computer can be used to improve it”. This approach assists design education studios to adopt a bottom-up process, the reverse of the traditional top-down design process.

Gross (1994:56) provides a useful summary of the role of the computer within the architecture schools’ curriculum and the policy the schools should follow “We must create a computing culture among students, a culture knowledgeable about the current state of hardware and software, demanding with respect to new capabilities, and rooted in the purposes of architecture and design. We should aim at a curriculum that goes deeper than computer-aided drafting and that prepare students to design and develop computer applications in architecture and planning".

### 3.2.3 In the Design Process within ADE

To investigate the potential of computers in the architectural design process within ADE means that must deal with controversial issues according to the nature of the architectural design process itself, which is still not clearly defined. Zutphen (1990:273) argues, "The architectural design process is a complex, multidisciplinary process in which we have to deal with the many regulations, standards, and procedures of different participants and companies. There are also constraints on time and costs. This complexity makes teaching CAAD difficult".

What we are looking for is that the computer should reflect how the designer's mind represents the design ideas in an available solution through computer advice (Dodge, 1998:8).

It is appropriate to address the teaching of architecture based on Plocke's view (1996:365) which consists of two elements: I-*Teaching ideas*, searching for the reasons to provide a medium of conversation through using words or language to describe a picture. II-*Teaching practical skills*, dealing with a picture (image and drawing) through training the memory (senses and mind) to abstract the facts in order to express ideas (words).

In this explanation, we can clarify a status for the computer to assist students during the design process to refurbish the human memory by getting, storing, manipulating, and retrieving the picture; initial information at this level of design process, to explain words (the primary information) that is in fact stored somehow in the computer memory.

According to the earlier explanation, it can be seen that computers are involved in the design process before actually starting by way of available information from a database somewhere on the Internet, in the beginning stages, when half-way through, and to present design ideas at the end of the process period.

Seebohm (2001:181) points out that there are two directions of using CAAD in design processes in general: I-in the generation and construction of a three-dimensional form. II- in the use of the computer to examine and simulate a design idea from different points of view (specialist knowledge) such as structure, energy (overshadowing and shading device requirements), natural and artificial lighting, acoustic response, as well as for social issues such as configurational analyses and people flows in public spaces and building etc.,

Allow participants of design members to communicate with each other from the early stages of a design process.

Lawson (1982:9-10), Selle's Cantos et al. (1995:27), Novitski (1999:39), Wormald (1997:259), and Fuchs & Wrona (1994:44-45) categorize several roles of computing in architectural design to assist the design process, according to the different capabilities of the available system:

I. Use of the computer as a ***General Tool***. Students should know about computers by understanding how these systems operate in their main areas of symbolic manipulation (textual; numerical graphical), to use the computer as advice to present information and for organisation and management.

II. Use of the computer as a ***Graphic Presentation Tool***. To explore effectiveness as graphic media appropriate in architectural thinking and presentations.

III. Use of the computer as a useful tool to ***Generate Alternative Compositions***. This is achieved by utilising two main capability features, geometrical transformation (modelling and visualization) and using the computer to generate forms.

IV- Use of the computer as a device for modelling that allows the perception of architectural form, space and composition to evaluate different solutions, "Working with 3D (Three-dimensional Modelling) software makes the students better 3D thinkers. The amount of information they can imagine and test extends their design abilities," according to Dingeldein (see, Novitski, 1999:39).

Similarly, McCullagh (see, Wormald, 1997:259), defines the potential benefits of 3DCAD for designing: "in principle 3D (Three-dimensional Modelling) modellers allow the designer to reap more of the inherent interactive benefits of using a computer. Design, especially at the concept development stage, requires a highly interactive process, but most traditional modelling and visualisation techniques normally require the designer to 'start from scratch' if they make a mistake or want to try an alternative. In principle, 3DCAD allows the designer to experiment freely with such features as; angle of view, colour, surface finish, lighting, product graphics, radii size, and overall dimensions etc. without fear of losing the original concept".

Fuchs and Wrona (1994:44-45) describe the responsibility of the computer model (virtual model) in various phases of the design process as follows:

*Conceptual design phase:* the model in this level has to be the most flexible, which also means avoiding accuracy, and is mainly of use to communicate within the design team as early sketches to illustrate ideas. The literature review shows the slowest growth and minimum usage of virtual modelling in this phase.

*Design development*: "the models require flexibility at the level of the details of various scales, while the main elements of the project do not change or do not change drastically, "It can be generalised that the use of the virtual modelling techniques is the highest in the design development phase, and it is still growing there" (Fuchs & Wrona, 1994:44-45).

*Design presentation:* first introduced in virtual modelling in the early stages of CAAD, and concerned with the main function of virtual modelling, Fuchs and Wrona, argue, "It will collect all available data and present it in the most informative way (different for various purposes, while the working drawings are as much the presentation model as the set of architectural rendering) for the audience" (Ibid).

Smith[xxx] (Dodge, 1998:7) described her approach in the design process as follows "In my own work I ask myself 'how can I show this?' at every step of the design process. I now abstract in my mind what the computer represent. I can see my design element through the AutoDesk CAD system, then 3Dstudio, then PhotoShop, then the different print options", It is obvious that to choose the right options from the computer application available in each stage of the design process requires first that the student understand the problem requirements, and second has the ability to discover the technique. The design process takes place inside the designer's head, as Lawson (2002:39) noted, and only one person knows the right tool for the design process: the designer himself.

According to human's reactions towards anticipating in communications, the design process as apart of human communication to solve particular problems through identifying needs, it cannot figure a specific map for the design process and apply it to all designers to follow it and make experiments on it. In this part, the dissertation will discuss the suitable view of mapping the design process to discover the potential of computer applications to bring out the benefits of integrating the computer within the design process.

The literature reveals that many authors have tried to map a logical route through the design process; the main idea behind such mapping “is that it consists of a sequence of distinct and identifiable activities which occur in some predictable and identifiably logical order “(Lawson, 2002:31).

In an attempt to draw a clear definition of the design process Lawson (Ibid: 48) charts maps, which in fact revise the well-known The Markus/Maver map of the design process.

According to Lawson, the design process was divided into three stages (outline proposals, scheme design, and detail design) in the longitudinal route, each stage consisted of three common activities (analysis, synthesis and evaluation incorporating appraisal, and decision activities - see Markus/Maver map) with an interactive cycle between activities, and return loop between stages “ the design process seen as a negotiation between problem and solution through the three activities” (Ibid: 47).

Scianna (1996:393) drew up other simple map for the design process (Table 6), which consists of three main stages (Briefing, Schematic Design, and Detail Design); each stage needs a specific type or character of CAAD software features.

As we can see from Table 6 each activity within the design process needs a different support tool, for example, a generic tool [xxxi] can be used in all stages according to capability of this tool as strong in representation, such as, a word processor for writing reports, a spreadsheet program for support providing tables of cost estimates and bills of quantities, cost estimates, etc.

It is useful to use parametric tools-based programs, such as the thermal analysis programs to calculate and visualize thermal behaviour within design schemes; Acoustic analysis programs are used to visualize a room’s acoustical behaviour to arrive at a decision.

According to Table 6, thermal analysis software can be used at the schematic design stage to give some idea to the designer about the performance of his design. In addition, the designer can use the same software to figure the thermal behaviour of design spaces before final draft submission, and as can be seen from the same table the designer does not need to use the thermal analysis in the briefing stage.

| Stage / Program types | Briefing | Schematic Design | Detail Design |
|---|---|---|---|
| Word Processor | Reports on general features | Reports on design features | Reports on building or components features, specifications, construction activities |
| Spreadsheet | Perfunctory costs estimate | Rough project cost estimate | Generation and pricing of bill of quantities costs estimate |
| Hypertext | | Looking technical information in laws or regulations collections on CDs | |
| Drafting | | Layout parametric sketches | |
| CAD | | General dimensions and layout definition | Drawings of buildings parts and components |
| Gis | Site information assumption | | |
| Quantity Material and Costs Estimate | | | Generation and pricing of bill of quantities costs estimate |
| Thermal Analysis | | Calculation to establish the best shape in respect with orientation and site environmental features | Final thermal behaviour evaluation plants design |
| Acoustic Analysis | | Checking of design features in comparison with site features Rooms acoustical behaviour evaluation | Acoustic verification of building components Final rooms acoustical response evaluation |
| Visual Analysis | | Checking of lighting features also in comparison with site features Rooms illuminance evaluation | Final daylight and glare index evaluation Rooms light sources definition |
| Structural Analysis | | | Structure elements verification |

**Table 6: Use of programs of the CAAD environment in the different project stages (Scianna, 1996:393)**

#### 3.2.3.1Architectural Design Process between Traditional and CAAD

The use of computer in the architectural design process raised and still raises strong arguments between those who agree to teach CAAD within the design education studio and those who prefer to follow the conventional manner. Park (1996:325) argues “there are still technologies that are not broadly accepted as useful to the designer especially in the early design stage. This is because CAD systems use the monitor and mouse, which differ from the sketch paper and pen of manual media”.

This argument also raises the pedagogical question: Why we need to use a computer in ADE instead of conventional trend? Or how does the ADE process change due to an application of computer technologies?

From the point of view of the educational process in architecture, Asanowicz (1996:53) illustrates a clear comparison in Table 7 between traditional architectural education and architectural education incorporating the computer, attempting a twelve-point answer to the previous questions:

| Characteristic feature | Traditional didactic | New approach of education – CAAD |
|---|---|---|
| Kind of activity | Lectures from specific disciplines | Multi-disciplinary activities |
| Type of knowledge | Answer to the question “What” | Answer to the question “How” |
| General teaching methodology | Monographic | Inductional |
| Detailed teaching methodology | Lectures, seminars, tests, consulting etc. | Dynamic activity, inter-level student groups |
| Preserving of knowledge | Relay race system, without repeats | Spiral system |
| Link with a practical experience | Academic knowledge | Knowledge derived from practical experience |
| Coordination | Disintegration of architectural and urban planning research | Integration of architecture, urban & space planning, environment |
| Teaching priorities | Equal status of all disciplines | All disciplines subdued to design process |
| Strategy of study | Required detailed knowledge from all disciplines | Complex study of a problem |
| Quantity of staff involved | Range of 6-15 students per teacher, per hour | Range of 6-8 students per inter-disciplinary group of 4 teachers |
| Qualifications of staff involved | Specialists, experts | Generalists |
| General characteristic of curriculum | Stationary curriculum | Dynamic curriculum |

**Table 7: Two different directions in architectural education (Asanowicz, 1996:53)**

As can be seen from Table 7, the activities within the traditional approach based on lecture, differ from the way of learning in multi-disciplinary activities, in other words, the former way is more teaching than learning and the latter is more learning than teaching.

The new approach of teaching architectural design needs to involve general staff who follow lectures, seminars, and test teaching methodology, rather than the specialist. Expert members of staff are needed to share the new approach of teaching architecture.

The traditional way of teaching architecture, according to table 6 generally relies on transmitting academic knowledge rather than knowledge driven from practical experience, and that implies a stationary curriculum rather than dynamic curriculum.

Based on information availability, the design process with the computer provides more information compared with the traditional process (paper and pencil based process).

Moreover, technologies can now offer devices that translate between two media, for instance it can transform paper images into digital images through flatbed scanners and vice versa.

Other devices are offered by technologies allow the designer to transfer hand drawing and sketches to digital format, it called the Electronic Drawing Board (EDB).

## 3.3 What is special about CAAD studio teaching?

The literature shows that there have been many attempts to identify the criteria of using the computer in the curriculum of architectural education.

According to Bridges (1986:333) the main purpose when teaching CAAD in architecture schools should be "to define basic elements of the subject that should be taught". This is not a new theme, as there has been a vigorous debate between the traditionalists who see CAAD as a discrete skill and those who see CAAD as an integral part of any architectural design studio. Therefore this section attempts to discuss this conflict of views by posing two questions:

*How may we teach CAAD in the architectural design studio? Or how may we teach design in the computing studio?* (Penz et al., 1992)

*How can computer-mediated materials be used in different architectural education situations?*

According to Mark (2000:79) the policy of an architectural curriculum has to address two areas related to computer technology "One curriculum area is learning to design by means of the formal, spatial and data analysis that are enabled by computer technology. The second curriculum area is learning to design for a built environment and infrastructure that incorporates new methods of commerce and computer mediated social interaction".

Institution policy also has to place a clear position for the instructor role in the CAAD curriculum. In attempting to define such a role, Akin (1990:315) argues, "The instructor is expected to learn about the functionalities of the computer and design operations compatible with computation. He/she must be able to define processes of design that encourage productive use of the computer during both design and presentation. Also, the instructor will have to acquire new skills or aids to supplement his/her knowledge about technical functionalities of the computer-such as, geometric manipulations of form, technical analysis of buildings, and general competence with the use of the medium of representation".

The NAAB[xxxii] in 1983 established four main performances around computer responsiveness requirements that should be met by students in architectural design education courses based on ninety-four points, which are summarized by Bridges (1986:334) as follows:

I-The students are required to understand techniques of analysis including such visual tools such as diagrams, charts, models and drawings; also quantitative and computer based tools applicable to architecture.

II-They must understand the types of communications media generally used in architecture, including computer-based techniques of graphic presentation.

III-They should understand the basics of computer usage in the process and some illustrative areas of application including design, documentation, financial management, word processing and information storage and retrieval.

IV- a student should be able to convey the essentials of building or project design by such means as orthogonal drawings (plan, section and elevation), oblique and perspective drawing, freehand drawing, computer-aided drawing and photographs.

Roberts, (1996) has defined four broad categories of CAAD teaching methods:

I- *Design by Modelling:* A new way of aiding students in appreciating the nature of their work. From the point view of the time consuming nature of the task, the digital model plays a clear role in using the computer as a fast device to generate a model instead of the physical form. Roberts (Ibid: 383) affirms "A common use of computer models is one where a student prepares a simple sketch on paper. This is then transferred to the computer by way of either a scanner or by manual digitisation and converted into a Three-dimensional Modelling. From this model, a student is able to critically analyze the design (both visually and/or by the use of some performance analysis software). The student continues the process by sketching over a print out and the process repeats itself".

This method breaks down the design process into two parts (the creative part on paper, and an analytical decision making part carried out by the assistance of the computer).

II- *Design presentation.* This trend was considered the common area of using the computer within the domain of architectural practice.

From the point of view of education policy, the student can take this approach for avoiding allowing the computer to limit his design process by using computers in passing on information about his design ideas from different position.

III- Design by computation. This method is less common today, but in the past it attracted research interest that taught a new methodology for architecture design. This approach is based on using existing designs, which offer ready plans by computer as the starting point, that is, by giving the chance to the designer to rework design problems that have been previously solved by senior designers (Roberts, 1996:384). The CAAD researchers developed a number of computer-based systems in order to assist students to analyse and select the appropriate solution to the architectural problem.

IV-The Virtual Design Studio (VDS). The literature shows that VDS[xxxiii] was considered a new type of design working environment or as a new direction of CAAD (Peng, 2001:7), and it appears where CAAD has been developed in the context of group work, therefore the reader can find the same subject under different titles such as: computer supported collaborative work (CSCW) or computer supported collaborative design (CSCD) in other references.

According to practical experiments, the CSCW environment needs: e-mail, video, audio, a common drawing platform (whiteboard), direct written communication (talk), file transfer, and the shared use of programs (application sharing) (Schmitt, 1999:30). Therefore some are defined this way as “an ***Internet-based environment*** to support teaching and learning in architecture education” (Yeung et al. 1998:93 among others).

VDS[xxxiv] took place in the 1990s, as a result of the union of four tremendous technological advances (Mitchell, 1995:52): the development of computer networking and the Internet (LANs and WANs) or (Closed Net and Open Net) according to Peng (2001:7) definitions, the development of digital video, the development in integration of video with computational processes, and the development in handheld, wireless, digital telecommunications devices, aiming to support human communication and collaboration by reducing costs and difficulties in communication between members of design teams (geographical distribution) (Mitchell & McCullough, 1995:441).

In general, contributions to the debate on CSCW are divided into two sub-areas (Mitchell & McCullough, 1995:451, Peng, 2001:7): I-*Collaborative drawing or drawing systems*, which "extend conventional single-user systems, experimental drawing tools are designed and implemented to be used by a group of users for undertaking collaborative design in various spatio-temporal situations". II-*Collaborative writing system*, which is the area that deals with border scope (writing of constructional notes or specifications) in CSCW, where the medium used during CSCW time could be image, drawing, text, audio, or video, as clarified in Table 8.

| | **Asynchronous mode** | **Synchronous mode** |
|---|---|---|
| **Time** | Different time | Same time |
| **Place** | Different place | Different place |
| **Text** | Electronic mail | Online forum |
| **Audio** | Voicemail | Telephone |
| **Image** | Fax | Whiteboard |
| **Video** | Videomail | Videoconferencing |

**Table 8: Aspects of two different VDS modes illustrated from (Mitchell & McCullough, 1995:451) & (Wojtowicz et al., 1995b: 42-43).**

As can be seen in the table, under Synchronous mode members of a design team can discuss the design idea using Whiteboard alongside Videoconferencing at the same time. Meanwhile, members of design teams who use the Asynchronous mode can send their notes about the design idea via electronic mail using a fax device to send their sketches, all at different times.

The VDS was described as a new way of collaborative design work, and so in architectural education (Schmitt, 1999), Wojtowicz and his colleagues (1999:482) argue "The term Virtual Design Studio was coined as the new paradigm for computer-aided design, refined from being a purely technical and creative process to being also a social endeavour".

For a clearer description, Schmitt (1999:30) states that CSCW or VDS as an important aspect "is possible only in networked computer environments". VDS is a means of sending back and forth data files between two or more geographically isolated designers (reading and writing states) throughout the network, wishing to design together in spite of this separation, working in the computer atmosphere and using modem connections over conventional telephone lines, and based on sending each other updated revisions of the design work. (Wojtowicz et. al., 1995a: 9-10).

According toTable 8, the VDS or virtual design collaboration can take many forms (Schmitt, 1999:33, Bakergem, 1995:29): I-Asynchronous (different time collaboration), which is more structured with some risks in the loss of creative inspiration according to Bakergem (1995:29). This form of VDS can support communication between members of the design team in different places at different times by electronic mail, voicemail, fax for image, and videomail. II-in Synchronous form (real time collaboration). Members in separate locations can communicate with each other through videoconferencing at the same time using whiteboard for sending images or to sketch, supported by chat-room facilities for sending voice critique on design processes and ideas.

This approach adopts the latest trend in architecture education offered by computer technology to enhance the way of teaching architecture design over the barriers of time and distance which interrupt, anticipate and critique the design idea from different views.

"Architecture is a very specific discipline, which consist of the knowledge from arts, sciences, engineering, and more. One of the focuses in architecture education is to teach how to express and communicate design ideas with the multimedia or other technologies, such as virtual reality (VR)" (Yeung et al., 1998:93)

As a result of "widespread acceptance of the previous decade's explosive growth in digital education" as Strojan & Mullins (2002:15) describe it; several institutions now appreciate the importance of giving the computer such space in the field of specialization, for which they offer specific BSc (Hons) in Virtual Reality Design under the Architectural Foundation Programme, for example, at the University of Huddersfield[xxxv]. And for some evaluation to such experiments during last decades, Yeung et al. (1998:93) comments, "Over the past two decades, researchers have used computer and communication technologies, such as VR and multimedia, to construct teaching and learning environments. Some results are promising".

From the literature review, Mitchell & McCullough (1995), Wojtowicz (1995), Garcia (1995), Bradford (1995), Kvan (1997), observe several issues arising when schools of architecture start to change the medium of instruction from the traditional mode (face-to-face) studio into emerging VDS, which can be categorized into three types that limit the goal of design collaboration:

I-Technical issues, for example, cost, file formats and complexity, proper directories, system compatibility and transfer sharing data that contain on-line drawing, feasibility, VR environments, etc.

II-social aspects of design collaborations, such as the issue of identity and architectural language within globalisation in the networked society (Strojan &Mullins, 2002:15) the issue of cross culture collaboration, in other words (Wojtowicz, 1995).

III- the Pedagogical aspects of VDS.

1-knowledge resources. The Internet will become one of the important resources of knowledge and by emerging CSCW mode in architectural education, institutions can share the same resources of knowledge by connecting with each other via LANs or WANs.

Students via LANs and WANs can ask experts (remotely located) to offer advice, which becomes a new way of information.

Mitchell &McCullough in their book "Digital Design Media" (1995:456) discuss the point of view of external examiners and internal reviewers. They argue "In design schools, virtual design studios potentially allow visiting design critics to provide criticism of student projects from their home offices or even while they are travelling, and they also open up the possibility of assembling design juries in an entirely new way".

2- With the emergence of the new approach there is another obligation added to the traditional role of instructors. In addition to guiding and encouraging the students, the instructor must also help the students to master a new medium, which appears to the majority as difficult to control, and cumbersome. Adapting the new approach will bring a new way of communication via machine; consequently, communication through VDS has to be more structured than in the traditional manner.

3- The studio master's contribution. Based on asynchronous communication methods the instructor can give his view on a student's work, which was considered important to introduce "the student to the realms of tacit knowledge which cannot be accessed through book learning" said Kvan (1997:172)

4- Setting for design teaching. VSD can be thought of in a number of arrangements. One of the ideas is based on a link-up of students who have been separated into groups. Each group consist of students from different school, required to do designs based on a specific topic: “in order to accomplish the tasks, they had to work collaboratively”[xxxvi] via the Internet and WWW technologies.

In another idea, the instructor is remote from students for who are unable to attend classes, commonly known as the “Distance Learning” method.

The literature review shows that many instructors continue to debate whether virtual design studio (VDS) or the conventional classroom setting is better. Yeung et al. (1998:93) argue that VDS is just one more alternative to express and represent architectural design ideas to overcome barriers facing the architectural education process.

Yeung et al. (Ibid: 97) illustrate the learning and teaching features for an Internet-based learning system (On-line Education or CSCW in other references) as in Table 9.

| | |
|---|---|
| Electronic lecture notes | Providing with student-customized learning materials |
| Message system | Connecting the course participants so as to achieve communication and collaboration purposes |
| Discussion | Enabling real-time chat or threaded discussions |
| Interactive quizzes and self-assessment | Generating on-line quizzes which are marked by the server |
| Course creation | Allowing the instructors to construct or modify their materials |
| Course management | Having a database management system which helps to organize the course materials |
| Student management | Having a database management system which helps to organize the student information and to track the individual user so that customized services can be provided |

**Table 9: The Yeung, Cheung, Yen &Cheng's features of On-line Education**

It can be seen from the table that the CSCW can offer real-time chat between groups despite different locations, for example, a School of Architecture somewhere in England can establish a timetable with any other school in Scotland to discuss specific design problems that they have agreed to study before.

The Internet based learning system can give an opportunity to schools and instructors to publish materials to students who are unable to attend face to face design studios.

Using the VDS approach in ADE is considered a promising topic in need of in-depth research.

## *3.4 Concepts of CAAD Integration in the Architectural Curriculum*

From the history of the last decade, the field of computer technology has achieved vast improvement and has had an important impact on our daily life processes. It has had the greatest influence on the structure of architecture education in general by trying to absorb the possibilities, which are accessible by using computer technology.

As a consequence of accepting the integration of CAAD within architectural education, the structure of the architectural curriculum towards integration of CAAD has become the subject of many assumptions, especially related to the design studio-thinking process, Koutamanis (1999:240) argues "In recent years, the structure of CAAD courses and in particular their relationship to the rest of the architectural curriculum has become the subject of endless speculation and wide experimentation".

The approaches to integrating CAAD in architectural education can be divided into two categories:

**Firstly: according to the usage of computer connecting with design researcher methodologists' trends.**

Since the 1970s the CAAD researchers had been concentrating their studies toward using computers in design activities based in two directions: Intelligent Systems and the Design tool. The aim behind their research is to help architects design in less time, with less effort, or with fewer mistakes (Tweed, et al., 1999:18).

According to Lee's views in his article "The Changing Face of Architectural Computing Research" (1999:12), table 10 illustrates the differences between the two directions of computer use in the design field in general and architecture design in particular.

| | **Intelligent System** | **Design Tool** |
|---|---|---|
| Computer | As a thinking machine | As a design tool |
| Concept | Computability of design | Usability of computer |
| Ideology | Rationalism | Pragmatism |
| Related fields | Artificial intelligence | Computer science |
| Features | Academic, Theoretical | Commercial, Practical |
| Design systems | Knowledge-based systems<br>Expert systems<br>Case-based systems | CAD drafting modelling programs<br>Information-management systems |

**Table 10: Lee's table of two different directions features in CAAD (Lee, 1999:13)**

As can be seen in the table, the first approach of using the computer was as a thinking machine. The idea behind this was based on supplying the computer with design knowledge, rules, and principles, aiming to get an ideal solution from previous experiences, and during the 1970s and until the mid 1980s, this approach was spread all over instituitions and became a common academic feature of integrating CAAD within architecture design education. The second trend is to view computers as a design support tool in drafting and modelling, and introduce the computer to architecture practice as an aid design tool, also appearing as a commercial software aspect.

**Secondly: according to sequences of learning and teaching logic base**

**I- The early stage of learning CAAD**

At the beginning phase of incorporating CAAD with architectural education in the 1980s, with little experience, CAAD was introduced as a separate course or “ block” according to Bridges’s explanation in his paper to PARC83 conference (Bridges, 1983) about adapting CAAD course within the Department of Architecture at the University of Strathclyde. At that time the general trend was to divide the structure of CAAD teaching in the architectural curriculum into two performances, as shown in Figure 26:

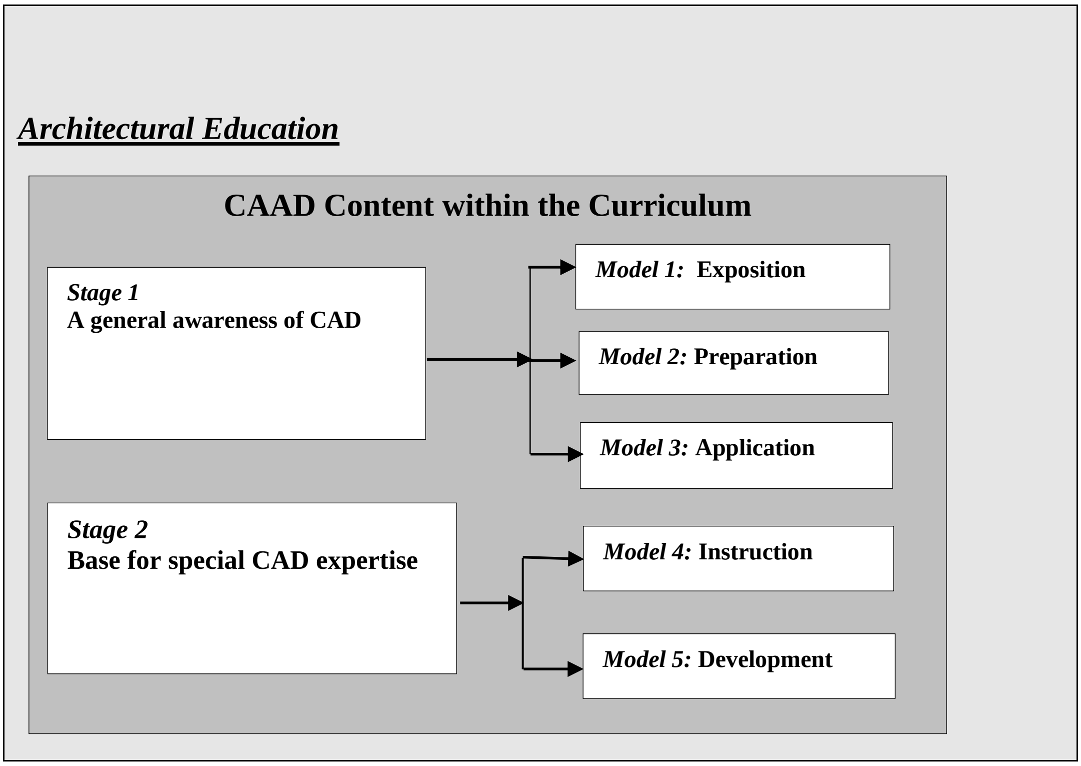


**Figure 26: The structure of CAAD education within the architectural curriculum during the 1980s illustrated from (Bridges, 1983).**

Stage 1: The purpose of this stage is to give students a general awareness of CAD (not known as CAAD yet). It consists of three models, Model 1 *Exposition*: as an introduction course concerns to give general ideas, concepts, and demonstrations, Model 2 *Preparation*: The aim is to practise by using a range of Programs, Model 3 *Application*: to achieve a level of skill in using more than one program within design studio work.

Stage 2: This stage establishes a base for Special CAD expertise, for students who wish to complete their career as CAD specialists. This stage is divided into two models: Model 4 *Instruction:* the aim to gain deep knowledge of hardware and software systems. Model 5 *Development:* specifying, implementing and maintaining hardware and software systems.

**II- The last decade**

The proliferation of affordable powerful computers and clarity of computer prompted institutions and instructors to revise CAAD teaching by restructuring the curriculum.

Koutamanis (1999:240) believes that CAAD contents can be introduced to the curriculum of Architectural education through three basic learning areas: Computer literacy, CAAD literacy, and Integration of design and computing.

-*Computer literacy:* gives basic information to students who do not have prior practical experience in computing, aiming to refigure same equitable base for all students.

-*CAAD literacy*: theoretically considers the next main step, aiming to give a clear picture of using the computer as a tool, mainly taken as separate courses or models within ADE's curriculum. This learning area is divided into three aspects: Drawing and modelling with the computer, advanced technologies, History and theory of computational design.

-*Integration of design and computing*: considered a significant change in architectural education in last decade, as a result of the proliferation of using computers within the design process in practice. Koutamanis (Ibid: 241) describes that change to CAAD course attention itself "from technical subjects to the theory and practice of architectural design" through posing question of '*How can design issues build on computational technologies*?'

Koutamanis states that this area of teaching will raise distinct pedagogical issues from the role of CAAD instructors' point of view: the design instructor becomes CAAD instructor and vice versa "who give either (a) CAAD courses that place emphasis on designing 'traditional CAAD teaching' or (b) design courses that involve and integrate computing".

The school policy has to draw attention to the fact that architectural education must focus on architectural design issues rather than technology. Stevens, (1988:81) declares that the introducing of CAAD to institutions' curriculum has to cover the truth, so that any school introducing new ideas relating to technology and programming keeps in mind the vital point that what matters is the "quality of thinking and design".

## *3.5 What are the main obstacles affecting the use of the computer within the studio of architecture design education?*

Both researchers and associations who deal with architectural education face the most important questions, why does CAAD not fully exist in current Schools*?* And, to what extent can CAAD be integrated to the architectural curriculum?

Ellington ([09], 1987:11) lists three important factors facing full adjustment of computers in education as a problem of adapting computer technology:

1-*Technical factors.* Despite the rapid progress made over the last two decades on both direction hardware and software, there are still some difficulties that work against the easy use of computers in Schools of Architecture.

On the issue of software programme language, the architecture institutions solved this by using commercial CAD software packages, known as 'user friendly' software packages.

Time-sharing and ease of access to the machine besides other technical issues revealed one of the major obstacles facing the network system to meet the peak demand appropriately within the school. The time wasted in solving this problem will shift the student from the central aim of the design course, which is solving the design problem itself, as Penttilä (1996:351) points out "Too often a CAD-architect finds out that 80% of his time is devoted to solving technical problems or changing the systems' setting-it means 80% less time to architectural problems and 80% less time to teaching".

There is no doubt that the way to solve these problems is by increasing the capacity and the number of the machines available, which is part of schools' management issues.

On the other hand, the compatibility of software is one of the most serious difficulties that can often arise in particular within the institution already equipped with special types of machine, for example, the use of a CAD software package designed for use by one kind of computer. Therefore, an institution that has enough proper equipment will become one of the selection criteria for the student.

Some CAD packages are difficult to use without providing separate course for them (Reynolds, 1993) and this issue will hinder the student from using up-to-date packages.

"The implementation of all of the other tasks that CAD could facilitate, such as integration of CAD databases with other applications, has proved so difficult that it has been abandoned in practice. Getting the computer to work properly just producing drawing is difficult enough. Technologists never have much to say about implementation difficulties, discounting them as trivial, the fault of naïve users, or soluble with the next generation of hardware or software (and, of course, more money). Yet as all architects know only too well, getting any computer system or program of any sophistication up and running, and keeping it that way, is a major task " (Stevens, 1997:78)

*2-Attitudinal factors or individual attitude*

The attitude of both instructors and students toward using computers in education was considered one of the principal factors to have a substantial influence on the spread of teaching CAAD within a school's curriculum.

The literature show, (for example, Ellington [9] (1987:13), Cipriani et al. (1990:359), Gross (1994:56), QaQish (1997:88)) that the interest is a very important key-learning factor with computers. From the experiment and experience of teaching CAAD courses it is noted that CAAD affected students at three levels, which show the students' attitude toward learning architectural design with CAAD:

I-students who are interested and trust the new possibilities, thus are willing to use the full potential of the machine, by using 3D(Three-dimensional Modelling), 2D drafting etc.

II- student who are not interested even can foresee the possibilities of CAAD, thus they are only willing to investigate its full potential.

III-Students who are personally enthused and have curiosity to investigate all the possibilities of CAAD, those will achieve higher outcome than the first two.

The high-level interest within students will raise a qualification of design performance in ADE that will affect the design productivity.

Consequently, Instructors in Schools of Architecture have to pay attention to the different effects students' attitude toward responses to using a computer, as a tool will have in their study.

On the other hand, the uninterested instructors in teaching CAAD within architectural education courses have great influence on architecture curriculum development too.

Reynolds (1993:11) defined the main reason of instructors' attitude as "Personal problems, which may also occur because some architects will be unwilling or unable to use the computer. Often some members of staff will not want to change working methods, which they have become used to and have found effective over the years. Also often some members of staff will simply find that they are unable to grasp the principles on which the machine works and will never be able to get the best out of it, however enthusiastic they are. Older architects are especially prone to both these problems, but they are found to some extent in all age groups".

By adopting CAAD as a new approach of learning architectural design, the status of instructors will change "from traditional role to that of a guide, advising students where the best place to obtain that knowledge, and the best way to use it" (Roberts, 1996:381), in other words to transfer the tendency of education from a 'passive' learning by lecture mode, to an 'active' learning-by-doing approach.

Similarly, Penttilä (1996:349-350) argues that "new computer-based tools and methods are not familiar to our traditional teachers, and so they simply can not cope with them. Co-operation with the 'older generation' is simply one important keyword", and he suggests two steps to avoid that as follows:

I- starts by a short introduction to the new tool, aiming of to give senior instructors a straightforward way to understand what the CAD-teaching is all about.

II- follows the introduction course by illustrating samples that have the advantage of supporting the new tool.

One realistic step to achieve a high co-operation of computer benefits with the instructors is for the school to set-up a policy to prepare instructors through short training workshops courses, to show them features of the new computer technology and how to integrate these features within architecture design education.

There are different factors that contribute to or hinder instructor's computer uses, involving two levels (Wang, 2002:155): I-At a personal level, the instructor must be clear about his own goals for using computers in teaching design courses. If those goals are not sufficiently clear the course will not achieve what the school expects. II- At the institutional level, instructors teaching CAAD courses need the support of administrators and colleagues, who can give rewards, discuss problems facing the CAAD course, help maintain CAAD facilities, offer training courses for new software, and provide funds to finance teachers' efforts.

Instructors, in adapting computer technology in design courses need to understand that the new approach within ADE is erected on new concept of "bottom-up" rather than "top-down" methodology in the design process, which starts hierarchically with a conceptual idea about the whole scheme and continues towards the implicit detailed design. So here the instructor is facing the pedagogical issue of learning through CAAD approach instead of traditional method trend.

Akin (1990) suggests three steps for an instructor to go through, when he integrates CAAD in the architecture design education studio:

I- learns useful general ideas about the functionality of the computer and its suitable methods of integration into the ADE, aiming to avoid wasting time by providing proper advice.

II-acquire new skills and gain more knowledge of the CAAD system; besides general competence in CAD media, in its use and presentation are one of the fundamental steps for teaching CAAD in ADE.

III-concentrate more on exploring design ideas, getting benefit from CAAD capabilities instead of focussing attention on pure software packages.

*3- Pedagogical factors*

The tendency to merge computer use within architectural education has become one of the main concerns in CAAD teaching. The literature shows that there still appears to be a degree of taught computing in institutions around the use of commercial CAD software packages that leads to the introduction of the role of CAAD into the studio of ADE as a drafting tool only or as a conventional tool. Thus, CAAD is not used as a way of enhancing the students' design abilities or of raising the experience of students (Roberts, 1996:381).

Bridges (1992:48), states "Our use of the computer follows the traditional process of the design studio-learning by doing- but flexibility of the medium and the possibility of easily manipulating designs (without destroying intermediate solutions) extends the possibilities far beyond those of the traditional studio".

Throughout the last two decades the field of architectural education has seen a lively debate about how to base the essential body of architectural knowledge to be conveyed to students without adding another subject to an already overloaded curriculum. Students should be given the opportunity of developing some familiarity with the computer knowledge during their studies; the additional load placed on the architectural curriculum, especially at undergraduate level is one of the biggest issues affecting the teaching of CAAD in a school's curriculum.

Within this vast area of study, different schools lay emphasis on different parts of the curriculum besides demanding a concentration on specific architectural issues in line with the educational aims or interests of their staff members. To follow contradictory ways in school policy creates an unclear picture for future students' careers.

To find sufficient, qualified members to teach CAAD is a serious and all too common problem facing Schools of Architecture everywhere.

Those are some of the many problems affecting the CAAD teaching and learning performance within the school's curriculum.

## *3.6 Summary*

This chapter has raised important issues, mainly around the core centre of merging computers within ADE and the architectural design process in ADE.

Those issues affecting the integration of CAAD in the architecture design studio have been discussed in both dimensions: technical and pedagogical.

The vast body of literature demonstrates that in general the CAAD teaching is organized in the curriculum of ADE into two modes of instructions: either, as a separate CAAD course, a conventional way of using the advantages of computer technology in ADE. Or alternatively, teaching CAAD within the architectural design studio course via a series of lectures.

There is more than one reason why offices do the majority of drawing and design work through CAAD technology: reductions in the PCs, increase in the available computational power, also the availability of effective and Low-cost software.

According to Wang (2002:161-162), instructors use computers in architectural design education in four ways. Firstly: as a drafting tool. Secondly: as an analysis tool. Thirdly: as a research tool. Fourthly: as a teaching and learning communication tool CALinCAD

Some issues around incorporating CAAD within ADE have been discussed, in general divided into three kinds: technical, changing social and cultural interactive communication, and pedagogical aspects.

The development in an integration of architectural education with computer technologies, will affect the method of teaching and learning within architecture design education in three most important areas: sustainability, user participation, and creativity (Petric & Maver, 2001:178), all dealt with in this chapter.

This work does not propose any new method of teaching and learning of CAAD within architecture design education, but gives in some depth the ideas for using computer technology in architecture education in general, and VDS as a feature of exploitation of the Internet and WWW technologies, as the latest usage trend in computers in ADE specifically.

Consequently, the dissertation up to this point needs more empirical studies in some depth to examine whether or not CAAD has been incorporated in existing Schools of Architecture, and to determine the extent to which this has affected architecture design education. The next chapter concerns UK Schools of Architecture as a realistic field to experiment, trying to answer:

I- *How do UK institutions of architecture teach CAAD in the ADE today?*

II- from UK instructors' point of view *how should UK Schools of Architecture teach CAAD in ADE? Integrated with design or as an independent course (pure skills)?*

III- *what are the main obstacles facing ADE integrating with CAAD in UK schools of architecture?*

There is need for more work to be carried out on the incorporating of CAAD, and the educational value added by virtual design studios to the design learning process, from theories of architecture education; for example, Conservatism theory, Critical theory, Radical hermeneutics theory and Pragmatism, etc. (Coyne, 1995) and how each theory considers using computers in architectural design education, thereby aiming to give a broader view of the relationship between architectural education and CAAD courses in the curriculum.

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# Chapter Four: UK Schools of Architecture Questionnaire Survey

## 4.0 Introduction

Schnabel (quoted in Mark et. al., 2002:209) argues that "New technologies have always shaped the curriculum of architectural studies". Does this view apply to UK Schools of Architecture? To test this claim, a questionnaire survey was carried out to examine the implications of a new approach to teaching architecture design within the UK schools of architecture integrating CAAD. The general aim is to draw lessons from past experiences in CAAD, to assist the Department of Architecture & Urban planning at El-Fateh University, Tripoli-Libya, and work out a strong base with a view to improving the current curriculum incorporating CAAD.

The contents of this chapter are organized as follows:

I- *Existing CAAD Courses available at UK Schools of Architecture*. This part concentrates on general features of the existing CAAD courses available at UK Schools of Architecture. These general features have been assembled from schools' prospectuses, student's handbooks, and through visiting schools' websites.

II-*UK schools questionnaire* survey. This part reports on the analysis of the questionnaire survey on CAAD courses in architectural education conducted in January 2003 (see a copy in Appendix I). The questionnaire was sent to CAAD instructors at various UK schools of architecture.

The main objective of this chapter is to review issues bearing on CAAD teaching and learning orientations and arrive at a better description of the developments and validation of the CAAD curriculum within current architectural design education at UK Schools of Architecture. Also, the data gathered from the questionnaire survey is used to draw and define a clear picture about the relationship between CAAD courses and the structure of UK schools' curriculum orientations, and serve as part of the basis for the recommendations made to the Department of Architecture and Urban Planning, Tripoli-Libya.

## 4.1 CAAD Courses available at UK Schools of Architecture

Since the 1980s, there has been a significant change in outlook and interest within UK Schools of Architecture, with such schools tending more and more towards integrating computers within an architectural design education curriculum.

According to the RIBA booklet “Schools of Architecture: with courses recognised by the RIBA 1999-2000” (RIBA, 1999), there are 36 Schools of Architecture providing undergraduate architecture design programmes in the U.K. (see *Appendix III* for a list of the schools, listed according to regions and cities alphabetically). The important characteristics can be summed up as follows:

- The syllabus for architecture at schools in the UK was outlined in collaboration with The Royal Institute of British Architects (RIBA), and the syllabus is structured in such a way as to lead to different categories (RIBA I, II, and III) after a certain period of time.

- Undergraduate architecture education at UK Schools of Architecture is commonly based on a two period structure of study, each period leading to a specific degree.

  The first period commonly takes three years, as a full-time course, followed by one year of practical training in a real practice office, leading a student to the Bachelor (with “Hons” in some cases) degree in Architecture. In some schools this level is exempted from Part 1 of the RIBA examination in architecture, for example, The School of Architecture and Design at The University of Brighton, The Welsh School of Architecture at Cardiff University, and The Department of Architecture –the School of Design Technology at the University of Huddersfield.

  The second period takes two years, and that leads in general to the Bachelor of Architecture (BSc [Arch]) or the Diploma in Architecture and is exempted from Part 2 of the RIBA Examination, for example, The Department of Architecture at The University of Cambridge, and The School of Architecture at The University of Dundee.

- The curriculum is organised into modules or courses with categories related to student level or student year.

- In general, teaching architectural design in UK schools falls under one of three common methods: one-to-one tutorials, small seminar groups, and public jury criticism.

- In general, architecture studies are centred on design activity, as in, for example, The Mackintosh School of Architecture, and The School of Architecture and Landscape at Kingston University.

- According to the second survey of The Commonwealth Schools of Architecture (1987), The School of Architecture at The University of Newcastle-upon-Tyne and The Architectural Association School of Architecture are the oldest schools in the UK. The first was founded in 1837, and architecture has been studied at the second school since 1847.

- (Department of architecture, landscape and 3D) at The Manchester School of Architecture at The Manchester Metropolitan University is the first department's name affected directly by adopting CAAD in education.

- Some schools started integrating CAAD within their architecture study programme from the mid-1970s. Examples of such schools include The School of Architecture at The University of Sheffield (Lawson, 1986:78), and The Department of Architecture-School of Arts, Culture and Environment at The University of Edinburgh (The second survey of The Commonwealth School of Architecture, 1987:188).

- The majority of CAAD courses are in the form of lectures and exercises spread over the term period.

- It can be seen from the current UK schools' syllabus that computer skills are already included under different titles or headings, for example:

-Communication skills or Design and communication (at, for instance, The School of Architecture at The University of Liverpool, The University of Lincoln, and The University of Dundee).

-IT or Computing (at, for example, The Department of Architecture at the University of Edinburgh, Bartlett School, The University of East London, The School of Architecture at The University of Newcastle Upon Tyne).

-Multimedia or Media and Communication or Architecture and Multimedia, (at, for example, The Department of Architecture at The University of Strathclyde and The University of Edinburgh).

-3D Drawing or 3Dskills, (at, for example, The Architectural Association School of Architecture, and Birmingham School of Architecture and landscape).

-Computer-aided Design, (at, for example, The Department of Architecture & Civil Engineering at The University of Bath).

-Under induction (Introduction) courses or within design studio course, (at, for example, Manchester School of Architecture, The School of Architecture and design at The University of Brighton, and The Department of architecture at The University of Edinburgh).

-Some schools award specific certification on input on computer knowledge, for example, The University of Huddersfield awards BSc (Hons) in Virtual Reality Design and BSc (Hons) in Architectural Computer Aided Technology under their Architectural Foundation Programme[xxxvii].

## *4.2 UK Schools Questionnaire Survey*

In January 2003, a survey of architectural education was undertaken by this research (Appendix I). The purpose of the survey was to find out all the facts about integrated CAAD within a school's curriculum using computers in architecture design education. This was carried out through investigating 36 schools in the UK, whose courses are recognized by RIBA.

This part deals with a case study which encompass the findings of a questionnaire survey investigating CAAD teaching and focusing on CAAD tutors at UK Schools of Architecture.

### 4.2.1 Why the questionnaire? And who are the participants?

When there are time limits, the questionnaire, as a method of data collection (Choen et al., 2001), is deemed to be the appropriate method and the fastest way of getting pure information about CAAD courses. Such information could be obtained from one of the main important resources by posting the questionnaire to CAAD tutors or design studio tutors.

To avoid the problems arising from the difficulty of controlling the sample of the study, the questionnaire was designed to cover only thirty-six UK Schools of Architecture, whose courses were recognised by RIBA (see Appendix III, and (RIBA, 1999)). To suit a descriptive case study, according to Yin classification (Choen et al., 2001:183), a *Structured Questionnaire* was chosen as a method of carrying out the survey.

The thirty-six schools were classed into four regional groups: England, Northern Ireland, Scotland, and Wales.

Two thirds of the questionnaire's questions have adopted the Dichotomous method, which asks the participant directly to answer Yes or No, and the other third is divided between the *Multiple-choice* and the *Rank Ordering* method (see Appendix I). The main reasons for choosing the Dichotomous method are based on Choen et al.'s (2001) arguments that: I- The Dichotomous method is quick to complete. II- The information within the Dichotomous method is straightforward to code and that it is helpful for using a computer statistic package to analysis the data. III- It is a useful method as a sorting device for subsequent questions.

The questionnaire was mailed to each named CAAD tutor and some of the heads of the schools. The statistical package for social sciences (SPSS 9.0 for Windows) was used to analyse the returns.

### 4.2.2 The Questionnaire: Objectives and Areas of Investigation

This survey had several interrelated objectives:

I. The questionnaire attempted to obtain the opinions of the CAAD tutors or design studio tutors at UK Schools of Architecture who were teaching the available CAAD courses in the academic year 2003.

II. The questionnaire attempted to determine the current method/ way of teaching and learning in CAAD courses in UK schools of architecture.

III. The questionnaire attempted to clarify weaknesses and strengths of CAAD policy components within schools, as well as present an objective view of the present state of computers' use in architectural education.

IV. The questionnaire was designed to get a better understanding about some pedagogical issues, for example, teaching CAAD and the main difficulties facing the process of incorporating computers within architectural design education, and the changing nature of design studio's environment after the incorporation.

V. To define and highlight the latest approaches to teaching CAAD relative to design studio formation and its culture, as adapted in UK Schools of Architecture.

## 4.3 Structure and Design of the Questionnaire Survey

To achieve all the previous objective, the questionnaire was divided into four main parts (see Appendix I) in an attempt to steer discussion around three pivots: school policy and CAAD course, teaching issues, student and studio environment.

1- The first part aims to gather general information about participants, ranging from the participant's name up to the experience of the participant towards teaching the CAAD package. This part was entitled "*CAAD Tutor/ Lecturer*" and consisted of three questions.

2- The second part aims to gather information about school's policies and CAAD courses. It consisted of seventeen questions and was entitled "*The Relationship between Curriculum and CAAD Course*".

3- The third part aims to gather information about: I-The general trend of teaching CAAD courses. II- The Main obstacles facing teaching and learning CAAD courses in UK schools of architecture. III-A Consideration of teaching and communication methods within UK architecture design education studios. This part consisted of fifteen questions and was entitled "*CAAD: Teaching methods, Timing and Resources*".

4- The fourth part was devoted to gathering general data and trends. This part consisted of eight questions and was entitled "*General Issues*".

## 4.4 Analysis of UK Schools of Architecture Questionnaire Survey

Important general information was gathered from the first part of the questionnaire survey, such as the name, the address, and the experience of the person who answered the questionnaire (see Appendix I). Three sections of the questionnaire have also collected information, facts, and opinions on integrating CAAD in architecture design education in UK Schools of Architecture.

### 4.4.1 The Response Rate of the Questionnaire Survey

| Region | The current picture of UK Schools of Architecture | | The returns: Schools individuals take part in the case-study | | | | |
|---|---|---|---|---|---|---|---|
| | N of schools recognised by the RIBA | Rate from the total UK schools | N of schools repies | | Response rate % | N of participants | % of participate |
| England | 28 | 77.7% | 19 | 52.77% | 81.00% | 29 p | 80.55 % |
| N. Ireland | 1 | 2.7% | 0 | 0.00% | 0.00% | 0 p | 00.00 % |
| Scotland | 6 | 16.6% | 4 | 11.11% | 17.00% | 6 p | 16.66 % |
| Wales | 1 | 2.7% | 1 | 2.7% | 4.16% | 1 p | 02.77 % |
| | 36 schools | 100% | 24 schools | 66.58% | 100% | 36 people | 100 % |

**Table 11: A comparative analysis of different response counts to the mailed and received of the UK questionnaire survey.**

Table 11 shows the number and percentage of schools that the questionnaire was mailed to and the numbers of participants replying per region. This research was maild 104 questionnaires to all 36 Schools of Architecture where in many cases several questionnaires were sent to a single instituition where several individuals taught CAAD. The returns were 36 (66.66%) that present 24 School of Architecture.

The information from table 11 indicates that the highest percentage of Schools of Architecture are scattered in England with 77.7% (28 schools), Scotland has only 16.6% (6 schools), whereas North Ireland and Wales have 2.7% each (one school each).

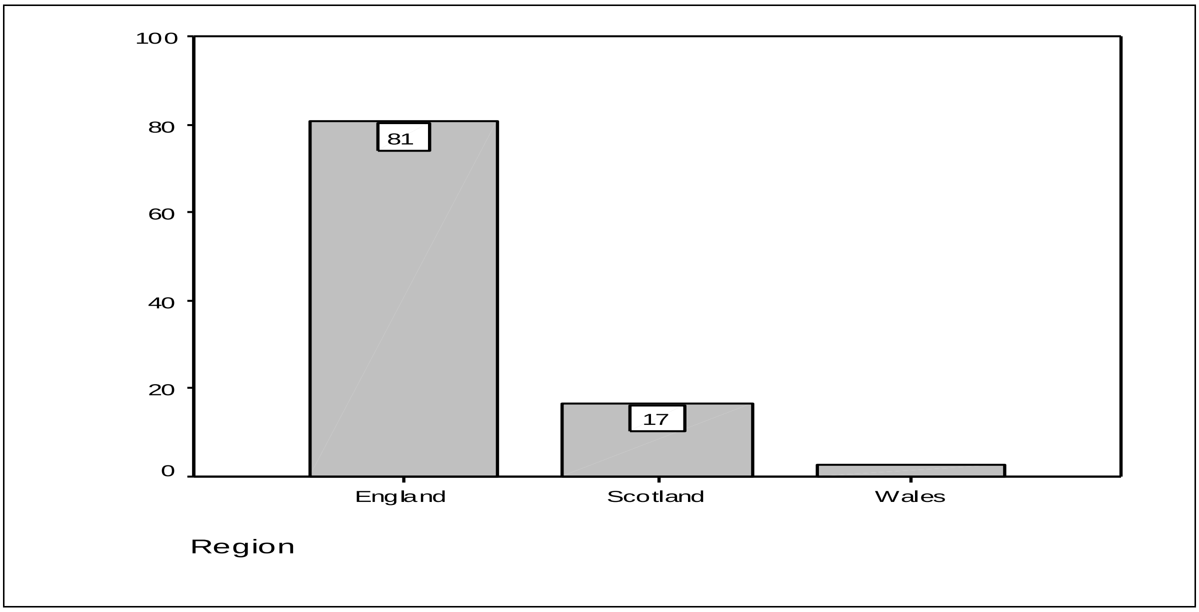


**Figure 27: Distribution of the response rates in the UK schools questionnaire survey by region.**

Figure 27 (a bar chart) shows the distribution of the response rate to the UK Schools of Architecture questionnaire survey by region. The vertical axis shows the percentage of a response rate and the horizontal axis shows the region's name of participants.

As can be seen from figure 27 and table 11, by far the largest response rate of 81% was from the England region respondents. On the other hand, only 17% came from the Scotland region, and the Wales region accounted for only a 2% response rate.

### 4.4.2Gender issues

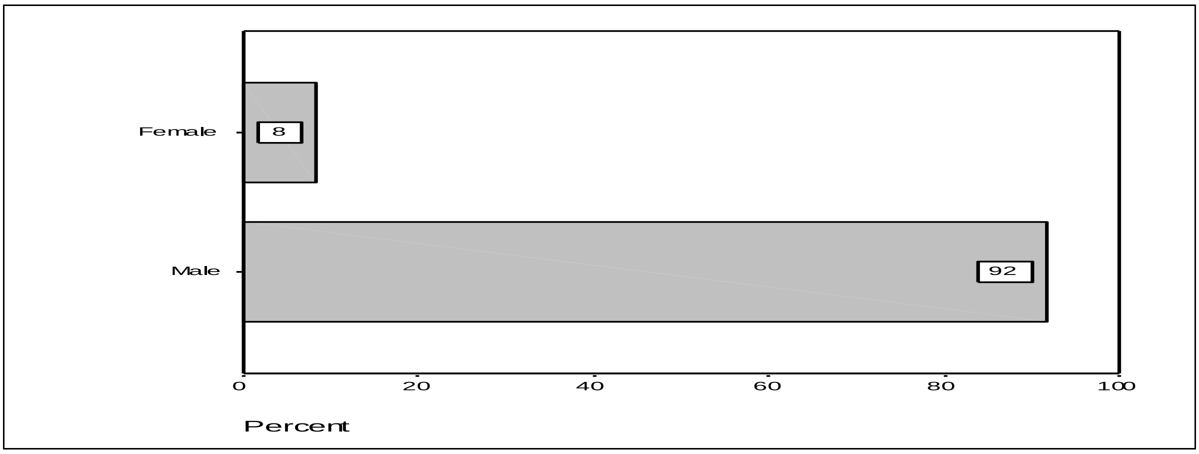


**Figure 28: A bar chart showing the analysis of the gender's response rate to the questionnaire survey**

Figure 28 shows the gender (female/male CAAD instructor) percentage to the questionnaire survey. It indicates that the percentage of female instructors was 8.33% compared with 91.66% of male instructors.

On other hand, figure 29 shows CAAD instructor's response to the question: Are there any different attitudes towards learning CAAD between female and male students? 75% of the respondents are convinced of no different attitude, while 25% do reveal that there is a difference and some instructors refer to a difference in gender behaviour; for example, female students are much more patient and attentive than male students towards learning architecture design via computer use.

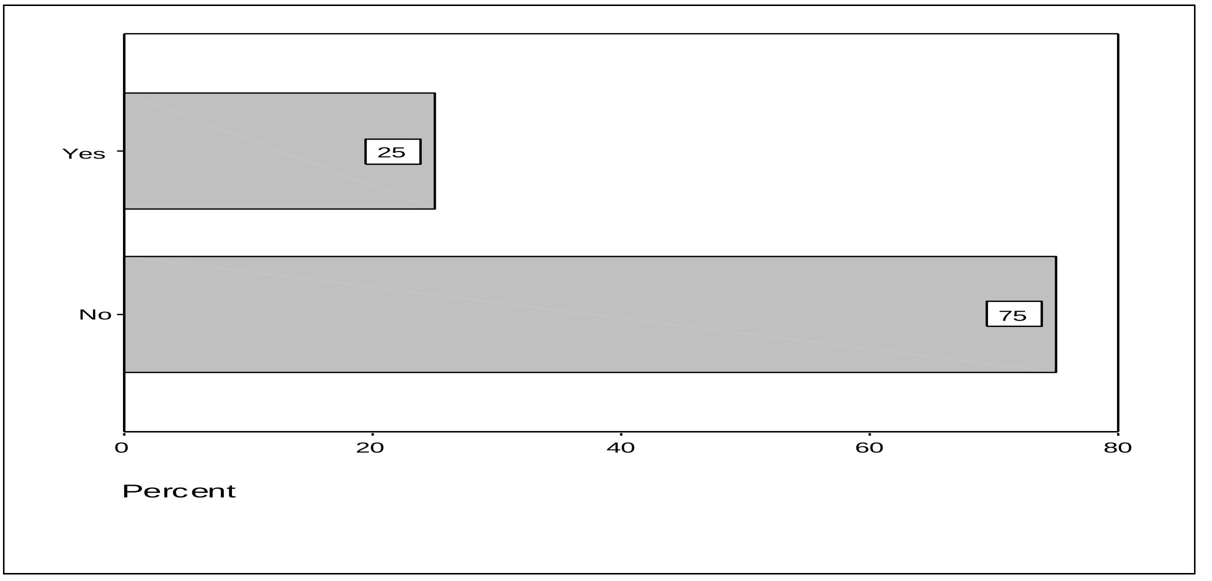


**Figure 29: The response rate to the question: Are there any different reactions towards learning CAAD between female and male students?**

This analysis could reveal that female instructors in UK Schools of Architecture have less interest in teaching CAAD in architecture design education.

### 4.4.3 CAAD instructors' issues

#### CAAD teaching experience

Question 2-1 of the UK questionnaire survey (For how long have you been teaching this course?) sought to identify the category of the respondents' experience in teaching CAAD courses. The question was designed to determine whether the majority of respondents have sufficient familiarity with teaching CAAD and therefore the ability to evaluate CAAD courses and provide better information about whether to use computers in architectural education or not.

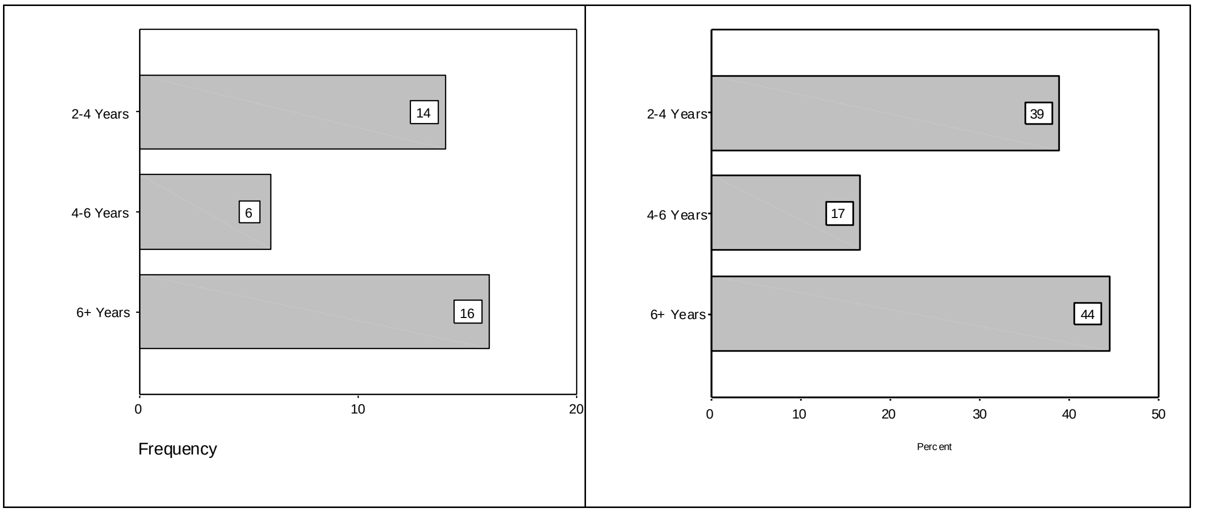


**Figure 30: The different experience's rate of the participants who teach CAAD courses in UK Schools of Architecture (Q1-2).**

Figure 30 shows that out of 36 participate, 16 (44%) reported having more than six years' experience in teaching the CAAD course. While 14 (39%) fall into the-two-up-to-six years' teaching experience category, and only six (17%) of the respondents indicated that they have between four to six years' teaching experience in the CAAD course.

The statistical analysis of CAAD teaching experience shows that the Mean= 2.05 years within a range between 0 and up to 6 years.

Consequently, some interesting and important factual information can be expected to come from the analysis of this questionnaire.

## Full-time and Part-time tutors

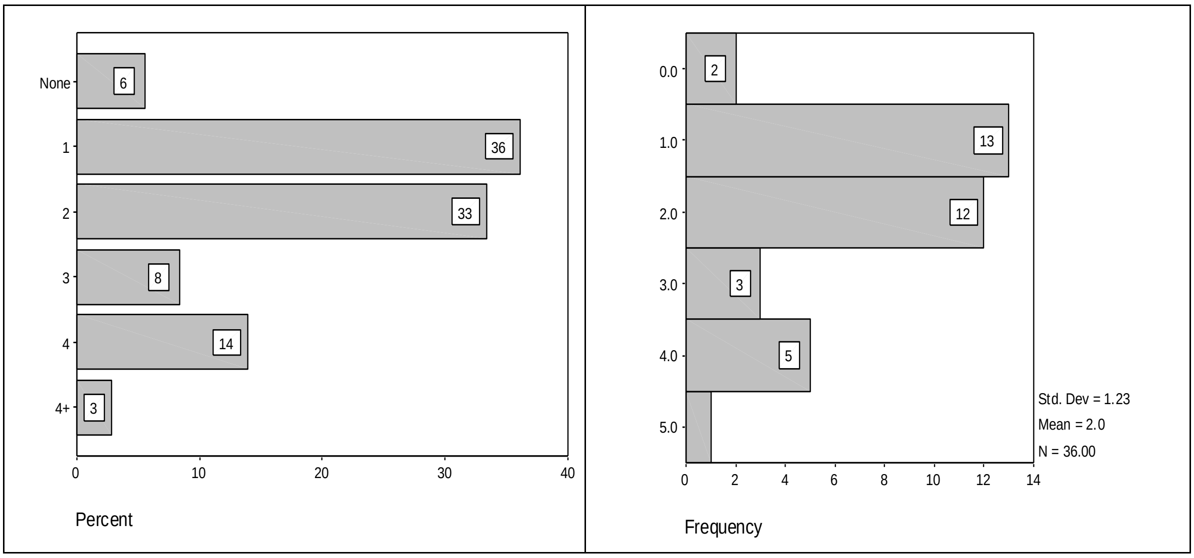


**Figure 31: A bar chart showing full-time tutors and part-time tutors who are involved in teaching CAAD courses (Q4-4).**

The analysis of the questionnaire survey revealed that the sum number of CAAD instructors involved in teaching CAAD courses is 78 instructors, 60.25% (47) were full-time instructors whereas 39.74% were part-time instructors.

As can be seen from the chart (Figure 31), there are 13 (36%) schools employing one full-time tutor, and 12 schools (33%) employing 2 full-time tutors, whereas 5 (14%) schools employ 4 tutors as full-time members of staff to teach CAAD courses.

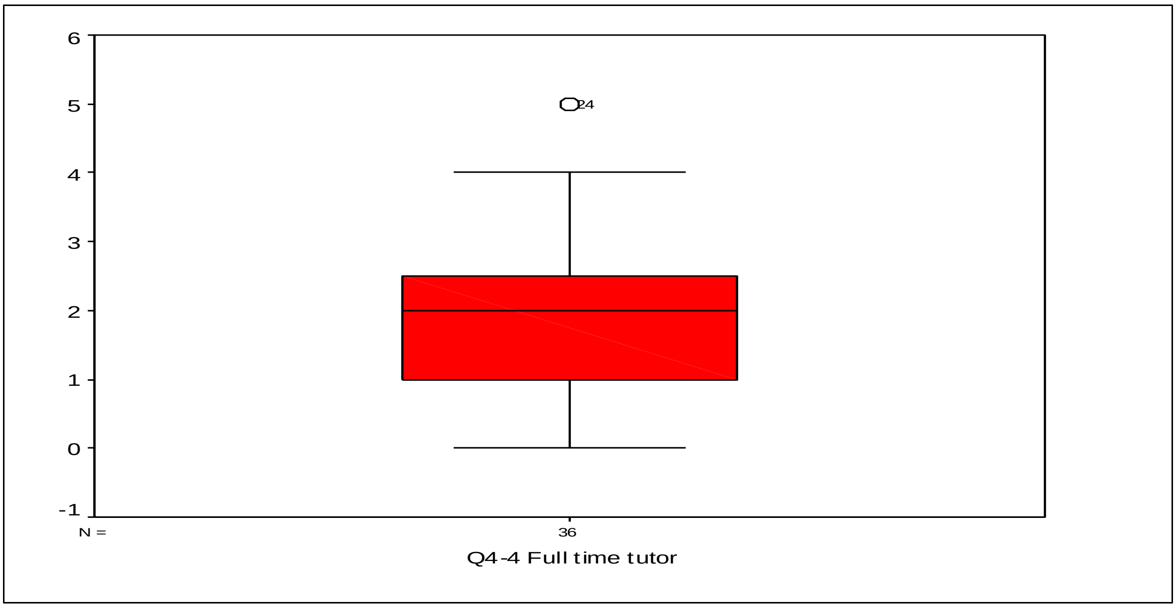


**Figure 32: A box plot describing the mode range on a five-point scale of full-time tutors at current UK Schools of Architecture.**

Figure 32 presents a visual indication of the mode range of tutors, who are currently employed as full-time members of staff (January 2003) in UK Schools of Architecture, and the range of the mode is between 0 up to 4 tutors per school and the mode is about two tutors.

It can be inferred from Figure 31 that Schools of Architecture understand the role and importance of CAAD tutors within architecture design education (ADE) in that they employ more full-time instructors who had CAAD knowledge. Figure 31 also indicates there is a shortage in full-time CAAD tutors in some other schools to cover all CAAD courses.

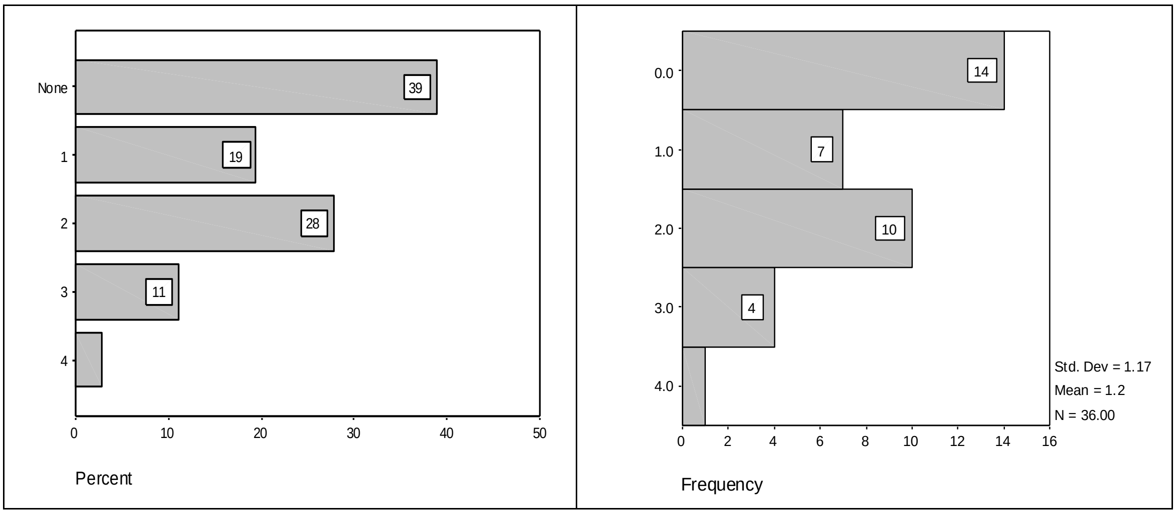


**Figure 33: The rate of part time tutors who are involved in teaching CAAD? (Q4-5)**

On the other hand, Figure 33 indicates that some schools still rely on part-time CAAD tutors, and, consequently, they seek help from local architectural practics to cover shortage in staff members within the school to teach CAAD courses within the architecture programme. As can be seen from the bar chart, there are 10 (28%) schools employing 2 part-time tutors, meanwhile 7 (19%) schools employ 1 part-time tutor.

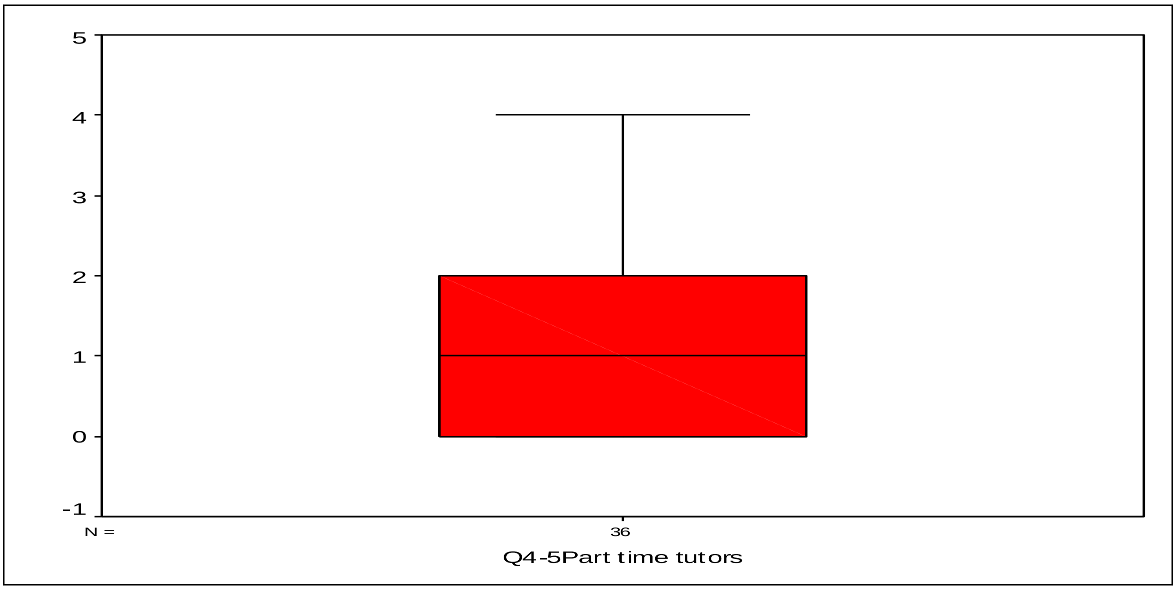


**Figure 34: The analysis mode of part-time tutors employed at UK Schools of Architecture (Q4-5).**

Figure 34 presents a visual indication of mode range of tutors, who are currently employed as part-time members of staff (January 2003) in UK Schools of Architecture, and the range of the mode is between 0 up to 4 tutors per school and the mode is about one tutor.

### Support and training for CAAD tutors

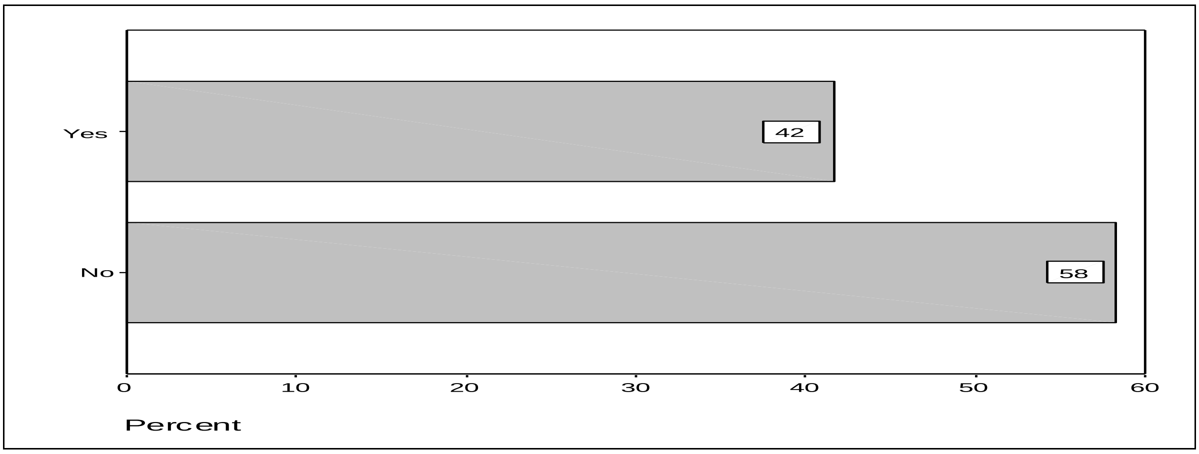


**Figure 35: A bar chart showing the training received by CAAD tutors. (Q4-7)**

Figure 35 shows the response rate on the support CAAD tutor had in regard to training in basic software skills, analysed from section four of the questionnaire. The participants were asked whether they received any training courses on new software or not.

It can be seen from the bar chart (Figure 35) that the results obtained from 36 CAAD instructors in 24 Schools of Architecture indicate that 42% of tutors have received training courses on new CAAD software, while 58% of the tutors have not. From these figures, it could be inferred that there is a weakness within schools' policies to set aside part of their income to support the CAAD tutors' role by providing them with introductory courses or workshops on new software packages.

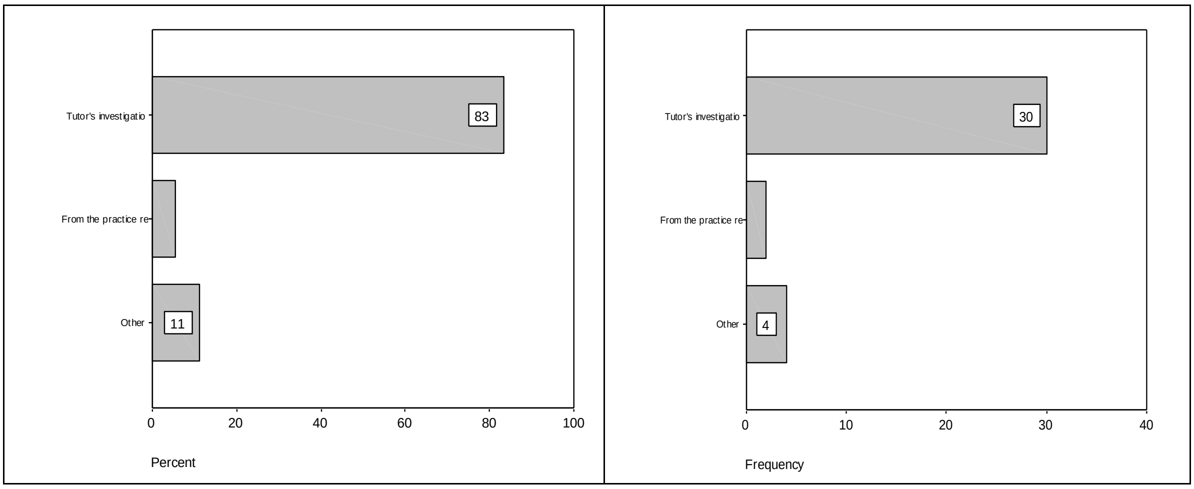


**Figure 36: Choosing a CAAD software package for teaching CAAD courses (Q2-11).**

Meanwhile, from Figure 36 it can be seen that 83.3% (30 cases) of respondents indicate that the school chose CAAD software packages for teaching CAAD courses based on tutors' investigations. However, only 5.6% (2 cases) indicated that their schools chose the CAAD software for teaching based on the practice demand.

These figures reveal that Schools of Architecture will have found difficulty in providing skill-based software courses appropriate to tutors that match the individual preference of each tutor, for example, AutoCAD, ArchiCAD, FormZ etc. This, consequently, will hinder student's future employment because the CAAD course taught does not correspond to the demands of the workplace.

### 4.4.4 School's policies on teaching CAAD

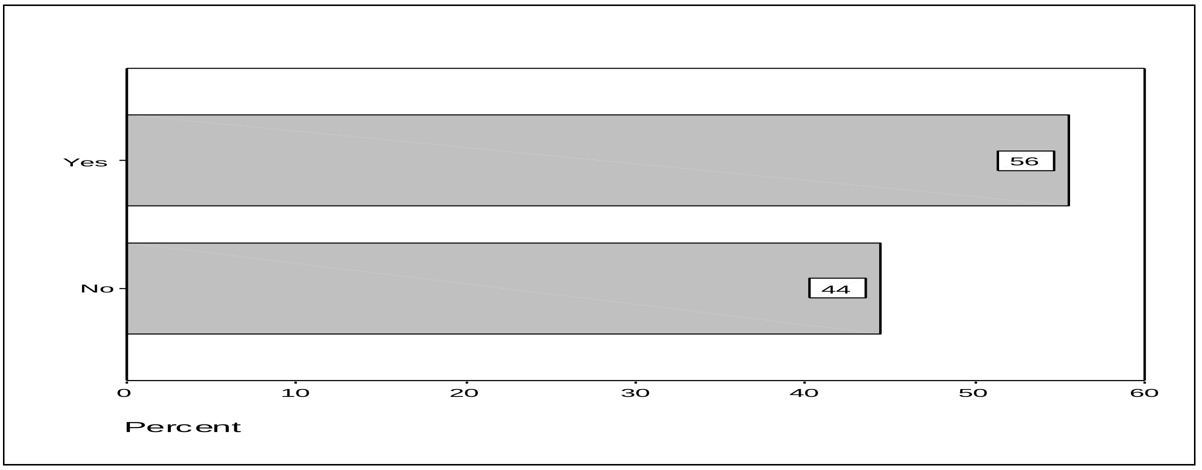


**Figure 37: A bar chart presents the availability of written policies for using CAAD in the architecture design curriculum. (Q2-1)**

Figure 37 shows the response rate on the available written CAAD objectives within UK Schools of Architecture. The subjects were asked whether the school's curriculum has specific written objectives or policy for incorporating CAAD in the architecture design studio, and if yes, do CAAD specialists within other schools share the same objectives towards giving students better knowledge?

The question (see question 2-1 in Appendix I) was designed to determine if there is a general and definitive acceptance of CAAD and its integration with the design studio within UK Schools of Architecture after more than two decades experience of teaching with CAAD.

As can be seen from the chart (Figure 37), 44% of response indicated that their schools have no specific written objectives or policy for using programmes in ADE yet. Whereas 56% indicated that they have.

From the analysis one could assume that there is still a weakness in understanding all aspects and benefits of CAAD role in the context of architectural design education. And the question that can be posed here is: why were UK Schools of Architecture unable to achieve common ideal objectives on integrating CAAD? The answer, as Neilson et al. (1991:74) argues, is because there are "no national guidelines which Schools of Architecture can refer to in trying to meet the demand for a greater degree of computer literacy in under-graduate students". Consequently, the absence of such national guidelines will compel each school to find its own rote and definition for incorporating the computer in architecture design education, separate from others.

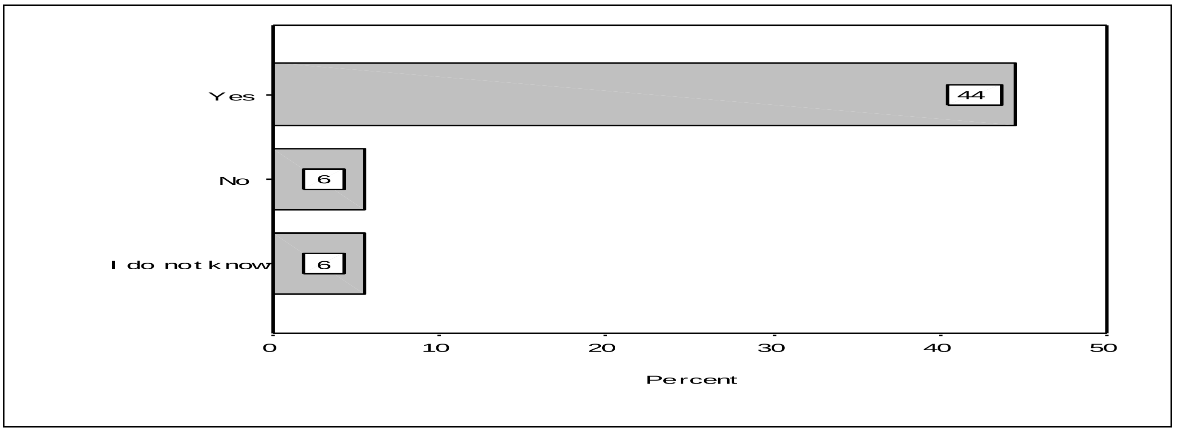


**Figure 38: Sharing CAAD objectives (Q2-2)**

Whether or not CAAD specialist share in schools the same objectives, the bar chart above (Figure 38) indicates that 44% reported that they share the same CAAD objectives compared with 6% of the respondents reported that they do not, and 6% did not know.

## 4.4.5 Studio environment

### 4.4.5.1 The approach of CAAD integrating

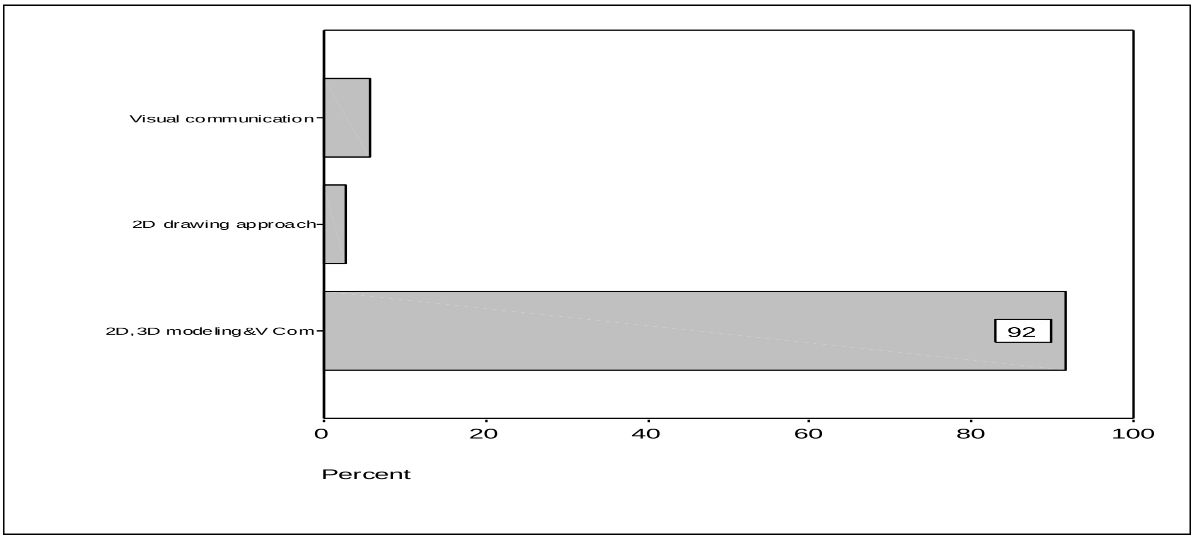


**Figure 39: The response rate to Question: Which approach do you think the curriculum should take in integrating CAAD? (Q2-10)**

The participants were asked which approach the architectural curriculum should take in integrating CAAD (see Q 2-10 from Appendix I).

On the whole, there is a strong tendency towards 2D draughting, 3D modelling and Visual Communication as approaches in integrating CAAD. An analysis of the above chart (Figure 39) indicates that out of 36 participants, 33 (91.7%) of the respondents believe that the approach of 2D and 3D modelling is the appropriate approach in integrating CAAD in the architectural curriculum, compared with 2 (5.6%) who reported that they prefer the visual communication approach, with only 1 (2.8%) of the respondents suggested that 2D drawing as the suitable approach for integrating CAAD.

**Chi-Square test**

The chi-square test is used to test the hypothesis whether variables within research's case-study are independent from each other or not; does variable X affect variable Y in some way or not.

**Test Statistics**

| | 4-2 How can you describe students toward learning/ using CAAD within the curriculum? | 2-10 Which approach do you think the curriculum should take in integrating CAAD? |
|---|---|---|
| Chi-Square[a,b] | 7.111 | 55.167 |
| df | 1 | 2 |
| Asymp. Sig. | .008 | .000 |

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 18.0.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 12.0.

**Table 12: The Chi-Square Test of independence between two variables.**

From table 12 it can be inferred that there was a significant relationship between the approach in integrating CAAD and students' attitudes towards learning and using CAAD ($\Xi^2=55.16$, $df=2$, $p=.000$), and this research therefore hypothesised that there would be an association between students' attitudes towards learning and using CAAD within architecture design studio and the approach of teaching CAAD and architectural design integration adopted by the school. The above Chi-Square proves that the kind of approach adopted in teaching CAAD affects students' attitudes towards learning architectural design. So students from schools adopting an effective approach of integrating CAAD with architectural design have abetter attitude and are more competitive than those from other schools with a lesser interesting approach.

### 4.4.5.2 Content and orientation of CAAD courses

The way CAAD courses are perceived within Schools of Architecture was considered a major factor affecting CAAD teaching within Schools of Architecture. There are observations that a percentage within institutions perceives CAAD as a separate course, which may affect CAAD, it's content and relation to design theory and process, identified by Asanowicz (1998:198) as the traditional CAAD architectural curriculum.

Thirty-six respondents were asked to describe the orientation of CAAD courses that are taught. This question concerned the relationship between contexts of the CAAD course in relation to architectureal design.

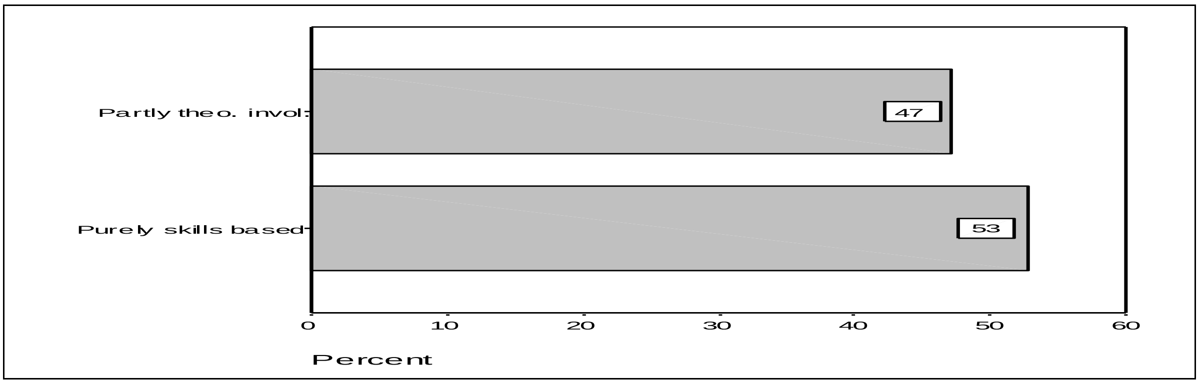


**Figure 40: The general orientation of CAAD courses taught within UK Schools of Architecture (Q3-1)**

According to Figure 40, 47% of CAAD courses are mixed between theory and hands-on exercises. On the other hand, 53% of the respondents reported that their courses are purely skill based.

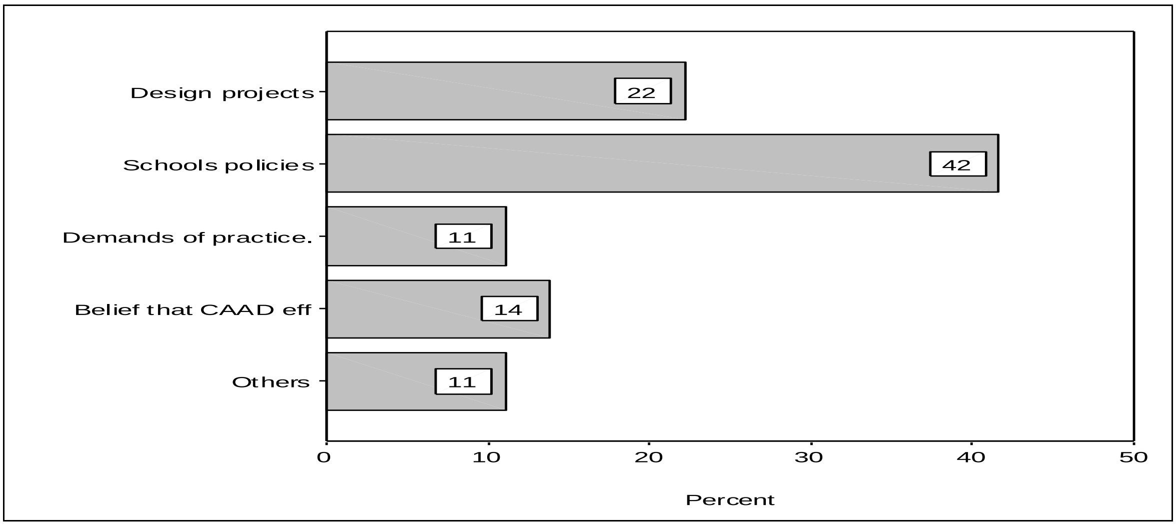


**Figure 41: A bar chart of about the content of CAAD courses in UK Schools of Architecture (Q2-4).**

The participants were asked about what determines the content of and the time scale allocated for a CAAD course. They were given five options to choose from: According to changes in the nature of design studio projects, following the school's policy, specific demands of practice and the intellectual belief that CAAD affects design perception.

It can be seen from Figure 41 that the contents of 42% of CAAD courses in UK Schools of Architecture are determined by the schools' policies, whereas only 22%

courses' contents are based on design projects. It can be inferred from the figure that a periodic review of the school's policy is very important to allow for changes in the design course and match practice demand.

**Test Statistics**

| | 3-1 How would you best describe the orientation of your CAAD course? | 2-4 What determines the content of CAAD course and the time period allocated for such a course? |
|---|---|---|
| Chi-Square[a,b] | .111 | 20.667 |
| df | 1 | 5 |
| Asymp. Sig. | .739 | .001 |

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 18.0.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 6.0.

**Table 13: The Chi-Square Test of independence between the orientations of CAAD courses and CAAD content determinants.**

From Table 13, one could assume that there is a strong relationship between CAAD policies available within the school curriculum and the CAAD course orientation. This means that studios of architectural education nowadays are more involved in computers than in previous decades, compared with QaQish's results (QaQish, 1997).

### 4.4.5.3 Teaching and Practising in CAAD courses

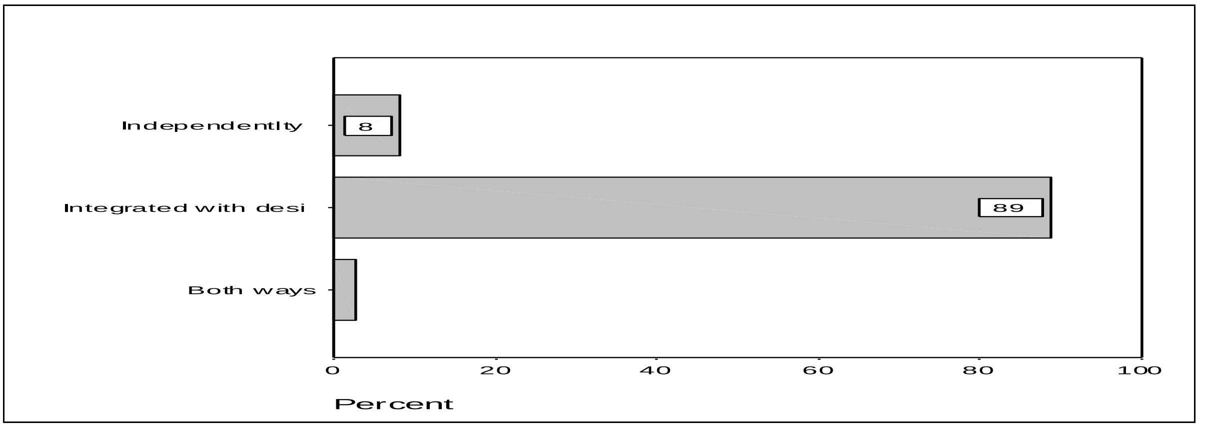


**Figure 42: The CAAD tutors' opinion towards teaching CAAD programmes (Q3-6).**

The same respondents were asked to give their opinion on the effective approach for CAAD integration within ADE, and were given three options to choose from: teach CAAD as a course independent of design, integrated with design studio work, or adopt a composite approach.

It can be seen from the bar chart (Figure 42) that the majority (89%) of CAAD tutors who participated in the questionnaire prefer to teach CAAD issues integrated with design studio work. Only a few (8%) of the respondents are interested in teaching CAAD independently from design issues. This reveals that the computer's potential, as an aid tool in architectural design education has become more obvious to design tutors than before. From the figure, it can be concluded that there is a strong tendency towards incorporating CAAD in architectural design studios work in UK Schools of Architecture.

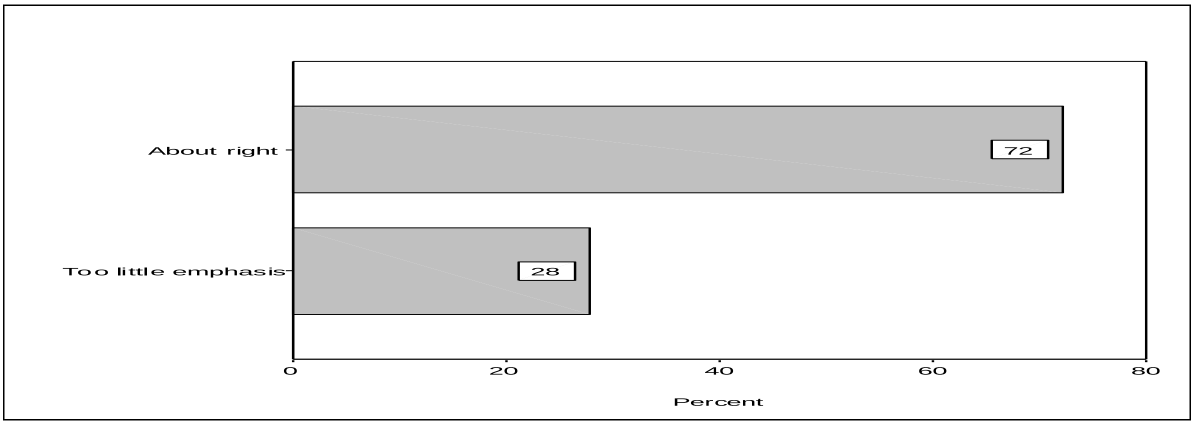


**Figure 43: A bar chart showing CAAD tutors' overall response to the issue of evaluating the emphasis placed on CAAD teaching (Q2-3).**

The respondents were asked to indicate whether their school's curriculum placed enough emphasis on CAAD teaching in general. The variable used to define the level of the emphasis varied between three levels: too much emphasis, about right, and too little emphasis. Figure 43 shows that 72% of respondents felt that their school had about the right emphasis, while 28% of respondents felt their schools placed too little emphasis on CAAD teaching.

### 4.4.5.4 Timing issues

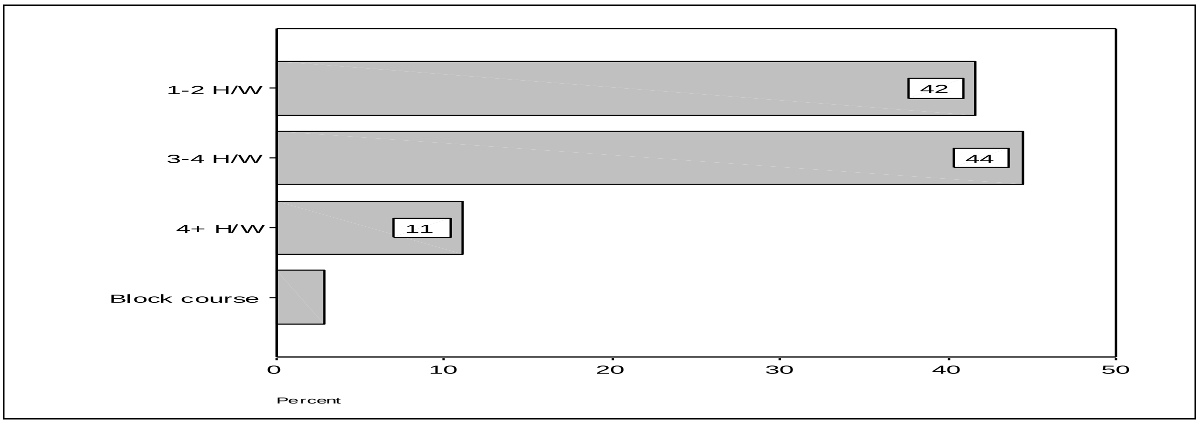


**Figure 44: The range of timetabled teaching of CAAD within UK Schools of Architecture (Q3-12).**

Figure 44 (a bar chart) shows the distribution of CAAD teaching hours which schools offer per week. The horizontal axis shows the percentage of hours timetabled for teaching CAAD courses and the vertical axis shows the teaching hours divided into four categories: 1-2 H/W, 3-4 H/W, 4+ H/W, and Block courses.

**3-12 How many hours per week is timetabled for teaching the CAAD?**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 1-2 H/W | 15 | 41.7 | 41.7 | 41.7 |
| | 3-4 H/W | 16 | 44.4 | 44.4 | 86.1 |
| | 4+ H/W | 4 | 11.1 | 11.1 | 97.2 |
| | Block course | 1 | 2.8 | 2.8 | 100.0 |
| | Total | 36 | 100.0 | 100.0 | |

**Table 14: Information / the statistical analysis of how many hours per week are timetabled for CAAD teaching courses provided by UK schools of architecture.**

It can be seen from figure 44 and table 14 that from 36 participants, 15 (41.7%) respondents indicated that their courses offer between 1-2 hours per week for teaching the CAAD. Whereas 16 cases (44.4%) offer between 3-4 H/W for teaching the CAAD, and only 4 cases offer 4+ hours per week. The statistical analysis shows that the mean offered for teaching CAAD equalled 1.77 H/W and the mode equalled 2. On other hand, the mean offered for practising CAAD equalled 1.5 H/W. That gives a mean equal to 1.8 H/W.

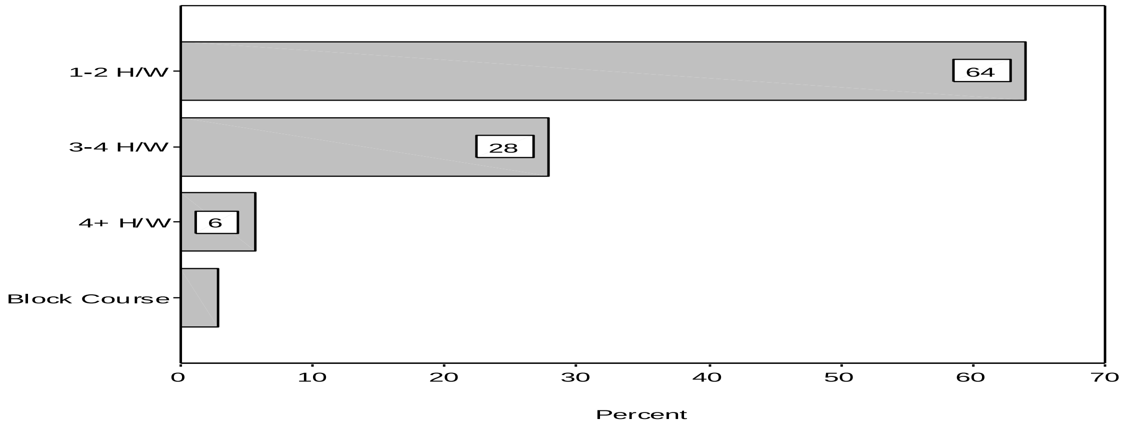


**Figure 45: A bar chart presenting the hours/W of training in CAAD courses across UK School of Architecture (Q3-13).**

The respondents were also asked to specify the number of hours of training within their courses.

Figure 45 shows that 64% of the respondents indicated that their students receive 1 to 2 hours of training on CAAD software per week. Whereas 28% of the respondents specified that their courses offer between 3 to 4 hours of training to their students per week. Meanwhile, only 6% of the respondents indicated that they provide more than 4 hours of training. And that gives a mean equal to 1.5 H/W.

### 4.4.5.5 Communication in ADE

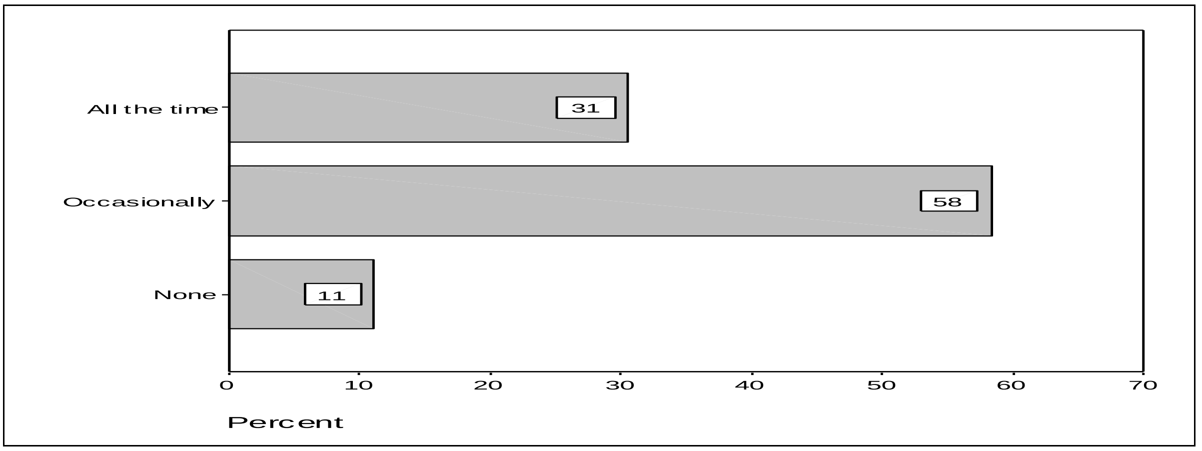


**Figure 46: A bar chart showing the tutors' attitude towards using e-mail to communicate with students (Q3-10).**

Figure 46 shows the bar chart analysis of the instructors' answers to the question: How often do you use e-mail to communicate with students about the course that you deliver? (They were given three choices: all the time, occasionally, and none).

The analysis shows that 58% of respondents use e-mail occasionally, which means that the e-mail as a tool of communication is gaining ground as a new approach within the architectural education community, whereas 31% of the participants already use e-mail all the time to communicate with their students. However, for 11% of instructors, the benefits of e-mail as a tool of communication are not clear as yet.

### 4.4.5.6 Course delivery

It would seem that within architectural design education there is more and more reliance on the use of computers in communication between instructors and students in general and in course delivery in particular.

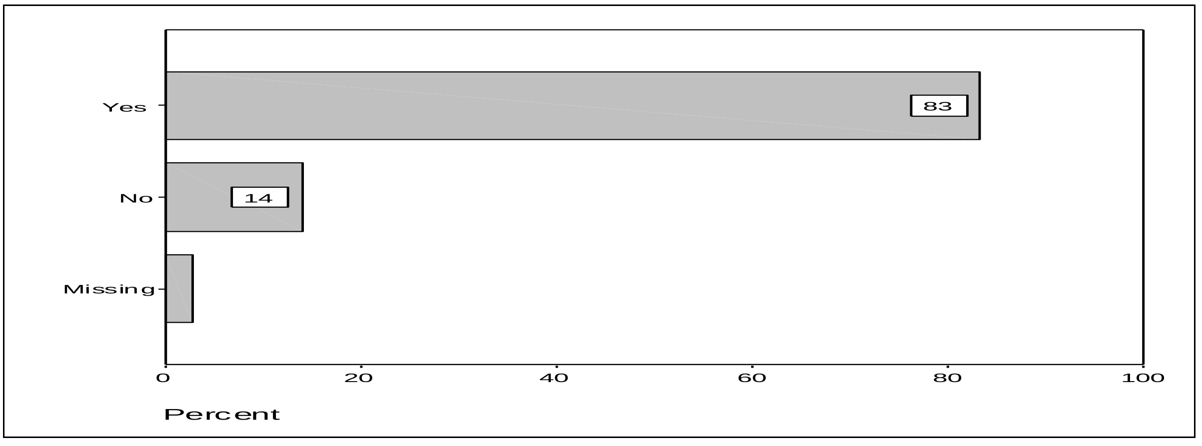


**Figure 47: The respondents' rate to Q Do you provide any written materials or manuals to students in CAAD practising sessions? (Q3-8a).**

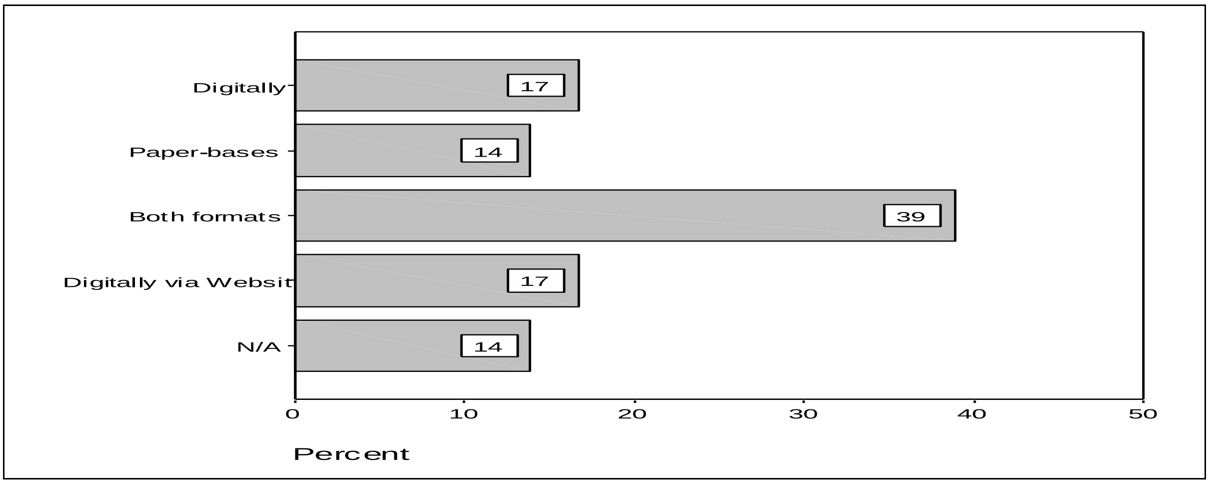


**Figure 48: The format of written materials provided to students in CAAD practising sessions (Q3-8b).**

As can be seen from (Figure 47 - 48), 83% of the respondents indicated that they provide written materials to their students. 17% of the respondents provide written materials in digital format, while 39% in two formats (paper-based and digital format). On the other hand, 17% reported that they provide digital material via websites only.

The simple bar chart (Figure 48) for UK's schools tutors participated in the questionnaire survey shows that 39% of the respondents are used to providing written material in both digital and paper-based formats to students in CAAD practice sections; while17% use the digital format via WWW to provide the written materials. The analysis illustrates that the digital format alone and the paper-based format alone come third with 14% of respondents' answers each way.

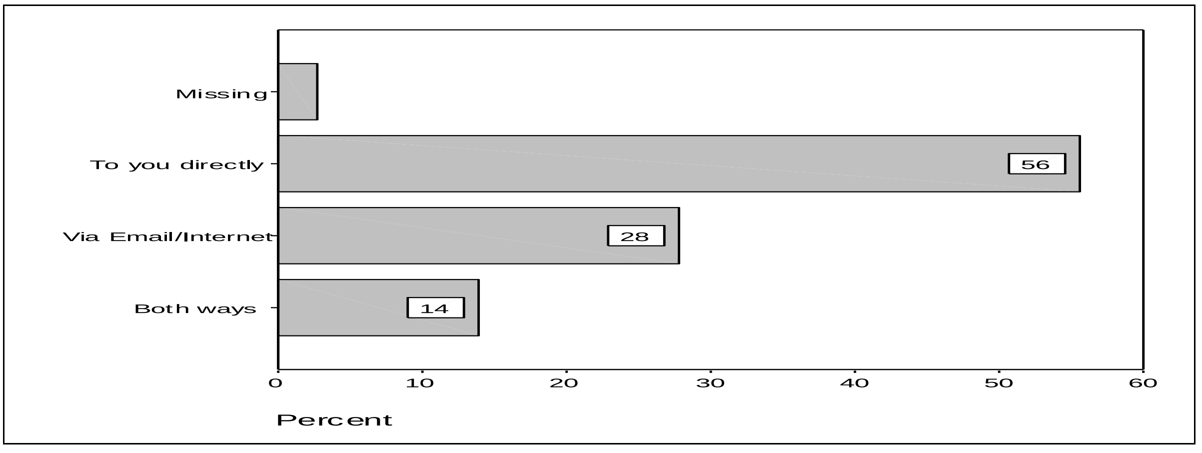


**Figure 49: The response rate to Q. how do your students submit their CAAD course work? (Q3-9a)**

Respondents were asked to indicate whether students submit their CAAD course work directly to instructors or via e-mail. The question was designed to determine the importance and role of the computer in students' work within ADE. The analysis revealed

(Figure 49) that 56% of the respondents said the students submit CAAD course work directly to instructors, and 28% respondents said they do so via e-mail.

On the other hand, 53% of replies shows that students submit CAAD course work directly to tutors in both formats (paper-based and digital); meanwhile 22% submit it in digital format only (Figure 50).

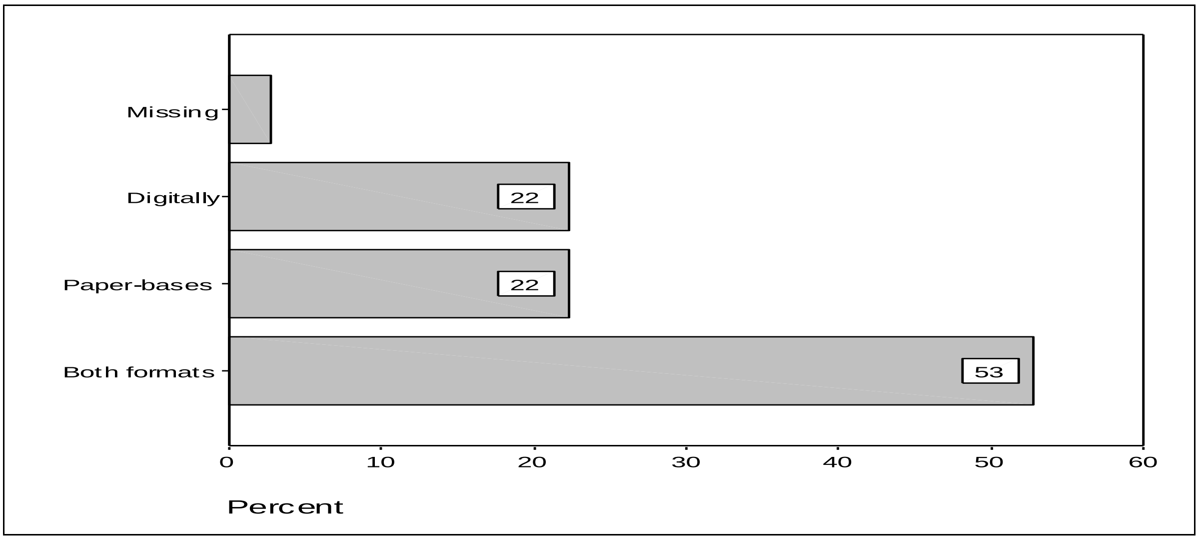


**Figure 50: The respondents' answer to Q. in what format? (Q3-9b).**

### 4.4.5.7 Virtual reality

The questionnaire survey asked participants whether or not their schools have introduced virtual reality in the curriculum and, if yes, in which year? (They were given five choices: 1st year, 2nd year, 3rd year, 4th year, and 5th year).

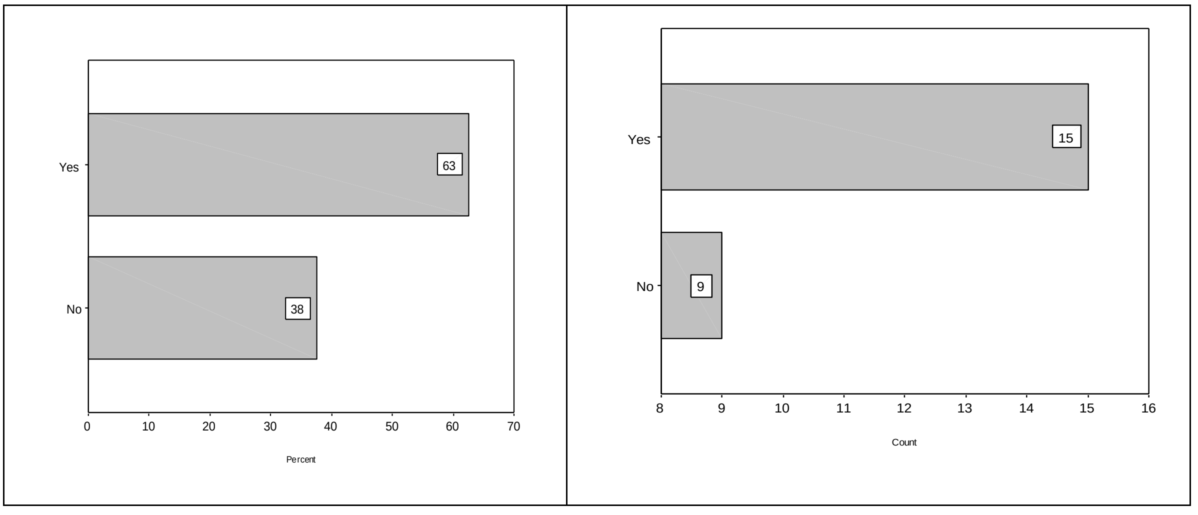


**Figure 51: The answer to question: Have your school introduced Virtual Reality in the Curriculum? (Q2-16).**

The results obtained from 36 participants in 24 Schools of Architecture (Figure 51) show that 63% (15 schools) of UK Schools of Architecture have introduced virtual reality into the school's curriculum, whereas 38% (9 schools) of the respondents indicated their schools have not introduced virtual reality yet.

On the other hand, as can be seen from figure 52, from the 15 Schools of Architecture that introduced VR, 5 schools (33%) introduced VR in the first year, and another 5 schools (33%) introduced it to third year students. Meanwhile, two schools (13%) introduced it in the second year, and another 2 schools introduced VR in the fourth year. Only one school (7%) recorded the introduction of VR to fifth year students.

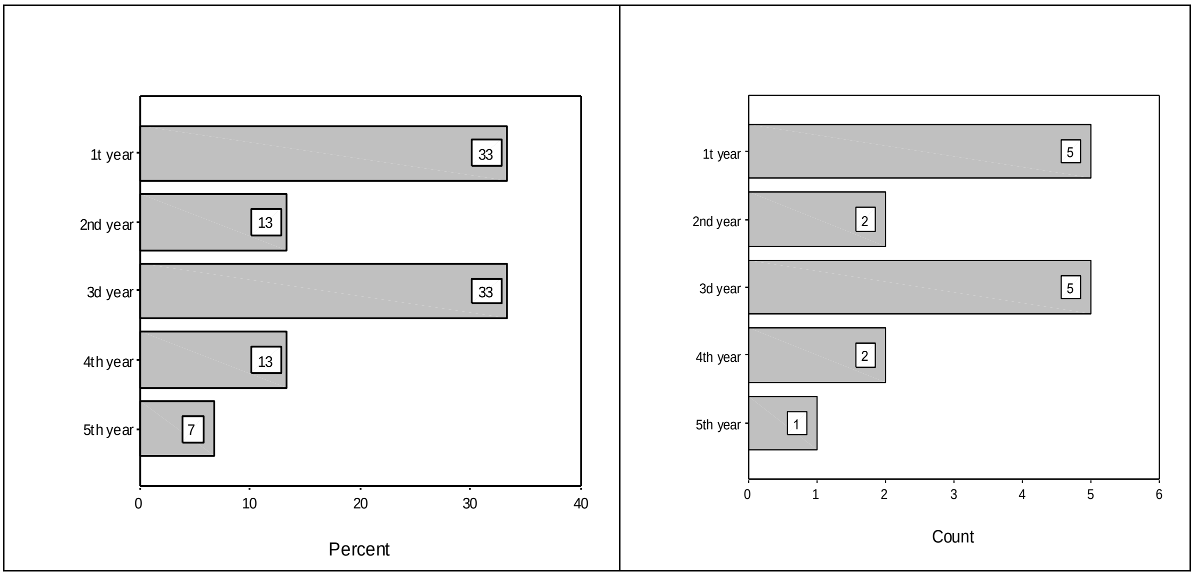


**Figure 52: The answer to question: To which year does the school introduce Virtual Reality? (Q2-17).**

This indicates that the role of VR within architecture design education has become clearer as a support tool for the design process, and that the main problem is that there is no general agreement as to which year VR should be introduced within the school's curriculum: should it be at the end of the first degree in architecture, or after a year out practicing? Further research is needed in this area.

### 4.4.5.8 CAAD Facilities

The literature reveals that the location of a computer laboratory and the relationship with a design studio space was considered one of the main factors affecting both the learning environment and the overall CAAD role in design studio education.

Respondents were asked to indicate where their school placed CAAD hardware (PCs or MACs), and were given four options attested within UK Schools of Architecture to choose.

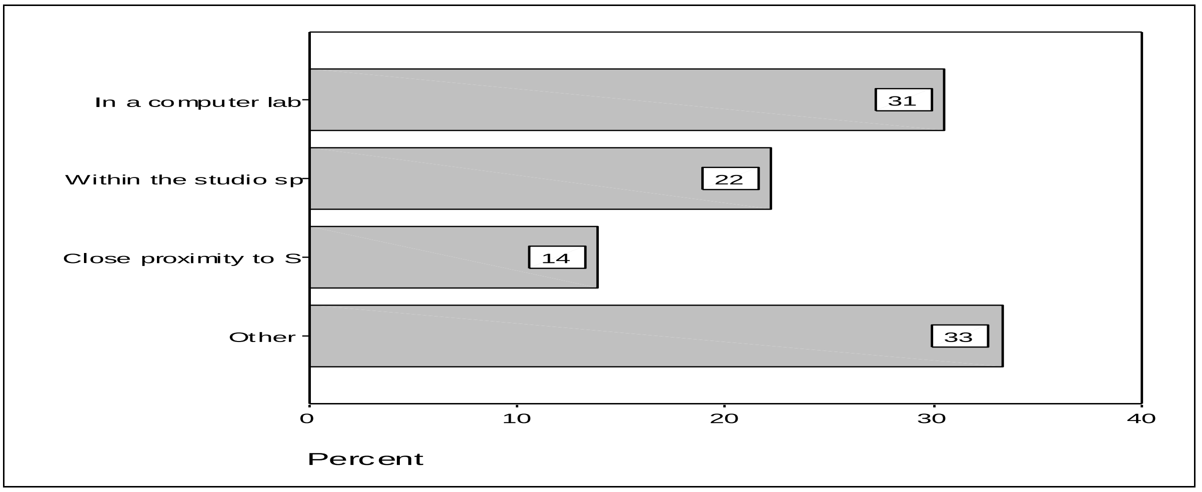


**Figure 53: Computer analysis showing the location of CAAD facilities in UK Schools of Architecture (Q3-3).**

Figure 53 shows the respondents' rate of placing of CAAD hardware within UK schools of architecture. The analysis revealed that 31% of UK Schools of Architecture still located computer facilities in a separate space (a computer laboratory), whereas 22% of the respondents reported that their school located computers within the studio space, and 33% of the respondents chose the other category, which combines the three solutions. This reveals that there is a tendency towards using different solutions aiming at finding a better direction of using CAAD facilities within architecture design education.

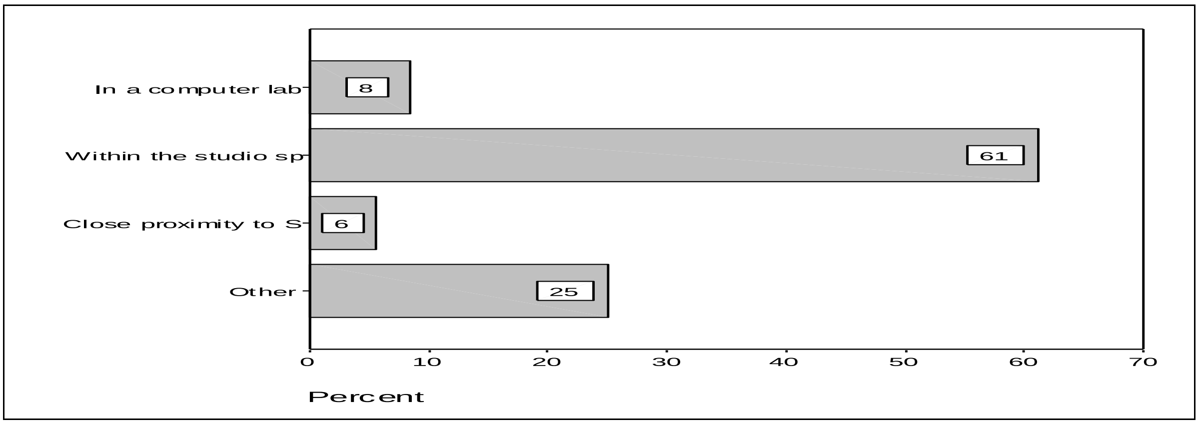


**Figure 54: In your opinion which of the above settings is more effective for CAAD teaching/integration within design? (Q3-4)**

Respondents were asked to identify which is the effective setting for CAAD facilities. As can be seen from the bar chart (Figure 54), only 8% of the respondents reported that setting the CAAD facilities in a separate computer laboratory is a better solution, meanwhile 61% of the respondents are of the idea of setting CAAD facilities within the studio space.

We can infer from the analysis that the wider majority of CAAD tutors in UK Schools of Architecture favour adopting CAAD facilities within the studio space.

### 4.4.5.9 CAAD Software

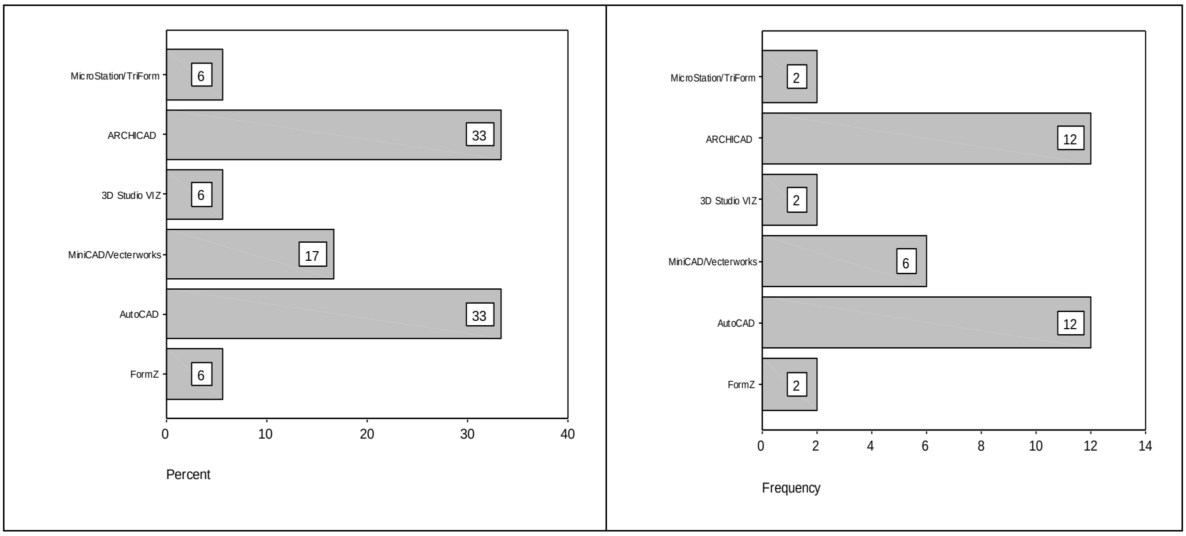


**Figure 55: A bar chart showing the analysis of the highest common use of CAAD package within UK CAAD courses (Q2-12).**

Figure 55 relates to the use of CAAD packages within CAAD courses in UK Schools of Architecture. Respondents were asked to name the CAAD package they used in CAAD courses.

It was apparent from the bar charts that ARCHICAD and AutoCAD are the most widely used packages in architecture design education, with a rate of use of 33.3% (12 cases) each. MiniCAD, VectorWorks, with (6cases; 16.7%) came second in use. Other software MicroStation/TriForma, FormZ, and StudioVIZ (2cases) rated 5.6% (2 cases) each. In spite of the smallness of the study's sample, the analysis reveals that AutoCAD is still the most common package in use within Schools of Architecture, a finding that agrees with the results of "A World-wide Questionnaire Survey on the Use of Computer in Architectural Education" conducted in mid 1996 (QaQish, 1997) (QaQish & Hanna, 1997).

### 4.4.5.10 The obstacles meeting CAAD courses

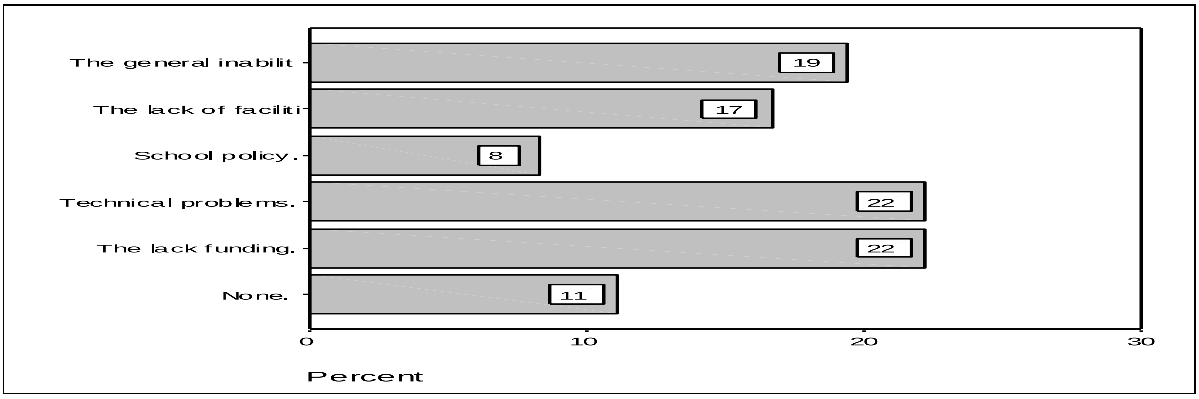


**Figure 56: A bar chart showing the main obstacles against meeting CAAD courses objectives? (Q3-5)**

The analysis carried out on the obstacles faced when teaching CAAD courses has revealed (Figure 56) that technical problems and the lack of funding constitute the major hindrances facing CAAD integration in the architectural curriculum, drawing the highest rate of 22% in each category. The general inability to understand the CAAD culture within UK Schools of Architecture constitutes the second obstacle meeting the teaching of CAAD courses with a rate of 19%.

Pursuing the same line of objectives, the respondents were asked to identify the main problems facing students during the CAAD course (Figure 57). Out of 36 respondents, 36% reported time limitation is the main problem. Lack of resources, with 17% of returns, came in as the second category. With 14% respondents' rate, a mixture of problems came in third place and fear of using the computer came in fourth place with 11% respondents' rate.

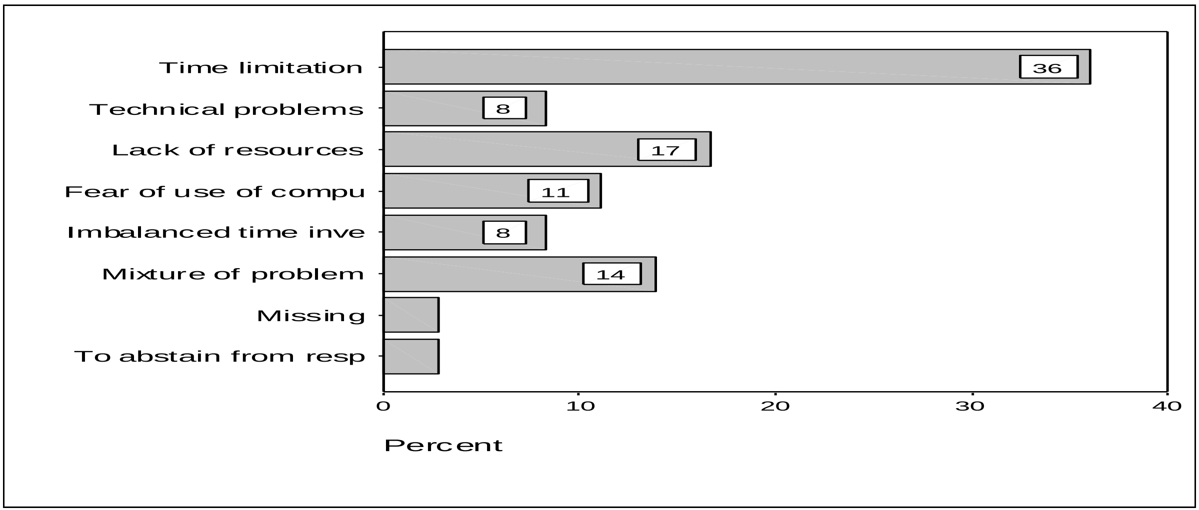


**Figure 57: The respondents' rate to the question: What do you think it is the main problem facing students during the CAAD course? (Q4-1).**

**Test Statistics**

| | 4-1 What do you think it is the main problem facing students during the CAAD course? | 3-12 How many hours per week is timetabled for teaching the CAAD? | 3-13 How many hours of training/practicing per week do you provide for CAAD software package in the course? |
|---|---|---|---|
| Chi-Square[a,b] | 23.111 | 19.333 | 34.444 |
| df | 7 | 3 | 3 |
| Asymp. Sig. | .002 | .000 | .000 |

a. 8 cells (100.0%) have expected frequencies less than 5. The minimum expected cell frequency is 4.5.

b. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 9.0.

**Table 15: The Chi-Square Test of independence between three variables.**

According to Table 15, there was a significant relationship between problems facing students during the CAAD course and the number of hours per week timetabled for teaching the caad course ($\chi^2$=19.33, *df*=3, *p*=0.000). The Chi-square test also shows that there was an association between problems facing students during the CAAD course and the number of hours per week timetabled for training provided for CAAD software package in the course ($\chi^2$=34.444, *df*=3, *p*=0.000).

Here schools of architecture should address carefully the issue of teaching and training hours on offer to students on software packages in CAAD courses.

## *4-5 Summary*

The literature review (Chapter I, II, and III) shows that there is notable evidence that both architectural education policy and teaching methods have changed after integrating computers within the architectural design education's curriculum. This chapter aimed at testing this hypothesis by investigating the UK Schools of Architecture as a case study, and at drawing a fuller picture on architectural education and integrating CAAD in a curriculum.

In January 2003, the UK Schools of Architecture Questionnaire Survey was mailed to seventy-five (75) Instructors in thirty-six (36) different schools whose courses are recognized by RIBA.

The aim of this survey was to acquire better views concerning architecture design education (ADE) when integrating CAAD within the curriculum in UK Schools of Architecture.

The questionnaire survey was divided into four sections. The first section was concerned with general information about participants, the second with the relationship between the curriculum and the CAAD course, the third with CAAD and teaching methods, timing and resources thereof, and the fourth section with general issues facing the integration of CAAD in ADE.

The statistical package for social sciences (SPSS 9.0 for Windows) was used to analyse the results of the questionnaire exploring the institutions' instructor opinion. Furthermore, the summary of the findings is presented as tables and bar charts.

Owing to the small sample size, in that only 36 respondents from 24 UK Schools of Architecture took part in the survey, any conclusions from this analysis should be viewed with caution.

In general, UK Schools of Architecture offer students two kinds of degrees, the first after year 3, and the second after year 4. The professional training year out is usually taken after the third year.

The most important points that emerge from the analysis of the UK questionnaire survey are:

-The survey had revealed that the majority of UK schools of architecture have moved in the direction of adapting the CAAD culture within the curriculum.

-From the 75 questionnaires mailed, 36 participants responded, presenting the views of 24 Schools of Architecture, accounting for 66.58% from the total rate. The response rate of 80.55% was recorded from the England region. Meanwhile 16.66% was recorded from the Scotland region and only 2.77% response rate was recorded from the Wales region.

- 53% of the respondents thought their CAAD courses are purely skills-based, whereas 47% were of the opinion that the orientation of their courses is partly theoretical, involving lectures, and partly practical, involving exercises.

- The majority (89%) of UK CAAD tutors who participated in the questionnaire indicated a preference for teaching CAAD issues integrated with design studio work.

- The analysis of the questionnaire survey reveals that the two most common CAAD packages in use in architectural education in UK Schools of Architecture are ARCHICAD and AutoCAD.

- 92% of the respondents were of the opinion that 2D draughting, 3D (Three-dimensional Modelling) with Visual communication is the appropriate approach for teaching architectural design integrated with CAAD. At the same time, 89% felt that Schools of Architecture should teach CAAD integrated with design.

- The analysis of the questionnaire has revealed that 63% of the UK Schools of Architecture have introduced Virtual Reality into the curriculum, whereas 38% have not yet done so.

- The questionnaire investigates the time issue by asking the participants how many H/W are timetabled for teaching the CAAD course. The analysis shows that 42% of the schools offer between 1-2 H/W, whereas 44% offer between 3-4 H/W for teaching the CAAD course.

- 58% of the participants indicated that they occasionally used e-mail in communications with students about course notes compared with 31% who used e-mail all the time. Only 11% reported that they did not use e-mail at all.

- 28% of the respondents felt their schools placed too little emphasis on CAAD teaching. Whereas the majority, 72%, felt their school had about the right emphasis.

- With regard to course delivery issues, the analysis revealed that only 28% of the respondents reported that students submit CAAD course work via e-mail. 96% of the respondents still use the traditional way.

- Both the technical problems and the lack of funding were reported as the highest main hindrances facing CAAD course objectives in the UK Schools of Architecture with a rate of 22% each.

- The analysis of the questionnaire survey showed that 36% of the respondents felt that time limitations was the main problem facing students during the CAAD course (Q4-1). While 17% felt that the lack of resources was the main problem, only 8% felt that technical problems were a factor. It is concluded that the number of hours per week for both teaching and practising CAAD are extremely important issues facing schools in their attempt to successfully teach architecture design integrating CAAD.

- The analysis also revealed that out of the total number of CAAD instructors involved in teaching CAAD courses in UK Schools of Architecture, 60.25% are full-time instructors, whereas 39.74% are part-time instructors.

- As to the placing of CAAD facilities, out of 36 respondents, (61%) reported that the location of CAAD laboratory within the studio space is the appropriate and the most effective setting of CAAD facilities for CAAD teaching. Only 8% reported a preference for a separate computer laboratory as an effective setting for CAAD teaching.

- Although the majority of UK schools of architecture have broadly accepted computers, general agreement does not go beyond the basic steps of integrating computers in architecture design education and does not reach the full integration of computers as part of schools' conventional policy. Consequently, several remarkable individual school's attempts to creat leads to general guidelines in the absence of national guidelines of how UK Schools of Architecture integrate computers in their curriculum.

To sum up, the analysis of UK Schools of Architecture Questionnaire Survey revealed, in general terms, that the environment of architectural design education studio is becoming increasingly digital in nature, a finding that tallies with one of the final conclusions of the 2002 round table session at 20th eCAADe (Mark et al., 2002).

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# Chapter Five: Conclusions, Recommendations, and Prospective research

This chapter summarises the conclusion of this research in the form of guidelines to assist the Department of Architecture and Urban Planning at El-Fateh University, Tripoli-Libya, to permit the integration of CAAD in the curriculum currently being implemented in architectural education.

The advances in CAAD through the general development of computing technology, attracted interest of architects to use those advances in the design process, and, consequently, obliged Schools of Architecture to integrate the computer into architectural education as a new tool to meet the needs and demands of architectural practice.

The above facts all together posed some important questions: How and when should CAAD be introduced in the curriculum of architecture design education? To what extent can CAAD be integrated into the architectural curriculum? As the main research problem this research examined the CAAD course environment with teaching and learning issues within the course as reluted subsidiary problems. The research hypothesis was that one of the problems of full CAAD integration in architectural education is the general cultural gap in understanding the role and potential of the computer and its capability as an aid to the design process.

The thesis has discussed the main points relating to integrating CAAD within architectural education in terms of computers' capabilities and their role and application in the architectural design process (Chapter I & II). The relationship between CAAD and architectural education (Chapter III), and the strengths and weaknesses of incorporating CAAD within architectural design education also are set out.

The thesis sought CAAD tutors' opinions about integrating CAAD within the architectural curriculum. To this end, a questionnaire survey was administered in January2003 as an instrument for collecting data to highlight advantages and disadvantages of integrating CAAD in UK Schools of Architecture. This case study was intended to illuminate important issues deemed relevant to integrating CAAD.

The results obtained from the questionnaire were analysed using SPSS 9.0 where several types of statistical tests were illustrated by tables and charts to describe the findings. The most important results are now summarised and presented as part of Chapter IV.

This thesis aimed at answering the main question: To *what extent can CAAD be integrated into the architectural curriculum?*

## *5.1 The Department of Architecture and Urban Planning at El-Fateh University, Tripoli-Libya: Historical background and general features of architecture programme*

The Architecture programme has been taught in the Department of Architecture and Urban Planning at El-Fateh University since its foundation in October 1969 under UNESCO guidelines to meet urgent political and societal needs at that time.

The department, which was established and is still part of the Faculty of Engineering, is the oldest Architectural School in Libya (Ben-Taher et al. 1999). The main important features of architectural education within the department are as follows:

-The education policy aims to give students a chance after the second year to choose from two options: architecture design or urban design.

- Since 1979, the department has offered a ten semester architecture programme as a full-time study leading to the degree of Bachelor in Architecture (BSc Architecture).

-The design studios are the main focus of activity within the department supported by a number of other courses, including sets of humanities subjects (history, social and cultural studies, urbanism) and technology subjects (structures, building construction and environmental studies).

-The design studio consists of six design courses (face-to-face architectural design studios), one at each semester in sequence and according to a prerequisite base order (One before Three, Two before Four, Three before Five and Four before Six), culminating in a final design project, which allows students, guided by supervisors to choose their design theme freely.

-The syllabus of the architectural design course includes design theory and practice using a realistic site as a vehicle and a special design problem. This process is supported by traditional methodologies of design and drawing using pen and paper.

-In late 2001, the Higher Education Committee subsidised the department, thus affording an opportunity to obtain its first separate computer laboratory, which consisted of 20 PCs (Pentium 3 350MHz) as shown in Figure 58, running Windows 98, AutoCAD, 3DMax, Photoshop and CorelDraw, as design tools to encourage the department to improve the curriculum.

**Figure 58: The Computer laboartory at the Department of Architecture & Urban Planning, Tripoli-Libya (July 2003).**

-The department started to provide short courses on CAAD in the academic year 2003 as an elective course to third year's students. CAAD tutors were volunteers from the department's instructors. The course was skills-based to meet the needs of professionsal practice.

## *5.2 CAAD and Architectural Curriculum; Results, Conclusions & Recommendations.*

From chapters I, II, III, and IV, it can be concluded that while there is a wide acceptance of integrating computers within architectural education, the computer's role and its potential as a design tool is still problematic.

This thesis started by reviewing the history and development of computers related to architectural education, investigated the impact of computers on architectural education in general, and sought to come out with a series of recommendations for a better integration of CAAD into the design studio.

Conclusions and recommendations, based on core arguments developed in chapters (I, II, III) and the findings from the case-study including the questionnaire survey of UK schools (Chapter IV) are drawn below.

### 5.2.1 Policy's aims

The growth of IT and computing culture within a society brought challenges to architecture schools by means of forcing schools to integrate computing into curriculum, and finding ways to enhance students' knowledge and skills in computing.

The initial object of any CAAD policy should be to increase the quantity and the quality of design ideas by developing students' ability and their skills to use computers through intensive practical work.

Formulating architectural educational policy was considered to be the key issue within Schools of Architecture to achieve the best possible integration of CAAD within ADE. From the analysis of the questionnaire survey 42% of CAAD course content follows the schools' policies.

It is recommended that:

1- The department's curriculum should be revolutionised to generate a computing culture among students that goes further than using CAAD as a drafting tool, and deploy CAAD as a cognitive device that help students to conceive ideas in 3D.

2-The desired development of architecture design education in relation to CAAD must show an understanding of the needs of practice, but it should not be dominated by it .A balanced curriculum should use CAAD as a 3D device to motivate students without allowing the focus on CAAD skills or practice needs to guide the school's curriculum.

3- Teaching CAAD without an architectural design value is useless. Therefore, one should look at CAAD courses within Schools of Architecture not as separate courses from other courses particularly design. This is found to be a major factor affecting CAAD teaching. In the survey 89% of UK CAAD tutors prefer to teach CAAD issues integrated with design studio work. Only 8% prefer to teach CAAD separately from design courses for different reasons.

4-The department's curriculum should aim to integrate computers within the design process to make students aware that a theory of design is affected by the type of media used, and from that point it is recommended that CAAD should be taught and learned from an early stage of students' learning.

5-To establish effective CAAD teaching within architectural institutions, it is recommended that the school's policy should incorporate CAAD in every course as a backbone of the curriculum, so that the many benefits the computer offers become part of students' knowledge.

6-There should be no place for separate CAAD courses in the curriculum except as a support, mainly to cover new issues in computer technology, or introduce new software packages.

7-Each design studio integrating CAAD should provide a theoretical introduction beside an opportunity to develop skills through intensive practical work, aiming to assist the student with tools to examine design's ideas, analyse data, explore and present design concepts, and to communicate with others during the studio's activities

8-The department should teach CAAD by relating it to architectural issues instead of teaching it as a separate course. In other words the use of CAAD in design studios should come after students have learned the essential facts about design itself and after they have learned how to technically manage a CAD-system (at last for a year, which is equivalent to two semesters)[xxxviii].

This can be achieved by dividing the department's policy towards CAAD integration into two phases as in Figure 59:

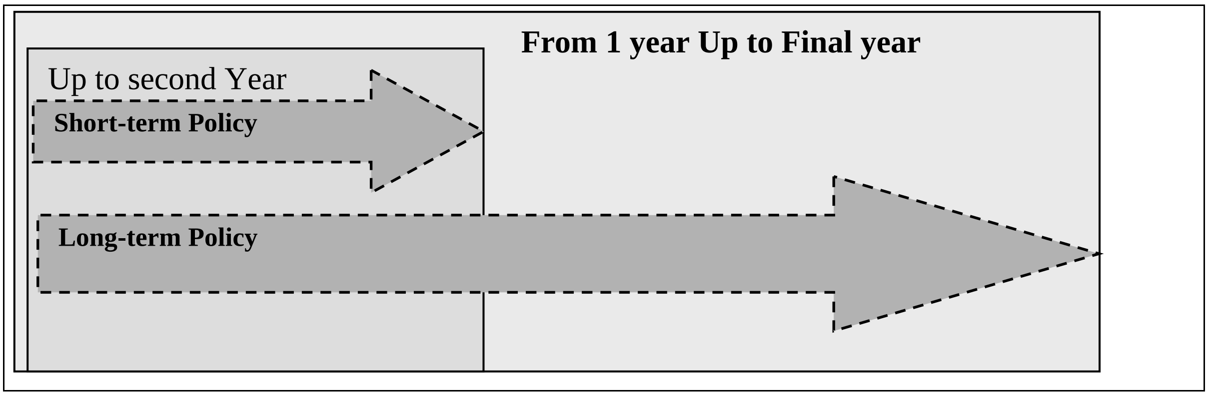


**Figure 59:Proposal diagram for long-term and short-term policy**

*I- Short-term policy*- using the computer as a target: teach students how to use the computer to first establish a computer culture and improve student's knowledge of CAAD. The CAAD could focus on course (Tool using) as part of the design studio process.

*II- Long-term policy*- using computers as a partner in the design process: teach the student CAAD principles, CAAD to assist the development of design ideas, CAAD for analysis, critique, and also as a tool for performance evaluation.

To achieve all previous points it is recommended that the department have a 'CAAD policy committee' responsible for deciding what to teach in CAAD and who teaches CAAD subjects. The committee should share all decisions about CAAD teaching with design tutors to meet the department's policy.

### 5.2.2 CAAD Courses, Curriculum, and Methodology

A change in design approach with respect to computers' abilities may take place if the incorporation of CAAD responds to the need of design studio work itself. The content of architectural study programs should become more flexible, varied and takes on board architectural practice demands.

The general agreement between schools of architecture that first year students now come to study with wide ranging backgrounds, skills and expectations means that the department should be aware of the difference between two kinds of students: first year students and the rest of students.

From general notes that came from different experiences of integrating CAAD within Schools of Architecture (Chapters II, and III), and the results from the analysis of the questionnaire survey (Chapter IV), the thesis suggests the following CAAD framework.

Divide students within CAAD learning into two levels, aiming to "serve a broader set of career paths that can be supported under the constraints of professional accreditation requirements" (Mark et al. 2002:169):

1- *Basic level*. The main aim of this level is to teach Students to use computers in general. The course within this level can move rapidly through several software packages using one of two models:

- Model One. This model attempts to teach students how to use: a word processor; a paint software package; a two dimensional drafting software package; a three-dimensional solid modelling software package; digital imaging tools. Through this model, the student becomes familiar with the role of computers as tools for image making, drafting and modelling.

- Model Two. Learn to use: a spreadsheet; a database program; a statistical package; a Geographic Information System (GIS). Through this model, the student becomes familiar with the role of computers as tools for analysis and decision-making.

The objective of the Basic level is to be satisfied when the computer is used by the student in every day working (design exploration, presentation, and communication "An introductory curriculum should cater to and shape this variety, allowing students to achieve a basic level of computing skill and knowledge while still allowing potential advanced exploration" (Chase, quoted in Mark et al., 2002:207)

Several points can cut as guidelines to achieve aims such as: I-Replacing bad computing practices with good ones by 'bridging courses'. II-Demonstrating the potential of computing tools for design. III- Encouraging a considered approach to the use of computing tools. III-Providing an appreciation and understanding of the benefits and difficulties in using the computer in conjunction with or instead of non-digital methods

2- Intermediate and advanced level (Model Three). The aim of these levels is to cover: Desktop publishing; Animation; Multimedia; and sharing work methods. These levels attempt to force the use of CAAD software as means of visualisation and animation involving the design process. The round table session of ecaade 2001 suggested several subject areas could be covered within these levels as in Table 16, and the thesis adopted as addition recommendation.

According to the table, the main aim of the basic level is to introduce students to computer knowledge by covering a set of computer based design applications including basic geometrical modelling, digital image processing, digital video, scanning and output media as tools for the design process.

The intermediate level attempts to expose students to different aspects of computer applications such as: three-dimensional modelling and rendering applications, explores moviemaking as an approach to critique the design idea, the relationship photography and drawing (2D and 3D), beside starting to introduce the advanced simulation techniques such as Structural analysis programmes.

| | | |
|---|---|---|
| Proposing of CAAD Curriculum consist of three levels each level contain subject areas | A-Basic Level | A1-Digital Design Media |
| | B-Intermediate Level | B1-Geometrical Modelling and Rendering |
| | | B2-Digital Media and Drawing |
| | | B3-Structural Analysis. |
| | | B4-Digital Moviemaking and Animation. |
| | | B5-Computables of Design. |
| | | B6-Spatial Simulation Techniques. |
| | C-Advanced Level | C1-Computer Aided Manufacturing and Robotics |
| | | C2-Digitalization of the Third Dimension |
| | | C3-Laser Surveying and Photogrammetry. |
| | | C4-Performance Simulation: Energy. |
| | | C5- Performance Simulation: Digital Acoustics and Synthesis. |
| | | C6- Performance Simulation: Artificial and Daylight Representation |
| | | C7-Digital Technology and Communications Media. |
| | | C8- Computation of Construction |
| | | C9-Geographic Information Systems |
| | | C10-Spatial and Data Analysis Methods. |

**Table 16: The Ideal computer curriculum suggested by round table session of ecaade2001 illustrated in Mark et. al., 2001)**

Although seeking an optimum level of well-integrated CAAD is controversial in architectural education. Generally speaking some steps should be followed:

I. The department should concern itself with balanced architectural design courses: to teach the student the principle of CAAD and the computer as an essential tool alongside conventional ones.

II. CAAD-education should be taught during the whole span of architectural curricula

III. The curriculum environment should be directed towards more learning by doing rather than teaching.

IV. Students should be encouraged to learn to use computers in research and in design

V. The department should concentrate on teaching students more modern communication skills beside traditional ones, such as e-mail, especially within collaborative team work,.

### 5.2.3 Framework for CAAD Courses

To establish effective CAAD tools within ADE, the writer proposes that the department should adopt a CAAD course framework based on three main stages. By such means each design studio can implement the same mechanism according to course objectives.

Stage1: *Skill-based* or *Skill-centred*, as an introductory CAAD with aiming to focus attention on skill building and taught separately from architecture.

Stage 2: *attempting to cover visualisation and animation skills related to design aspects*. The department can suggest different CAAD software to be implemented and integrated through instructors' experiences, such as FormZ, etc.

Stage 3:*Project-based teaching* or *Knowledge centred*, as part of architectural design course as means of design presentation and analysis, which reflects the nature of practice which is based upon the delivery of architecture design solutions in a project setting.

### 5.2.4 Choosing CAAD Systems

Students of architecture today are fortunate in terms of the array of CAAD tools provided by recent advances in computer technology, although there is no specific CAAD system suitable for every class of design and for every stage of the design process.

Consequently, choosing CAAD software was considered a difficult task for schools (Chapter I, II, III), and in general the department cannot choose specific CAAD software for teaching in isolation from other educational issues. For example, to which year of the undergraduate study and specifically, to which stage of the design work? Is it for sketching at the early design stage or for the analysis or final presentation? For what type of design work is the CAAD programme needed (drafting, rendering, modelling, communication)?

To choose suitable CAAD software for teaching architectural design, several key points should be considered:

-The package should be inexpensive and well suited to low budget computers and printers.

- For introductory courses (Bridge courses), software package should be general and works with all types of hardware platforms (PCs, MACs).

- Should be useful for final drawings as well as the early stages of the design process.

-CAAD software package should be science-based to be used as an analytical tool during the design process.

### 5.2.5 The Learning Environment

#### I- The Approach to CAAD Integration

Some common approaches to integrate CAAD are: visual communication approach, 2D drawing approach, and 2D, 3D modelling & visualisation approach.

From the survey it can be seen that 92% reported that the architectural curriculum should take both the 2D, 3D modelling and the visual communication approach in integrating CAAD.

It is recommended that the department adopt 2D, 3D modelling & visualising as an optimum approach for CAAD integration within architecture design education.

### II- CAAD tutors' issues

Finding competent instructors in general and CAAD specialists in particular within schools of architecture is one of the main obstacles facing the adoption of CAAD in architectural education.

There is a trend to replace full-time CAAD instructors with part-timers due to budget cuts in schools of architecture in general. The UK questionnaire survey indicated that 60% of instructors are full-time whereas 39.74% are part-time instructors. The department should employ part-time instructors to assist full-time CAAD specialists.

By employing additional part-time instructors the department can have an added flexibility and richness to the design studio course.

### III-Communication in ADE

The strong feeling within CAAD specialists (Chapter II & III) that the way of communication (including course delivery) between instructors and students, and the manner of CAAD course work submission during architectural design studios, is essential to achieve the CAAD course objectives.

The result produced general agreement among design course tutors to use digital media and e-mail facilities as a communication tool for different course activities instead of conventional manner.

From the survey (Chapter V), 58% of CAAD instructors use e-mail occasionally, whereas 31% use e-mail as a tool to communicate with students all the time. In addition, tutors reported that they are providing written course materials to their students and the majority in digital format in different ways included via schools' websites. Therefore, it is recommended that the department should fund the CAAD facility towards establishing a computer network connection with LANs and WANs in general.

## IV- The Location of CAAD Facilities

The issue of effective positioning of CAAD facilities have proved to be problematic for architecture design education performance in general and architecture design studio in particular (Chapter I).

In the survey 61% of respondents indicated that placing computer facilities within studio space is the effective setting for CAAD teaching within design, compared with only 8% who thought that placing CAAD facilities in a computer lab is more effective. Therefore, it is recommended CAAD facilities be sited within the studio space. The department of architecture should ensure a proper working of those facilities to achieve the desired standards of teaching and learning.

## V- CAAD Practicing Time

There was evidence that the practice period offered within CAAD courses was one of the main obstacles to students' performance in CAAD courses.36% of the respondents felt that time limitation was the main obstacle facing students.

It can be concluded that the more time students spend on practicing, the more confident they become and this will engender a positive attitudes toward using CAAD in the design process. From the health and safety point of view, the total hours work (the course training time) with a computer should not exceed four hours each time, to avoid student fatigue, and to prevent the task from becoming boring.

## VI- Virtual Design Studios

The rapid development of computer technology since the first commercial uses of CAD in the early 1960s, and specific developments in computer networking (the evolution of the Internet and WWW technologies) (see Chapter II) from the mid 1990s onwards, all gave Schools of Architecture a great opportunity to obtain benefits from the implementation of the idea of the virtual design studio.

Although the superiority of virtual design studio (under CSCW trend of teaching and learning architectural design) adopted as a new approach to motivate students and prepare them well for their future career (Chapter III), in general there is little sign of VR being widely used as a teaching medium within architectural education.

The survey of UK Schools of architecture appears to show that VDS as an approach to teach architectural design is still in its infancy. Of the 24 schools that participated in the questionnaire, only 63% have introduced VR to their curriculum.

From the 15 UK Schools of Architecture, who introduced VR to students, 5 (33%) schools introduced VR to first year, and 5 schools introduced VR to third year. Only 2 (13%) schools introduced VR to second and fourth year. In other words, there is no general agreement to which year should VR be introduced in the school's curriculum.

As a result, of the development of computer networking and the Internet (LANs and WANs) matched by the development of other computer technology devices such as digital telecommunication devices, handheld devices, and wireless, will give schools of architecture opportunities to collaborate design studio work breaking international, national and local boundaries.

The Department of Architecture and Urban Planning, Tripoli-Libya, should adopt the VDS as a learning method through two directions: synchronous mode and asynchronous mode. It should be concerned with two issues:

I- Intellectual: adopt a VDS approach to highlight the issue of growth in a common information culture (globalisation) and the issue of local identity.

II- Financial: make more funds available to VDS. There is a common feeling that funds for computing are inadequate to prepare students to meet practice demand, both in terms of the number of machines provided and the up-to-date CAAD software packages.

However, both issues need further research.

### 5.2.6 General Comments on adopting CAAD within ADE

-Within students' skill, the department should not spend time in teaching first year students word-processing, e-mail or hardware, and instructors should focus on essential architectural design education with the new media.

To overcome the lack of basic computer literacy, it is recommended that the level of IT literacy and skills as a common knowledge must be offered by faculty as an elective course to ensure that students enter the architectural study programme with a basic level of computing skill, besides ensuring that bad computing practice is replaced with good one.

-The CAAD course must concentrate on the potential of computing tools for architectural design and never start with CAD-specific technical facts.

-To create a computer culture within the department, the CAAD course should be taught by all architectural design tutors, and to achieve that the school should support instructors in different ways: upgrade the instructors' knowledge by offering them intensive CAAD sessions, or separate workshops for new media, so that they become confident in dealing with digital issues and give students better advice. ADE should be supported by a group of CAAD-experts.

## *5.3 Future Expectation*

Computers were viewed as a technical device for decades and that affected the degree of implementation of the computer as a design aid/ partner within architectural education. Recently CAAD has been viewed not just a helpful tool but also the future tool.

The development of computer technology is moving at a fast pace that makes it hard to any researcher to predict what the future will be. However some directions are clearly visible"the models become more 'intelligent', they allow for the faster retrieval of data and more integration between different aspects of information." (Fuchs et al., 1994: 45).

The optimistic future path for CAAD education, which is an ideal evolution path, will take place "when changes in the future are the most desired ones" (Penttilä, 1996:349), this writer expects the future of CAAD education to be based on three main avenues of developments: changing the way of communication and language, further development in digital technology and the revolution in virtual reality aspect (future tool), and the rapid development in CAAD software.

### 5.3.1 The language of communication within ADE studios

The integration of computer science with architectural knowledge will bring about a new architectural education approach, with new ways of communication and new words or terminologies to express architectural design meanings (think, express ideas and produce work).

Integrating computers with architectural education will also affect the every day communication language between students in architectural studio. “Computing, like any other specialized area, has developed its own jargon. Sometimes new words are invented, but more often existing words are given special meaning. The use of jargon terms, although necessary, tends to obscure what are generally simple concepts” (Gero, 1977:399).

From the language point of view, integrating computers with architectural education will offer a new approach for the design process, a new way of expression (verb and image) and that will cause some difficulties to both instructors and students at the same time.

The author believes that the daily language within ADE studio will become more symbolised, which is the result of two mixed disciplines: architecture and computer science.

The communication’s language within architecture design education is another area to be investigated by further research.

### 5.3.2The character of the future tool

The advent and the development of the laptop computer will change the character of architectural design education in two ways: I-the design studio place will have to accommodate different communication equipments for every stage of the design process and slowly the drawing board will disappear. II-The shape of architectural education studio after the introduction of laptops computers and wireless connections will become an undefined place or a ‘mobile space’.

## *5.4 Directions for future research*

This section outlines a topic that was suggested for further investigation orginally suggested by eCAADe 2002 (Mark et al. 2002) with same modifications:

Title: *CAAD Curriculum and Organization for the first year study of architectural design*.

Subject: Pedagogy issue of Structuring CAAD curricula for the First Year.

Issue: “What is the stepped educational sequence needed to inculcate advanced computer technology expertise in a context characterized by a range of student aptitudes and experience levels, different teacher attitudes and abilities, and in a context dominated by design studio problem solving" (Mark et al. 2002).

-To examine how CAAD should be best integrated in the first year study curriculum by specifically looking at where about and what areas.

-What is the student reaction to the CAAD course within architecture curriculum? Do students accept or reject using the computer during the design process?

-The effect of VR integration on team and individual teaching of architectural design, and what approach should be taken to introduce VR to first year students.

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# Appendix I: Questionnaire

**Cover letter**

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14 October 20

Dear Sir or Madam

I am a postgraduate student at Mackintosh School of Architecture-Glasgow, I am reading for a master degree by research entitled: CAAD Teaching in the Architectural Curriculum: a Case-study of U.K Schools of Architecture.

I am attaching with this letter a questionnaire regarding my study, please could you fill in the questionnaire and mail it back to me. I enclose a self-addressed stamped envelope for your perusal.

I honestly thank you in advance for your time and support in answering the questionnaire, and I look forward to hearing from you.

Yours Sincerely

Fouzi M. Azez

M. Arch. Student

Postgraduate Studies

**Introduction**

This questionnaire is a part of M.arch. (Dissertation) entitled: "*CAAD Teaching in the Architectural Curriculum; A Case-study of U. K. Schools of Architecture*" undertaker at Mackintosh School of Architecture, Glasgow School of Art.

The aim of the questionnaire is to investigate options for using computers within architectural education and specialists' opinions of them, focusing on the place of CAAD within the curriculum and the way of teaching CAAD in U.K. Schools of Architecture in which courses are recognised for exemption from Part 1 and Part 2 of the RIBA Examination in Architecture.

The results will serve as a guideline to the Department of Architecture in Tripoli-Libya as a means to improve the current curriculum and adopt a design-based CAAD culture in general.

***- If I may ask you to kindly pass a copy of this questionnaire to other CAAD staff in your school, to allow them to participate, for more accurate outcome.***

## *1- CAAD Tutor/ Lecturer*

*Please fill in the blank space where appropriate or tick (♦) when needed.*

### 1-1 Fill in the following:

Name of Participant (BLOCK CAPITAL) ……………………………………

e-mail:…………………………………….. Tel:………………………

Gender: ☐ Female. ☐ Male.

Name of your School: ………………………………………………..

Name of your course: …………………………………………………

Your position in the course: ………………………………………….…

Academic Background: …………………………………………….……………
…………………………….……………………………
…………………….…………….

Your role within the School: ☐ Advice only. ☐ Lecturer only.
☐ Lecturer and design tutor. ☐ Design tutor only.

**1-2 For how long have you been teaching this course?** (Tick one box)

☐ 2-4years ☐ 4-6years ☐ 6+

**1-3 Did you use/ teach any Computer Aided Learning (CAL) package in general?** (Tick proper box)

☐ Yes ☐ No

## *2- The Relationship between curriculum and CAAD course*

*Please fill in the blank space where appropriate or tick (♦ ) when needed.*

**2-1 Does your School have specific written objectives / policy for using CAAD programmes in studio projects?** (Tick proper box)

☐ Yes ☐ No

**2-2 If Yes, Do you think CAAD specialists within other Schools shared these objectives?** (Tick proper box)

☐ Yes ☐ No ☐ I do not know.

**2-3 Does your school's curriculum places enough emphasis on CAAD teaching in general?** (Tick one box)

☐ Too much emphasis. ☐ About right. ☐ Too little emphasis.

**2-4 what determines the content of the CAAD course and the time period allocated for such a course?** (Tick one box)

- ☐ According to changes in design studio projects.
- ☐ Following the school's policy/ curriculum.
- ☐ Demands of practice.
- ☐ Belief that CAAD effects design perception / analysis.
- ☐ Others………………………………………………….

**2-5 Which members of the academic staff determine the content of and time allocated for the CAAD course?** (Tick one box)

☐ CAAD specialists only. ☐ All academic staff within the School.
☐ Design tutors. ☐ CAAD specialist and Design tutor jointly.

**2-6 Have there been any changes in the content of your CAAD course compared with previous years?** (Tick proper box)

☐ Yes ☐ No

**2-7 If Yes to Q2-6, is it for:** (Tick one box)

☐ More CAAD content. ☐ Less CAAD content.

**2-8 In which year within your school's curriculum is a student introduced to CAAD programmes for the first time?** (Tick one box)

☐ First Year. ☐ Second Year. ☐ Third Year. ☐ Fourth Year.

**2-9 In your opinion, when should the CAAD programme be introduced into the curriculum for the first time?** (Tick one box)

☐ First Year. ☐ Second Year. ☐ Third Year. ☐ Fourth Year.

**2-10 Which approach do you think the curriculum should take in integrating CAAD?** (Tick one box)

☐ For visual communication only. ☐ For visual communication and 2D drawing approach.
☐ 2D drawing approach only. ☐ 2D and 3DThree-dimensional Modelling design.
☐ Others……………………………………………………………………………..

**2-11 How does your School choose CAAD software packages for teaching?** (Tick one box)

☐ Tutor's investigation / Research. ☐ Commercial advertisement.
☐ From the practice requirement. ☐ Other……………………………

**2-12 What CAAD package does your course use for teaching?** (Tick one box)

☐ MicroStation / TriForma ☐ ARCHICAD
☐ 3D Studio VIZ ☐ MiniCAD
☐ AutoCAD ☐ Rhino
☐ FormZ ☐ Others…………………………………….

**2-13 If you introduce more than one package, Could you rank the order of usage for the following software packages?** On a scale 1-5 (1-The highest use, 2-The second highest, 3-low use, 4- Slightly used, 5-Very slightly used)

| | *None* | *1* | *2* | *3* | *4* | *5* |
|---|---|---|---|---|---|---|
| - MicroStation / TriForma | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - 3D Studio VIZ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - AutoCAD | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - FormZ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - ArchiCAD | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - MiniCAD | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - Rhino | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| - Other -A………………………… | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| -B………………………… | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| -C………………………… | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

**2-14 Did the School introduce a new Software package this year (02/03) which is not mentioned above in Q12?** (Tick proper box)

☐ Yes ☐ No

**2-15 If Yes to Q2-14, Can you name it?**

| Name | Description/ Function |
|---|---|
| 1-…………………………………… | …………………………………………….. |
| 2-…………………………………… | …………………………………………….. |
| 3-…………………………………… | …………………………………………….. |
| 4-…………………………………… | …………………………………………….. |

**2-16 Has your school introduced Virtual Reality in the curriculum?** (Tick proper box)

☐ Yes ☐ No

**2-17 If Yes to Q2-16 To which year?** (Tick one box)

☐ First Year. ☐ Second Year. ☐ Third Year. ☐ Fourth Year.
☐ Fifth Year ☐ To all Years.

## *3- CAAD: Teaching methods, Timing and Resources.*

*Please fill in the blank space where appropriate or tick (♦) when needed.*

**3-1 How would you best describe the orientation of your CAAD course?** (Tick one box)

☐ Purely theoretical oriented involving lectures and reading assignments.
☐ Partly theoretical involving lectures and partly practical involving exercises.
☐ Purely skills based.

**3-2 Can you describe the level of CAAD facilities in your School this year (02/03)?** (Tick one box)

☐ Quite good ☐ Good. ☐ Below average. ☐ I do not Know.

**3-3 Where are computer/CAAD facilities located in your school?** (Tick one box)

☐ *A*- In a computer room (Computer lab). ☐ *C*- Within the studio space.
☐ *B*- Close proximity to Studio. ☐ *D*- Other…………………

**3-4 In your opinion which of the above setting (in Q3-3) is more effective for CAAD teaching / integration within design?** (Tick one box)

☐ *A* ☐ *B* ☐ *C* ☐ *D*

**3-5 What do you see as the main obstacles to meeting your course objectives?** (Tick one box)

☐ The general inability to understand the CAAD culture. ☐ The lack of facilities
☐ School policy. ☐ Technical problems.
☐ The lack funding. ☐ None.
☐ Other……………………………………………………………………………….

**3-6 Do you prefer to teach a CAAD program independent of design or integrated with design?** (Tick one box)

☐ Independently. ☐ Integrated with design.

**3-7 Do you offer handouts during the CAAD course?** (Tick proper box)

☐ Yes ☐ No
Why?……………………………………………………………………………………

**3-8(*a*) Do you provide any written materials or manuals to students in CAAD practicing section?** (Tick proper box)

☐ Yes ☐ No

**3-8(*b*) According to Q3-8 (*a*), in what format?** (Tick one box)

□ Digitally. □ Paper-based.
□ Both formats. □ Digitally via website.
□ Other method……………………………………………..

**3-9(*a*) How do your students submit their CAAD course work?** (Tick one box)

□ To you directly. □ Via e-mail/Internet.
□ Both ways

**3-9(*b*) According to Q3-9 (*a*), In what format?** (Tick one box)

□ Digitally. □ Paper-based. □ Both formats.

**3-10 How often do you use e-mail to communicate with your students about the course in general?** (Tick one box)

□ All the time. □ Occasionally. □ None.

**3-11 As reference and help after the lecture do you prefer?** (Tick one box)

□ Advice students with your handout only. □ Handout with particular book.
□ Let them search about problem to solve. □ Other………………………………………….

**3-12 How many hours per week is timetabled for teaching the CAAD?** (Tick one box)

□ 1-2 H/W □ 3-4 H/W □ 4+ H/W

**3-13 How many hours of training/Practicing per week do you provide for CAAD software package in the course?** (Tick one box)

□ 1-2 H/W □ 3-4 H/W □ 4+ H/W

**3-14 How many PCs/Macs are dedicated for CAAD teaching this year (02/03)?**

…………………………….. PCs. …………………………. Mac.
……………………………..Silicon Graphic. ………………………….. Others.

**3-15 How many printers/ plotters / scanners and projectors does the school provide for CAAD teaching this year (02/03)?**

………….……………………….Printers ……….………………………..Scanners
……………………………………..Plotters ………………………………….Projectors

## *4- General Issues*

*Please fill in the blank space where appropriate or tick ( ♦ ) when needed.*

**4-1 What do you think it is the main problem facing students during the CAAD course?** (Tick one box)

□ Time limitation. □ Technical problems.
□ Lack of resources. □ Fear of use of computer.
□ Imbalanced time investment: more toward learning CAAD than Design.
□ Mixture of problems.

**4-2 How can you describe students' attitudes toward learning / using CAAD within the curriculum?** (Tick one box)

□ Competitive. □ Co-operative. □ Normal. □ I do not know.

**4-3 Are there any improvement in the school's curriculum this year (02/03) toward using CAL in general and CAAD in particular?** (Tick proper box)

☐ Yes ☐ No

**4-4 How many full time tutors are involved in teaching CAAD? (**Tick proper box)

☐ None ☐ 1 ☐ 2 ☐ 3 ☐ +3

**4-5 How many part time tutors are involved in teaching CAAD?** (Tick proper box)

☐ None ☐ 1 ☐ 2 ☐ 3 ☐ +3

**5-6 How many technical staff members are employed to support CAAD courses?** (Tick proper box)

☐ None ☐ 1 ☐ 2 ☐ 3 ☐ +3

**4-7 Do CAAD tutors receive any training on new software?** (Tick proper box)

☐ Yes ☐ No

**4-8 From your experience, are there any different reactions toward learning CAAD between females and males students?** (Tick proper box)

☐ Yes ☐ No

# Appendix II: Glossary of CAAD Terminology

This appendix presents a glossary of common CAAD terminology, which has now become an ordinary language within CAAD courses. These were extracted from different references during the research period, to serve two objectives:

1-To help readers understand the meaning of all issues about CAAD, and provide intersubjectivity between researchers dealing with such a subject.

2-To prepare a mini dictionary as a preliminary course material for future planning and use.

**Address:** A label, name or number identifying a particular location in the store of a computer. (Compion, 1968:306)

**Address:** Location where data is stored in memory. (Howes, 1989:127)

**ADE:** Abbreviation of *Architecture Design Education.*

**ADSL:** *Asymmetric Digital Subscriber Line*. A communications technology that allows data to be sent over existing copper telephone lines. ADSL supports data rates from 1.5 to 9 megabits per second when receiving data and from 16 to 640 kilobits per second when sending data. (Jolliffe et al., 2001:319)

**Alias:** A shortcut pointing to a file or document. A *domain name* such as www.greatbuilding.com is an *IP address*. (Cohen, 2000:267)

**Animation:** A sequence of images displayed rapidly, producing the impression of movement. Real-time animation is produced as it is requested, rather than from a previously stored set of images. (Crosley, 1988:179)

**Animation:** Making moving pictures. (Howes, 1989:127) (Woodward, 1997:137)

**APL:** *A Programming Language*. A high-level language that makes extensive use of mathematical notation. (Reynolds, 1987:204)

**Application:** A shortened form of application program; a piece of software that is used for performing specific tasks, such as word processing, drawing, or managing a database. Applications referred as tools. (Cohen, 2000:267)

**Application:** A computer program that is dedicated to a specific task, rather than controlling the computer's operation. (Crosley, 1988:179)

**Application software:** Software produced to carry out specific tasks, e.g. word-processing. (Howes, 1989:127) (Woodward, 1997:137)

**Array:** To make multiple copies of a drawing element in a line, grid, circle or arc. The term also refers to a pattern of elements that result from the array process. (Crosley, 1988:179)

**Array:** The automatic generation of a rectangular or circular pattern of selected entities or blocks at specified intervals. (Kronenberg Bsc, 1987:113)

**Array:** A set of items of data arranged consecutively in computer memory. (Reynolds, 1987:204)

**Artificial intelligence:** The concept that computers can be programmed to make decisions and "learn" from previous experience. Expert systems are generally considered a form of artificial intelligence. (Crosley, 1988:179)

**ASF*:** *Advanced Streaming Format*. A streaming multimedia file format developed by Microsoft. ASF has been submitted to ISO and IETF for standardization. It is expected eventually to replace the older AVI format. (Jolliffe et al., 2001:319)

**Assembly language:** A low language, which converts a programming language to machine code. (Howes, 1989:127)

**Associative dimensioning:** A computer-aided drawing system in which dimensions are linked to specific drawing elements; when the elements are moved, the dimension lines are automatically moved and the dimensions are revised. (Crosley, 1988:179)

**Attribute:** A descriptive tag attached to a drawing element. This text uses the term to refer to the numeric or textual tags that a CAD user may define. (CAD software also assigns attributes, internally, to describe characteristics like colours, layers, and line types). (Crosley, 1988:179)

**AutoLISP:** A version of the LISP programming language that has been adapted as a command language in AutoCAD. (Crosley, 1988:179)

**Automatic dimensioning:** A computer-aided drawing system for adding dimensions to a drawing with minimal user input, according to previously defined rules for location and precision. (Crosley, 1988:179)

**AVI*:** *Audio Video Interleave*. The file format for Microsoft's Video for Windows standard. (Jolliffe et al., 2001:319)

**Axis:** A line on a coordinate system that is used as a reference for the location of objects on a plane or in space. (Crosley, 1988:179)

**Backing store:** That part of a computer store, which is not contained within the central processor unit. (Compion, 1968:306)

**Backing store:** A memory of large size, but low retrieval time compared with main memory; usually refers to disc storage. (Reynolds, 1987:204)

**Backup:** A copy of the data stored on a computer made on such media as tape drives, Zip or Jaz disks, or other hard drives, in case the computer's hard drive fails. (Cohen, 2000:267)

**Backup:** To make copies of a file, to prevent loss of data in the event of hardware or software failure. Backups can often be made automatically with the aid of utility programs. (Crosley, 1988:179)

**Backup:** Copies of software and data kept for security purposes. (Howes, 1989:127)

**Bandwidth*:** How much data or information you can send through a connection. Usually measured in bits per second. A full page of English text is about 16,000 bits. A fast modem can move about 15,000 bits in one second. Full-motion full-screen video would require roughly 10,000,000 bits per second, depending on compression. (Jolliffe et al., 2001:319)

**Bar chart:** A method of displaying project scheduling that portrays chronological sequences of activities. (Crosley, 1988:179)

**Basic:** A high-level computer language widely used for instruction, business applications, and microcomputer programming. (Crosley, 1988:179)

**Beta testing:** In the software development process, distributing the product to a test group of potential end users, to identify problems and elicit feedback. Beta testing is the second stage of testing candidate software, after alpha testing. (Cohen, 2000: 267)

**Binary:** The base two number system that computers use to express numbers digitally. Thus 1=1, 2=10, 5=101, 10=1010, and so on. (Cohen, 2000:267)

**Bit:** The smallest unit of digital data. A bit has a value of either 1 or 0. Abbreviated with a lowercase b, as in "56 Kbps modem" compare to byte. (Cohen, 2000:267)

**Bit:** A binary number, either one or zero. (Crosley, 1988:180)

**Bit:** binary digit-The basic unit of information in a computer. A number of bits may be taken together to form a character. (Reynolds, 1987:205)

**Block:** A group of drawing elements that can be manipulated as one. A block may be "redefined" whereupon all occurrences of the block are replaced with a new version. (Crosley, 1988:180)

**Block:** A selected group of entities treated as a single library component by editing functions and to which textual information can be attributed. (Kronenberg Bsc, 1987:113)

**Block articulation:** To add detail to a block, then redefine it so that each occurrence will be replaced and detailed accordingly. (Crosley, 1988:180)

**Boot/ Boot up:** To start up a computer. The operating system is loaded into RAM, and the computer is then ready to run application. (Cohen, 2000:268)

**Box:** In computer-aided drawing, an area outlined on the display screen for the selection of drawing elements, or for zooming in or out. Synonymous with window and fence. (Crosley, 1988:180)

**bps:** *Bits per second* a measure of the speed at which data is transferred. 1 Kbps = one thousand bits per second, 1 Mbps = one million bits second. (Cohen, 2000:268)

**Browser:** A client program that uses the Hypertext Transfer Protocol (HTTP) to make requests for, and then display, Web pages on behalf of a computer user. The first browser was Mosaic, released in 1992. (Cohen, 2000:268)

**Browser:** A tool used to view pages and audio/video content published on the WWW. Browsers often include support for e-mail and electronic newsgroups. (Schmitt, 1999:85)

**Bug:** An error in a program that will cause a malfunction in program operations. (Crosley, 1988:180)

**Bug:** A fault in software or hardware that causes things to go wrong. (Howes, 1989:128) (Woodward, 1997:138)

**byte**: A chunk of digital information that is eight bits long. (Crosley, 1988:180) Abbreviated with a capital B, as in "64 MB of RAM." A *Kilobyte* (KB or Kbyte) is approximately a thousand bytes (2 to the $10^{th}$ power, or 1,024 bytes). A *megabyte* (MB) is 2 to the $20^{th}$ power, or 1,048,576 bytes. A *gigabyte* (GB or gig) is two to the $30^{th}$ power, or 1,073,741,824 bytes. And a *terabyte* is 2 to the $40^{th}$ power or approximately a thousand billion bytes (a thousand gigabytes). Compare to *bit*. (Cohen, 2000:268)

**byte:** A group of bits, generally eight that a computer can process as a single unit; sometimes referred to as a computer "word". (Crosley, 1988:180)

**CAAD:** Abbreviation of *Computer-Aided Architectural Design*. (Reynolds, 1987:205)

**CAB:** *Computer Aided Building* a general term for the use of computers in the whole building process. (Gero, 1977:400)

**CAD:** Abbreviation of *Computer-Aided Design*. (Reynolds, 1987:205)

**CADD:** Abbreviation of *Computer-Aided Design and Draughting*. (Reynolds, 1987:205)

**CAD manager:** A role in a design firm; a CAD manager has responsibility for coordinating and planning hardware and software systems, as well as advising project managers and architects on the use of the system. (Crosley, 1988:180)

**CADI:** Abbreviation of *Computer-Aided Design Information.*

**CAD operator:** A specialist in using a computer-aided design system. This term is often used to imply a lack of other design and drawing skills, and is a remnant of the days when CAD systems required full-time specialization to learn and use. (Crosley, 1988:180)

**CAE:** Abbreviation of *Computer-Aided Engineering* (Phiri, 1999:52)

**CAI:** Abbreviation of *Computer Assisted Instruction*. (Gross, 1994)

**CAL:** Abbreviation of *Computer-Aided Learning*. (Cicognani, 1996)

**CAL:** Abbreviation of *Computer Assisted Learning*. (Gross, 1994)

**CALM:** Abbreviation of *Computer-Aided Learning for Maths.*

**CAM:** Abbreviation of *Computer-Aided manufacturing*. (Crosley, 1988:180)

**CBL:** Abbreviation of *Computer-based Learning* (Ellington [18], 1987:1)

**CD-ROM:** Abbreviation of *Compact Disk-Read Only Memory*: an information storage medium that can hold very large amounts of data. CD-ROM disks are read by lasers in disk drives that are similar to audio compact disks; they are similar also in that they are produced at a central location and cannot be written on by a user, and are thus ideal for widely used databases. CD-ROMs are also very durable. (Crosley, 1988:180)

**CD-ROM:** Abbreviation of *Compact Disk-Read Only Memory*: a compact disc which a computer can write to or read from. (Woodward & Howes, 1997:139)

**CD-R:** Abbreviation of *Compact Disk-Recordable* : system which allow information to be written to and stored on a CD. (Woodward & Howes, 1997:11)

**CGI*:** Abbreviation of *Common Gateway Interface*: A set of rules that describe how a Web server communicates with another piece of software on the same machine, and how the other piece of software (the 'CGI program') talks to the Web server. Any piece of software can be a CGI program if it handles input and output according to the CGI standard. Usually a CGI program is a small program that takes data from a Web server and does something with it, like putting the content of a form into an e-mail message, or turning the data into a database query. (Jolliffe et al., 2001:320)

**CGS:** Abbreviation of *Common Generic Structures*: Common Generic Structures are 2D or 3D objects, representing, mainly, a kind of spatial framework or skeleton that is constructed and can be used by all participants working in different domains of a design project. There are several important properties observed in common generic structures, including deformability, multi-perspective ness, and genericity. (Peng, 2001:194)

**Character:** A single symbol such as a letter of the alphabet. It is usually represented within the computer by a group of eight bits, when it is also termed a byte. (Reynolds, 1987:205)

**Chip:** A small slice of silicon or other material on which a circuit has been printed (Woodward & Howes, 1997:139)

**CI:** Abbreviation of *Common Images*: Are pictorial representations that are generated by design members putting proposed LDEs together and then transforming them into single compositions under the operation of shared integration concepts and methods. (Peng, 2001:193)

**CLI:** Abbreviation of *Command Line Interface*. A user interface that requires typing arcane commands to instruct the computer. DOS and UNIX are examples of operating systems using a command line interface. (Cohen, 2000:268)

**Clock:** a quartz crystal whose oscillations control the aped, measured in MHz, at which the central processor operates. (Woodward & Howes, 1997:139)

**CMC:** Abbreviation of Computer-Mediated Communication. (Koutamanis, 1999:238)

**CMCT:** Abbreviation of *Computer Mediated Collaborative Tools*. (Cicognani, 1996)

**CML:** Abbreviation of *Computer-Managed Learning.* (Ellington [09], 1987: 8)

**COBOL:** Abbreviation of *Common Business Orientated Language***.** The most commonly used high-level language. It is orientated towards commercial applications. (Reynolds, 1987:205)

**COM:** Abbreviation of *Computer Output to Microfilm*. (Gero, 1977:400)

**Command:** An instruction given to a computer program using terms that the computer software is programmed to understand. Commands may be typed, picked from a menu with a pointing device, or spoken, depending on the specific hardware and software. (Crosley, 1988:180)

**Compatibility:** the ability of computer systems to work together; the ability to transfer data from one computer or peripheral to another. (Woodward, 1997:140)

**Compression:** The reduction of file size to save storage space or transmission time. Some graphic file formats, such as GIF and JPEG, have compression built in. Programs such as WinZip and Stuffit perform compression on files and folders so that they move more quickly through the Internet. (Cohen, 2000:268)

**Computer:** An electronic machine that can process information according to programmed instructions. (Crosley, 1988:180)

**Computer program:** A set of instructions for controlling the operation of a computer. (Gero, 1977:400)

**Computer system:** A central processor unit together with one or more input, output and backing store devices. (Compion, 1968:306)

**Computer system:** A central processor unit together with one or more items of peripheral equipment. (Compion, 1968:306)

**Copy:** To make an exact duplicate of a drawing element, a file, or anything else. (Crosley, 1988:180)

**Copy:** A function in computer software, which allows software, text, drawings or files to be replicated. (Howes, 1989:129)

**Copy:** The replication of a group of entities or block to another location within the drawing. (Kronenberg Bsc, 1987:113)

**Core:** (also referred to as *main memory* or *main storage*). The internal storage of the computer which makes use of magnetic cores; this is in contradistinction to auxiliary storage. The size of the core is often used to describe the size of the computer. (Gero, 1977:400)

**CPD:** Abbreviation of *Continuing Professional Development*. (Teymur, 1992:75)

**CPE:** Abbreviation of *Continuing Professional Education*. (Teymur, 1992:75)

**CPU:** Abbreviation of *Central Processor Unit*. The electronic centre of a computer, which is responsible for controlling the complete computer system including all peripheral equipment. (Gero, 1977:400)

**CSCD:** Abbreviation of *Computer Supported Collaborative Design*. (Peng, 2001:1)

**CSCW:** Abbreviation of *Computer Supported Cooperative Work*. (Peng, 2001:6)

**CTI:** Abbreviation of *Computer in Teaching Initiative*. (Cicognani, 1996)

**CVA:** Abbreviation of *Complementary Virtual Architecture* that allows architects to create integrated physical and virtual environments that address the needs of a single program. (Wake & Levine, 2002:18)

**Cyberspace:** The space where a virtual communities (VC) dwells. (Cicognani, 1996)

**2D:** The capability to produce only orthographic, and manually constructed isometric, axonometric and perspective drawings. (Kronenberg Bsc, 1987:113)

**2.5D:** The capability to extrude isometric, axonometric or generate perspective projections automatically from plans. (Kronenberg Bsc, 1987:113)

**3D /Three-dimensional Modelling:** The capability to construct a genuine 3D Model from lines, arcs and library components, view it from different positions, and plot plans, sections and elevations from it which have never actually been drawn. (Kronenberg Bsc, 1987:113)

**Data:** A set of information supplied by computer user for processing by computer. It is also used to refer to both operands and results held within a computer. (Compion, 1968:307)

**Data:** Information supplied as input to a computer program, or information produced as output by a computer program; data may consist of digits, letters, symbols, numbers, names, words, sentences, descriptions, codes, etc. (Gero, 1977:401)

**Database / Data bank:** A structured set of information contained on some computer storage medium in the form of a number of integrated files of data. (Gero, 1977:401)

**Database:** A collection of information that is sorted and stored so that it can be easily accessed and updated. A relational database retains information in small pieces that can be accessed and recombined in different ways. SQL is a standard language for making queries from a database. (Cohen, 2000:268)

**Database:** A file, which contains information structured into a logical form. (Reynolds, 1987:205)

**Database:** a collection of data in a file made up records (rows) and fields (columns) with operations for searching and sorting. (Szalapaj, 2001:221)

**DBMS:** Abbreviation of *Database Management System*; A program, which manipulates a database in order to read or write information. (Reynolds, 1987:205)

**Dedicated computer:** A computer that is designed to use only one type of software, such as graphics or word processing. (Crosley, 1988:181)

**Desktop publishing:** Computer software systems that combine word processing and graphics with the ability to lay out and print pages in a manner similar to typesetting. (Crosley, 1988:181)

**Digital:** Technology that conveys messages by reducing the components to one of two states: on or off. On is expressed as the number 1; off, as 0. Data transmitted or stored with digital technology is expressed as a string of 1s and 0s. Each of these state digits is referred to as a bit, and a string of eight of them is a byte. Compare to analog. (Cohen, 2000:268)

**Digital:** Consisting of or operating with binary digits. (Howes, 1989:130) (Woodward, 1997:141)

**Digital compute:** A computer the input and output of which consist of alphanumeric- information, which takes the form of sequences of binary digits. Different types of input and output devices are used to interpret information in the forms in which it passes between a user and the computer; by this means the user is enabled to supply and receive information in the form in which it is most meaningful to him. (Compion, 1968:307)

**Digital plotter:** A computer output device used to produce hard copy drawn information; it can also produce written information on a drawing. (Gero, 1977:401)

**Directory:** A group of files that can be manipulated together as a group; directories have names and may include subdirectories. (Crosley, 1988:181)

**Directory:** Part of the disk filing structure under Microsoft DOS, enabling a disk to be effectively split up to store groups of files in a structured way. Sub-directories or directories within directories are possible. (Kronenberg Bsc, 1987:114)

**Disc:** An item of computer peripheral equipment used for storing data or programs. (Gero, 1977:401)

**Disc Storage:** A form of mass memory in which information is held as magnetised spots on the surface of a disc. The physical arrangement may take several forms: a disc pack is a number of discs on a common spindle; a cartridge disc is a single disc permanently enclosed in a rigid case; a floppy disc is relatively small, flexible and permanently enclosed in a cardboard sleeve; a Winchester disc is one or more discs permanently sealed within its housing. (Reynolds, 1987:206)

**Disk (not disc):** A storage device. Data are recorded in magnetised spots on concentric rings, called tracks. (Howes, 1989:130)

**Disk drive:** A mechanism for reading data on disks. (Howes, 1989:130)

**Display:** An electronic device or system for presenting information visually; generally a video monitor, LCD, or plasma screen. (Crosley, 1988:181)

**DDE:** Abbreviation of *Domain Design Expressions*. Domain Design Expressions are the outcomes from designers substantiating derivative structures with design expressions that contain specifications of domain-specific design substances or properties. (Peng, 2001:194)

**Domain name:** A unique name for a Web site, followed by a period ("dot"), and a broader classification of the site's sponsor: .gov (federal agency), .edu (educational institution), .org (nonprofit organization), .mil (military), and .com (commercial); or by a two letter such as .uk, .fr, .ca (United Kingdom, France, and Canada respectively). Compare to IP address. (Cohen, 2000: 269)

**Download/ Upload:** The process of sending or retrieving an electronic file from a server. When you retrieve your e-mail, you download your messages from the mail server at your ISP. FTP is used to upload and download files to a Web site. (Cohen, 2000:269)

**Down:** A computer is said to be 'down' if it is out of action. (Reynolds, 1987:206)

**dpi:** Abbreviation of *Dots per inch*. Usually used to describe the resolution of a printed document. (Cohen, 2000:269)

**Drafting system:** A computer system for draughting. (Howes, 1989:130)

**Drag:** To move a drawing element on a display screen by attaching it to the cursor, then moving the cursor. (Crosley, 1988:181)

**Drag:** The capability to move entities around the screen in real time enabling precise visual evaluation of the various positioning options before making a final selection. (Kronenberg Bsc, 1987:114)

**Drawing library:** A collection of drawings those are available to be inserted into other drawings. A drawing library can include symbols, architectural forms, text, building assemblies, rooms, buildings, or anything else that can be stored, on disk, as a drawing. (Crosley, 1988:181)

**DSL:** Abbreviation of *Digital Subscriber Line*. A technology for sending a high-bandwidth signal on ordinary copper phone lines that cohabit with regular voice and fax signals. The connection goes directly from the subscriber to the telephone central office and then to an ISP. (Cohen, 2000:269)

**Dumb systems:** term to refer to the development of computer-based drawing systems in the late 1970s and 1980s. (Peng, 2001:3)

**Elevation/Section:** A multilayered architectural drawing that includes both elevations and sections, on different layers. (Crosley, 1988:186)

**E-mail:** Abbreviation of *Electronic mail*, one of the Internet services, used for sending text messages to individuals and groups. E-mail enclosures are files attached to an e-mail message that may require some other kind of software at the receiving end to use. Such enclosures may involve encoding and/or compression. (Cohen, 2000:269)

**E-mail:** Abbreviation of *Electronic mail*, transmitted directly between computers without a paper version. (Woodward, 1997:141)

**Encoding:** On the Internet, the process of converting an e-mail attachment to a text file consisting of ASCII characters. (Cohen, 2000:269)

**Execute:** To carry out a program within the computer. (Reynolds, 1987:206)

**Explode:** To break up a defined block into its constituent elements. Synonymous with “unblock”. (Crosley, 1988:181)

**Facsimile transmission:** The process of scanning, transmitting and reproducing a pictorial image. (Reynolds, 1987:206)

**Fence:** In computer-aided drawing, an area outlined on the display screen for the selection of drawing elements or for zooming in or out. Synonymous with window and box. (Crosley, 1988:181)

**Fifth generation:** The next stage of computer development in which the aim is to achieve artificial intelligence. (Reynolds, 1987:206)

**File:** One or more computer records representing either data or a computer program organized on some form of computer storage medium. (Gero, 1977:401)

**File:** An organized collection of data that can be treated as a single unit by computer programs. Programs themselves are composed of one or more files. (Crosley, 1988:181)

**File:** A basic unit of storage with a name and information of a certain type. Files can be modified, saved, deleted, or sent to users or devices. (Szalapaj, 2001:221)

**File system:** The system for naming and organizing files within a storage device. Most operating systems use a hierarchical, inverted-tree like file system. The root directory or folder contains all other files and folders. (Cohen, 2000:269)

**Filed:** A part of a record in a database, which contains a single item of information. (Reynolds, 1987:206)

**Fillet:** To cause two nonparallel lines to intersect, either at a right angle or in a curve of a specified radius. (Crosley, 1988:182)

**Firewall:** A system to protect a privet network from unauthorized outsiders. The term can refer to hardware and software, as well as monitoring and management tools. (Cohen, 2000:269)

**Floppy disk:** A readily portable information storage medium consisting of a thin, flexible, round sheet of plastic, housed in a paper or plastic sleeve. Floppy disks are available in various sizes, densities, and data capacities. (Crosley, 1988:182)

**Flowchart:** A diagrammatic representation of the way in which a computer program is structured. (Reynolds, 1987:206)

**Font:** A set of text characters in a specific style and size, for example, Times New Roman, 18 point. Font and typeface are often used interchangeably. Font must be installed on a computer in order for them to display and print, although some types of electronic documents, such as PDF files created by Adobe Acrobat, have fonts embedded in them. (Cohen, 2000:269)

**Font:** A typeface, characterized by size and style. (Crosley, 1988:182)

**Format:** A predetermined arrangement (usually applied to the way data are expected or the arrangement in which the output is to appear). (Gero, 1977:401)

**Format:** The way data is organised; the process of organising a disk so that it can be read by a particular computer. Reformatting it will destroy all existing data. (Howes, 1989:132)

**Fortran:** A high level computer programming language, which derives its name from FORmula TRANslation. (Gero, 1977:401)

**Framework:** The invisible structure of a CAD drawing, which is based on the size and number of elements in a drawing and the relationships between them. Layer organization and the use of blocks play an important role in a drawing framework. (Crosley, 1988:182)

**Freeze:** In the display of a drawing, the elimination of undisplayed drawing layers from the calculations performed by the computer. (Crosley, 1988:182)

**FTP:** Abbreviation of *File Transfer Protocol*. An Internet service used to upload and download files to a directory on a server. (Cohen, 2000:269)

**FTP:** Abbreviation of *File Transfer Protocol*. Allowed the sending of files, telnet allowed the log-on to another machine. (Schmitt, 1999:15)

**Futurology:** The scientific study of future. Informal something that is done or talked about as though it was a scientific study: futurology (the practice of trying to say how the future will develop). (Longman Dictionary, 2000)

**GIF:** Abbreviation of *Graphics Interchange Format*; An Internet file type for compressed raster images. (Cohen, 2000:269)

**GIS:** Abbreviation of *Geographic Information System*. The name of computer software using by specialists related to urban design issue (Gross, 1994).

**GMS:** Abbreviation of *Group Modelling Space*, a common workspace created and evolved by members of a design team jointly for modelling the integration of design parts contributed by each member into larger design wholes. (Peng, 2001:193)

**GUI:** Abbreviation of *Graphical User Interface*, pronounced gooey. In contrast to a command line interface, a GUI allows the user to control the computer more intuitively, using icons, windows, pull-down menus, scroll bars, and the like. The first widely available implementation of a GUI was created for the Apple Macintosh in 1984, using ideas developed at Xerox's Palo Alto Research Centre. A GUI uses visual metaphors to relate computer functions to everyday life: desktop, trashcan, etc. (Cohen, 2000:270)

**Hard copy:** Generally any form of computer-produced document, often specifically applied to the printed copy of the data on a visual display unit. (Gero, 1977:402)

**Hard copy:** Output printed on paper as distinct from that appearing on screen. (Reynolds, 1987:206)

**Hard disk:** A large-capacity information storage device, generally fixed within a computer or in its own housing. Data capacities range from 5 megabytes to 900 megabytes. (Crosley, 1988:182)

**Hard disk:** a non-removable disk inside the computer or in a separate external unit. (Woodward, 1997:143)

**Hardware:** A term used to indicate physical items of computer equipment, e.g., the central processor unit, backing store devices, input and output devices. (Compion, 1968:307)

**Hardware:** Items of physical computer equipment, such as the central processor unit, disc or card reader, printer, visual display unit, magnetic tape storage unit, etc. (Gero, 1977:402)

**Hatch:** To fill a specified area with a predefined pattern. (Crosley, 1988:182)

**Hatching:** A pattern, consisting of lines, used to fill an area. (Crosley, 1988:182)

**Helper applications:** Software that enables a browser to display a particular type of file. E-mail programs also use helper applications to open received attachments. (Cohen, 2000:270)

**Hidden-line removal:** A technique in which a computer program automatically removes lines from a three-dimensional wireframe drawing, based on the location of planes and objects "in front" of lines. (Crosley, 1988:182)

**High-level computer language:** A set of commands and syntax with which sets of instructions can be written for computers. Unlike machine language, high-level languages use words and characters that are similar to spoken/written language. (Crosley, 1988:182)

**Home page:** The entry point of a Web site; the HTML document that visitors see first and that links them to the interior of the site. (Cohen, 2000:270)

**Host computer:** A central computer that provides information to one or more smaller computers linked to it. (Reynolds, 1987:206)

**HTML:** Abbreviation of *Hypertext Markup Language*, a simple computer language that tells the browser how to display elements on a Web page, such as text and graphics, and where to look for linked items. It does so with markup tags between beginning and ending brackets that provide instructions for display. (Cohen, 2000:270)

**HTML:** Abbreviation of *HyperText Markup Language*, a Web page authoring language. (Jolliffe et al., 2001:320)

**HTTP:** Abbreviation of *HyperText Transfer Protocol*, the set of rules for exchanging text and media files on the World Wide Web. HTTPS is the secure version used for electronic commerce. (Cohen, 2000: 270)

**Hybrid communication:** A general term for mixing techniques of hand drawing and scanning in communication and presentation. (Cicognani, 1996)

**Hyper mail:** Is a mail tool, which allows users o post and read e-mail messages from the web. (Cicognani, 1996)

**Hypermedia:** Consists of an extensively cross-referenced collection of textual and graphic information and tools for viewing, editing, and annotation. (Gross, 1994:58)

**Hyperspace:** Space of more than three dimensions (The New Oxford Dictionary, 1998)

**Hypertext:** (Computing) a software system allowing extensive cross-referencing between related sections of text and associated graphic material. A document presented on a computer (The New Oxford Dictionary, 1998)

**Hypertext / Hyperlink:** A means of organizing pieces of information with associative connections (links) between them. The World Wide Web makes use of hypertext by allowing text and media to be linked to other resources on the Internet. (Cohen, 2000:270)

**IBIS:** Abbreviation of *Issue-Based Information System.* (Gross, 1994)

**Icon:** A graphic symbol used to indicate a menu option on a screen (VDU) activated by the selection of the icon with the cursor. (Howes, 1989:133)

**Icon:** A symbol used to denote a menu choice or prompt, which is activated by selecting the icon with the screen cursor. Currently the most user-friendly method of controlling a program. (Kronenberg Bsc, 1987:114)

**ICT:** Abbreviation of *Information and Communication Technologies.* (Koutamanis, 1999:238)

**IGES:** Abbreviation of *International Graphic Exchange Standard*. A standard format for the transfer of drawing files. (Howes, 1989:133)

**IMS:** Abbreviation of *Individual Modelling Space*. Workspaces created and evolved by designers individually for modelling design expressions (e.g., diagrams, drawings, or any other graphical/ textual constructions) targeted at a particular design aspect or domain of a design project. (Peng, 2001:193)

**Information:** Anything with a defined meaning. (Howes, 1989:130) (Woodward, 1997:144)

**Information:** Knowledge or Facts. (Oxford Wordpower Dictionary, 2000:393)

**IT:** Abbreviation of *Information Technology*. (Reynolds, 1987:207)

**IT:** Abbreviation of *Information Technology*. A general term for all applications of computer technology, especially where the processing of significant amounts of information is involved. (Kronenberg Bsc, 1987:114)

**IT:** Abbreviation of *Information Technology*. Information Technology is the acquisition, processing, storage and dissemination of vocal, pictorial, textual and numerical information by microelectronics-based combination of computing and telecommunications. (Longley and Shain, 1989:165, see Phiri, 1999:1)

**IT:** Abbreviation of *Information Technology*. Information Technologies are necessarily concerned with electronic communication and electronically stored information. (Phiri, 1999:1)

**Information Technology:** The study or use of computer systems, etc for collecting, storing and sending out all kinds of information. (Oxford Wordpower Dictionary, 2000:394)

**Insert:** The inclusion of drawing or block within another drawing. (Kronenberg Bsc, 1987:114)

**Input (noun):** Instructions or data given to a computer by a user. (Crosley, 1988:182)

**Input (verb):** To give instructions or add data to a computer program. (Crosley, 1988:182)

**Input:** A term used to indicate either the method or the means for transferring information into a computer. (Compion, 1968:308)

**Input:** The process of transferring data or programs into the computer's internal store; sometimes used to denote the actual data to be input. (Gero, 1977:402)

**Input device:** A device used for transferring information from a data medium into the central processor unit of a computer. (Compion, 1968:308)

**Input device:** An item of computer peripheral equipment used to transfer data or programs into a computer, e.g.: card reader. (Gero, 1977:402)

**Input/Output:** A multiple term used to refer to the processes of both input and output of information. (Compion, 1968:308)

**IRC:** Abbreviation of *Internet Relay Chat*. (Cicognani, 1996)

**Insertion point:** A reference point by which a block or group may be located. Synonymous with "handle". (Crosley, 1988:182)

**ISP:** Abbreviation of *Internet Service Provider*; A company that provides Internet access and service to customers at the retail level. ISPs may serve a national or regional market. (Cohen, 2000:270)

**Interface:** a boundary, physical or logical, between two physical or logical systems; e.g. a person and a computer. (Woodward, 1997:144)

**Internet services:** The various types of communication supported by the Internet. These include e-mail, the World Wide Web, FTP, and others. Each Internet service is governed by a protocol, such as HTTP. (Cohen, 2000:270)

**Internet:** an anarchic and uncontrolled agglomeration of connected LANs. (Woodward, 1997:144)

**Intranet:** A private network that uses Internet protocols for internal communication within an organization. Some or all of the Internet services may be supported: e-mail, newsgroups, FTP, and the Web. (Cohen, 2000: 270)

**Imaging system:** A computer system (hardware and software) for capturing video images and manipulating (scaling, rendering, and combining) them. (Crosley, 1988:182)

**IP address:** Every node on a TCP/IP network has a unique address in the form of a numeral, such as 140.174.162.14. A domain name is an alias to an IP address. (Cohen, 2000: 270)

**Java*:** A high-level programming language developed by Sun Microsystems. Java is a general purpose programming language with a number of features that make the language well suited for use on the World Wide Web. Small Java application is called Java applets and can be downloaded from a Web server and run on your computer by a Java-compatible Web browser, such as Netscape Navigator or Microsoft Internet Explorer. (Jolliffe et al., 2001:321)

**JavaScript*:** A scripting language developed by Netscape to enable Web authors to design interactive sites. Although it shares many of the features and structures of the full Java language, it was developed independently. JavaScript can interact with HTML source code, enabling Web authors to spice up their sites with dynamic content. JavaScript is endorsed by a number of software companies and is an open language that anyone can use without purchasing a licence. Recent browsers from Netscape and Microsoft support it, though Internet Explorer supports only a subset, which Microsoft calls Jacript.

**JCL:** abbreviation of *Job Control Language*; a computer language, which allows the user to give instructions to an operating system regarding the execution of a job. (Reynolds, 1987:207)

**Joystick:** A pointing device that moves a cursor by pivoting a stick. (Crosley, 1988:183)

**JPEG:** Abbreviation of *Joint Photographic Experts Group*; an Internet file type for compressed raster images. (Cohen, 2000: 270)

**Keyboard:** A manually operated device with which letters, numbers, symbols and instructions can be set to a computer. (Crosley, 1988:183)

**Keyboard:** The most common input device. Resembles a typewriter keyboard with extra, often programmable, function keys. (Howes, 1989:133) (Woodward, 1997:144)

**KB:** Abbreviation of *Kilobyte*; 1,024 bytes, nominally 1,000 bytes. (Crosley, 1988:183)

**LAN:** Abbreviation of *Local Area Network*; a network of personal computers within a limited geographical area, typically a single building. LANs can be client server or peer-to-peer. (Cohen, 2000: 270)

**LAN:** Local Area Network; A system of passing information at high speed between computers. A dedicated wiring system is involved. (Reynolds, 1987:207)

**Language:** The basic language of a digital computer takes the form of a binary code; this is used as the means of communication and storage inside a computer. A programmer writes the instructions forming a particular computer program in what is referred to as a computer programming language; this allows the programmer to use a form of everyday English language instead of the computer's binary language. (Compion, 1968:308)

**Language:** A system for representing and communicating information between man and machine; a defined set of characters, vocabulary and rules of syntax. (Gero, 1977:402)

**Laptop:** A portable computer that can use batteries. (Howard, 1998:135)

**Laser disk:** A high capacity storage disk, which is read using a laser. (Howes, 1989:134)

**Laser printer:** A printer, which produces one page at a time. (Howes, 1989:134)

**Layer:** A means of grouping similar drawing elements so that they may be manipulated together. Analogous to sheets of tracing paper laid over each other, except that groups of layers may be managed together, as if they could be combined into a single sheet, then separated. Layers are referred to as "levels" by some software. (Crosley, 1988:183)

**Layer:** A 'sheet of tracing paper' on a drafting system; known also as a level or view. (Howes, 1989:134)

**Layer (level):** A transparent overlay on which information can be drawn, and which is usually user definable. Individual layers can be visible or suppressed to enable a variety of drawings each including different information to be plotted out from a single drawing file. (Kronenberg Bsc, 1987:114)

**LCD:** Abbreviation of *Liquid Crystal Diode*; used in displays and some electrostatic printers. (Crosley, 1988:183)

**LCD screen:** A display using liquid crystal diodes. generally monochrome, although colour LCD displays are also available. (Crosley, 1988:183)

**LED:** Abbreviation of *Light Emitting Diodes*; a technology used in alphanumeric displays and some electrostatic printers. (Crosley, 1988:183)

**Level:** In some CAD programs, this is synonymous with layer. We use the term here in the architectural sense, meaning a physical plane that differs in elevation from other levels. (Crosley, 1988:183)

**Library:** Stored, organised information or data. (Howes, 1989:134)

**Library:** A collection of frequently used drawing components, usually tailored to the individual user's needs which are inserted into drawings, and from which complete drawings can be built to speed the drafting process. Library components can be manipulated in a variety of ways before insertion. (Kronenberg Bsc, 1987:114)

**Light pen**: A hand-held pointing device that registers position when pointed at individual pixels on a computer display. A button or sensitive tip allows points to be picked. (Crosley, 1988:183)

**Linetype:** A categorization of lines by degree of continuity (continuous, dashed, dotted, or a combination) as displayed and/or plotted by a CAD program. (Crosley, 1988:183)

**Line weight:** The width of a line, as displayed and/or plotted by a CAD program. (Crosley, 1988:183)

**LISP:** Abbreviation of a high-level computer language, sometimes used in "artificial intelligence" programs. LISP stands for list processing, although some users claim it stands for "Lost In Stupid Parentheses" since it makes ample use of them. (Crosley, 1988:183)

**LDE:** Abbreviation of *Local Design Expressions*. Instances of LDE are design expressions showing, for example, what spatial forms or particular functions are modelled by the designer when embarking on domain-specific design tasks. We use LDEa to denote a local design decision made by a designer named a. (Peng, 2001:193)

**Log in:** The process of gaining access to a time-sharing system. (Gero, 1977:402)

**Mainframe:** A large computer. (Reynolds, 1987:206)

**Main memory:** The memory of the computer itself, as distinct from mass memory. (Reynolds, 1987:207)

**MACs:** Abbreviation of *Apple Macintosh platform or workstation system*.

**MB:** Abbreviation of *Megabyte*. It is equal 1,048 bytes, nominally 1,000,000 bytes or a 1,000 Kilobytes. (Crosley, 1988:183)

**Memory:** Usually refers to the internal (core) store of computer, which may be immediately accessed by the central processor. (Gero, 1977:403)

**Memory:** In computing, a holding place for instructions and data. One kind of memory is RAM, where the computer's central processing unit stores the operating system and application software in current use. Information kept in memory is more quickly available to the computer than that stored on a hard drive. When the computer is turned off, this kind of memory is emptied. (Cohen, 2000:271)

**Menu:** List of commands produced on the computer terminal, usually a graphic terminal. (Gero, 1977:403)

**Menu:** Items or commands shown on a screen for selection by a cursor or keystroke. (Howes, 1989:134)

**Meta:** In information technology, a more comprehensive or underlying definition. The new Internet language XML is said to be a Meta language because it is a language for defining languages. Some search engines can read Meta tags that Web authors insert in pages to categorize broadly the information contained in the page. (Cohen, 2000:271)

**Microcomputer:** A small, desktop-sized computer, generally designed for a single user. (Crosley, 1988:183)

**Microcomputer:** a stand-alone computer; Microcomputers cannot share data unless networked. (Woodward, 1997:145)

**Microdisk:** A small floppy disk housed in a rigid plastic sleeve. (Crosley, 1988:184)

**Microprocessor:** A processor that is entirely contained on a chip of silicon. (Crosley, 1988:184)

**Minicomputer:** A medium-sized computer, generally capable of supporting multiple users and multiple simultaneous operations. (Crosley, 1988:184)

**Minicomputer:** A computer, which can share data and which can support a number of users. (Howes, 1989:134) (Woodward, 1997:145)

**Mirror:** The duplication of a group of entities or block about an axis of symmetry. (Kronenberg Bsc, 1987:115)

**Modem:** A contraction of modulator/ demodulator; a device that converts digital signals to audible sounds for transmission over a telephone line. A modem at the receiving end is required to reconvert the signal to a digital stream. (Cohen, 2000:271)

**Modem:** A device for passing digital data from one computer to another over analog communication links, such as phone lines. Modems are available in several speeds, measured in bits per second (An acronym for modulator/ demodulator). (Crosley, 1988:184)

**Modification:** Changing or editing a drawing in any manner. (Crosley, 1988:184)

**MOOs:** Abbreviation of *MUDs Object Oriented*. (Cicognani, 1996)

**Motherboard:** The board within the computer on which the CPU components are mounted. (Howes, 1989:135)

**Mouse:** A hand-held relative pointing device with one to three buttons, used to move the on-screen cursor, enter commands, and pick points. A mechanical mouse registers position with a rolling ball on its underside; an optical mouse uses a light that reflects on a small pad. (Crosley, 1988:184)

**Mouse:** A device used for screen pointing and menu selection, which does not require to be used in conjunction with a digitiser, but which cannot be used to digitise existing drawings. (Kronenberg Bsc, 1987:115)

**Move:** To relocate an element or group of drawing elements from one location or layer to another. (Crosley, 1988:184)

**Move:** The displacement of a group of entities from their present location within a drawing to another location. (Kronenberg Bsc, 1987:115)

**MUDs:** Abbreviation of *Multi User Dungeons or Dimensions*. (Cicognani, 1996)

**Network:** An arrangement of points or nodes interconnected by communication paths. Networks can be described by their schematic structure, such as a star or ring, or their spatial distribution, as in LAN and WAN. Networks can be further characterized by the type of physical link employed (e.g. copper wire, fiber optic), by the communication protocol used (TCP/IP, AppleTalk), and by the type of signal carried (voice, data). (Cohen, 2000:271)

**Network:** (Applied to computers) two or more self-contained computers that are linked in order to share information and programs. (Crosley, 1988:184)

**Network:** A group of personal computers connected together and controlled by software to enable central storage and retrieval of information, communication of information from one station to another and shared use of peripherals. (Kronenberg Bsc, 1987:115)

**Network:** Linked computers. (Howes, 1989:135)

**Network:** two or more computers linked to share data or peripherals. (Woodward, 1997:146)

**Node:** On a network, a single connection point, which may be a redistribution point to other nodes (called a gateway) or an end point (called a host). (Cohen, 2000: 271)

**Node:** A point shown as a dot on screen, which can be used for quick reference to a location, or as a construction aid. (Kronenberg Bsc, 1987:115)

**Object:** A group of drawing elements; an object may be treated as one element or its individual components may be addressed separately. (Crosley, 1988:184)

**Object snap:** A computer-aided drawing mode in which picked points will occur at specified points of previously drawn objects, such as the “end”, “middle”, or “tangent”. (Crosley, 1988:184)

**Offline:** An item of computer peripheral equipment not currently connected to the central processor unit. (Gero, 1977:403)

**On-line:** A process carried out by a device, which is connected to, and controlled by, the central processor unit of a computer. (Compion, 1968:309)

**On-line:** An item of computer peripheral equipment connected to the central processor unit. (Gero, 1977:403)

**On-line:** Directly connected to a computer system. (Howes, 1989:135) (Woodward, 1997:146)

**Operating system:** The software that controls basic computer functions. Operating systems in widespread use include Windows 95/98/NT, Mac OS, and the various types of UNIX: Solaris, Linux, A/UX, etc. (Cohen, 2000: 271)

**Operating system:** A set of programs that enable a computer CPU, memory, and peripheral devices to function with applications programs. (Crosley, 1988:184)

**Output:** The process, or the result, of transferring information from the central processor unit to an output device where it is then intelligible to the user. (Compion, 1968:309)

**Output:** The information (data) produced by a computer as a result of some processing operation which is presented on some form of peripheral device. (Gero, 1977:403)

**Output:** Data, which comes out of a computer. (Howes, 1989:135)

**Output device:** A computer peripheral device, which enables information inside a computer to be displayed in a form that is intelligible to a user. (Compion, 1968:30)

**Output device:** A piece of equipment, which converts digital data from a computer to a form, which is understandable. This may be transitory on a VDU, stored on a disk, or produced as hard copy. (Howes, 1989:135) (Woodward, 1997:147)

**Package:** A computer program that can carry out a range of related functions in a certain application area. (Reynolds, 1987:208)

**Package program:** A generalized computer program written to meet the needs of a specific application area, e.g., draughting. (Gero, 1977:403)

**Pan:** The movement of the display window around the drawing having previously zoomed to the required level of detail. (The equivalent of ranging over the drawing with one's eyes) (Kronenberg Bsc, 1987:115)

**PASCAL:** One of the more modern high-level languages. (Reynolds, 1987:208)

**Path:** The route from the top directory of a computer via sub directories to a file. (Howes, 1989:136)

**Pattern:** A predefined, repeating arrangement of drawing elements that can be used to fill in a specified area, a process called hatching; "Pattern" is also used by some programs as a synonym for "block". (Crosley, 1988:184)

**PC:** Abbreviation of *Personal Computer*. A computer that is intended to be used by a single person. The term generally refers to a stand-alone microcomputer, although PCs can be linked in networks to each other to peripheral equipment, and to larger computers. (Crosley, 1988:185)

**Pixel:** A contraction of picture element. The smallest indivisible piece of a computer display or raster image. The physical area of computer displays and the size of individual image files are both described by their pixel dimensions. (Cohen, 2000: 271)

**Plotter (electrostatic):** A large dot-matrix printer that uses, typically, lasers, LCD or LED technology to draw CAD graphics on paper. Vector graphics must be converted to raster graphics in order to be plotted by a dot-matrix plotter. (Crosley, 1988:185)

**Plotter (pen):** A mechanical device that uses one or more pens to draw vector graphics on paper, velum, or plastic film. (Crosley, 1988:185)

**Plotter:** A graphics peripheral that draws lines under computer control. (Kronenberg Bsc, 1987:115)

**Point (word-processing and DTP):** The size of a printed character. (Howes, 1989:136)

**Polyline:** A line that may contain multiple connected segments at angles to each other. Some software allows a Polyline to be varied in width or fitted to a curve. (Crosley, 1988:185)

**PPP:** Abbreviation of *Point-to-Point Protocol*. When a modem initiates a session with an Internet service provider, it must first establish a connection, using PPP, before TCP/IP services can be served. (Cohen, 2000:271)

**Printer:** An output device used to print information. (Compion, 1968:310)

**Printer (dot matrix):** A device that places text or graphics on paper by printing closely spaced dot patterns. Dot matrix mechanisms include printhead-and-ribbon, ink jet, and electrostatic. (Crosley, 1988:185)

**Printer (electrostatic):** A type of dot-matrix printer that uses a laser beam, LCDs, or LEDs to place an image on paper. Capable of relatively high resolution. (Crosley, 1988:185)

**Printout:** A general description of printed pages output from a computer. (Gero, 1977:403)

**Processor:** A component of a computer that manipulates data according to specific instructions that are encoded within it, in conjunction with instructions received from external programs (software). (Crosley, 1988:185)

**Program:** A set of instructions for controlling the operation of a computer. (Gero, 1977:403)

**Program (architectural):** A set of instructions for the design of an architectural project. (Crosley, 1988:185)

**Program (computer):** A set instructions that tells a computer to perform specific tasks. Programs are written in special computer languages and are stored on electronic media, such as floppy disks. (Crosley, 1988:185)

**Protocol:** A means of establishing the ground rules common language that two or more computer systems will use to converse with each other. Protocols can be built on top of each other and are sometimes referred to as high-level protocols. TP/IP is the "low-level" protocol that forms the basis of the Internet. Built on top of TCP/IP are higher-level protocols such as HTTP, FTP, and SMTP. (Cohen, 2000:272)

**RAM:** Abbreviation of *Random Access Memory*. Can be thought of as a computer's short-term memory, which makes computer instructions quickly available to the computer's microprocessor. Data in current use by an application is stored in RAM rather than on a hard drive to make operations faster. (Cohen, 2000:272)

**RAM:** Abbreviation of *Random Access Memory*. RAM, rapidly addressable, volatile memory, usually in the form of silicon chips. RAM must be constantly supplied with power or the information stored within it will be lost. (Crosley, 1988:185)

**Random:** (Access Storage Device). An item of computer peripheral equipment, e.g.: a magnetic disc unit, which enables any individual items of data to be stored or located with little if any difference in access time. (Gero, 1977:404)

**Raster image:** A digital image consisting of pixels with values of brightness and colour. (Cohen, 2000: 272)

**RealVideo*:** A streaming technology developed by RealNetworks for transmitting live video over the Internet. RealVideo uses a variety of data compression techniques and works with both normal IP connections and IP Multicast connections. (Jolliffe et al., 2001:320)

**Redraw:** (Applied to computer display) To either regenerate or refresh a display, depending on the terminology of a particular program. Used here for "refresh". (Crosley, 1988:185)

**Rendering:** The way in which CAD models are presented, often involving the use of colours, textures, and lights to give models a realistic appearance. (Szalapaj, 2001:224)

**Replacement:** The exchange of one drawing element with another. When the element has been defined as a symbol or block, redefinition will cause all occurrences of a block to be replaced. (Crosley, 1988:185)

**Rescale:** The generation of a full-scale plan of specified dimensions from an inaccurate drawing, by applying a conversion factor to both axes. Frequently used to correct the size of digitised drawings which may have been distorted in the digitising process, or which may have been digitised from a drawing of no known scale. (Kronenberg Bsc, 1987:116)

**Resolution:** The number of pixels within a digital image, or the number of pixels that can be displayed on a monitor, expressed as an X by Y value. A monitor that can display 1,024 by 768 pixels is said to have higher resolution than a monitor with 800 by 600 pixels. In the context of printers and scanners, resolution refers to the number of dots per inch (dpi). (Cohen, 2000:272)

**Resolution:** The fineness or courseness, in rows of dots, that a computer graphic adapter and monitor are capable of displaying, measured in rows of dots. Common CAD resolutions range from 600*350 dots to 1700*1200. (Crosley, 1988:186)

**Roller ball:** An input device used for moving a screen cursor. (Howes, 1989:137)

**ROM:** Abbreviation of Read Only Memory; Chips, which contain pre-set data, which control the internal operation of a computer. (Howes, 1989:137)

**ROM:** Abbreviation of *Read Only Memory*, a built-in, “hard-wired” section of memory that contains basic instructions for allowing the computer to boot. ROM is not erased when the computer is shut down, as RAM is. (Cohen, 2000:272)

**ROM:** Abbreviation of *Read Only Memory*, a type of main memory that always contains a fixed set of information. (Reynolds, 1987:209)

**Root folder:** The folder (or directory) that contains all other files and folders in a Web site. (Cohen, 2000:272)

**Rotate:** The rotation of a group of entities a specified amount about a given point. (Kronenberg Bsc, 1987:116)

**Ruler:** A scale bar with divisions used to give a rough visual indication of proportions when sketching using CAD. The ruler can be synchronised with a precision snap grid for fast accurate drawing if required. (Kronenberg Bsc, 1987:116)

**Run:** One performance of a program on a computer, which involves input, processing and output. (Gero, 1977:404)

**Scale (verb):** To expand or compress a drawing element. (Crosley, 1988:186)

**Scale (drafting and modelling):** Input to computers is in real, full-size, dimensions. Scale refers to the increase or decrease of apparent screen scale, or to the scale at which a drawing is plotted. (Howes, 1989:137)

**Scanner:** A device for digitising printed pages such as photographs, typed text, magazine pages, and the like. (Cohen, 2000:272)

**Scanner:** An input device for converting pictures and photographs to digital data. (Howes, 1989:137)

**Schedule:** In architectural terminology, a list of materials and/or construction methods. (Crosley, 1988:186)

**Schematic design:** The initial design phase of an architectural project. (Crosley, 1988:186)

**Screen:** The television-like device that let’s you see what’s going on. (Howes, 1989:137)

**Screen menu:** An area of the screen used for the selection of menu items by screen pointing. (Kronenberg Bsc, 1987:116)

**Script:** A sequence of instructions written in computer languages such as Perl and JavaScript. Different from a program, because a script does not stand alone, it triggers an action to be carried out by another application. A common use for scripts on the Internet is to instruct a server about what to do with information that Web site visitors supply in on-line forms. (Cohen, 2000:272)

**SCS:** Abbreviation of *Shared Construction Set*: a set of modelling primitives introduced by members of a design team for the modelling of *Common Generic Structures* in a group modelling space. (Peng, 2001:194)

**Section/elevation:** A multilayered architectural drawing that includes both sections and elevations, on different layers. (Crosley, 1988:186)

**Server:** Can refer either to hardware, the computer that answers requests from clients, or to the software required to perform these operations. Each kind of Internet service requires a particular kind of server software: Web server, mail server, etc. (Cohen, 2000: 272)

**Shareware:** Software that is distributed on the Internet using an honor system that asks users to pay for them after an evaluation period. (Cohen, 2000: 272)

**Simulation:** The process of building a mathematical model of a process within the computer and observing the results. (Reynolds, 1987:209)

**SMTP:** An Internet protocol used for sending and receiving e-mail. Snail mail a disparaging term for the U.S. Postal Service. Spam unsolicited commercial (“junk”) e-mail. (Cohen, 2000: 272)

**Snap:** A computer-aided drawing mode in which all picked points will fall on a grid, at a user-specified spacing (snap resolution). (Crosley, 1988:186)

**Snap:** The ability to lock precisely onto features of drawings such as line endpoints, intersections, midpoints and nodes or to a dot grid of specified intervals known as a snap grid. (Kronenberg Bsc, 1987:116)

**Snap:** (draughting) the ability to lock on to features of drawings. (Woodward, 1997:149)

**Software:** The means by which the operation of a computer is controlled; software is the name given to the programs that cause a computer to carry out particular processing operations. (Compion, 1968:310)

**Software:** The collection of all the programs for a computer; this includes the housekeeping and accounting programs as well as the user written programs and application programs and packages. (Gero, 1977:404)

**Software:** A set of instructions that tells a computer to perform specific tasks. Software is written in special computer languages and is stored on electronic media, such as floppy disks. (Crosley, 1988:186)

**Software:** programs of instructions that tell a computer what to do. (Woodward, 1997:149)

**Solid modelling:** modelling in which solid objects are defined, and physical attributes can be assigned to them. (Woodward, 1997:149)

**Solid model:** A three-dimensional model based on shapes that are treated as solid forms by a computer. A solid model may generally be viewed as either a wireframe image or with shaded surface. (Crosley, 1988:186)

**Spatial database:** A graphic database in which forms may be represented on a three-axis coordinate system; lines, planes, and shapes may be drawn in any orientation. The resulting representation is a three-dimensional model. (Crosley, 1988:186)

**Spreadsheet:** software, which allows text, numbers and formulae to be entered in a grid of ‘cells’ and the manipulated. (Woodward, 1997:149)

**Spreadsheet:** An electronic table (or computer program for creating one) that displays data in columns and rows, and links cells (each column and row intersection) with formulas for performing mathematic operations. (Crosley, 1988:186)

**Storage:** means of storing programs and data, commonly hard or floppy disk. (Woodward, 1997:149)

**Storage device:** A device used for storing information inside a computer, e.g., core store, tape store, disc store, drum store, etc. (Compion, 1968:310)

**Storage device:** An item of computer equipment used for storing both programs and data, e.g.: a peripheral device such as a magnetic disc or tape unit, or the immediate access memory forming part of a central processor unit. (Gero, 1977:405)

**Storage device:** A container for computer files. Hard drives, CD-ROM drives, and tape drives are examples. Storage devices “read” and “write” the information to such media as magnetic disks. (Cohen, 2000:272)

**Stretch:** To move one part of a drawing element while leaving another part in place, increasing or decreasing the length of connecting lines or curves. (Crosley, 1988:186)

**Stretch:** The ability to move part of a drawing while preserving its connections to other parts of the drawing, often used to correct inaccurate plans and elevations or to visualise spatial relationships. (Kronenberg Bsc, 1987:116)

**Subdirectory:** A directory that is included within another directory; a subdirectory may include other lower level subdirectories. This arrangement is comparable to a tree structure, with the first directory called the root directory, and subdirectories branching out. (Crosley, 1988:186)

**Synchronous/Asynchronous communication:** Communication between two or more parties, which can occur at the same time, such as a telephone conversation (synchronous), or at different times such as an e-mail exchange (asynchronous). (Cohen, 2000:273)

**Talk window in CSCW:** is useful for quickly transmitting written information, especially for establishing audio or video connections. (Schmitt, 1999:31)

**TCP/IP:** Abbreviation of *Transmission Control Protocol* / *Internet Protocol*: TCP is the method used to break data messages into pieces (packets) for transmission on the Internet and to reassemble them at their destination. IP is the system of addressing and routing the messages. TCP/IP is the foundation of the public Internet and privet intranets and extranets. (Cohen, 2000:273)

**Technology:** Applied science: the branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and environment, drawing upon such subjects as industrial arts, engineering, applied science, and pure science. (Ching, 1996:382)

**Template:** A set of related symbols, stored together in a drawing library. (Crosley, 1988:186)

**Terminal:** A VDU and keyboard linked to a multi-user computer. (Howes, 1989:138)

**Text:** Alphanumeric characters. In a drawing, these may be entered directly at a keyboard, or transferred from a word processing program. (Crosley, 1988:187)

**Thickness:** The height of an entity or component when projected into three-dimensional space. (Kronenberg Bsc, 1987:116)

**Three-dimensional modelling (3D Modelling):** Representation of lines, planes, shapes or solids in space, in any plane, including nonorthogonal planes. Two-dimensional drawings may be extracted by “cutting through” a model. Models may be displayed as wireframes, shaded surfaces, or solid models, depending on the capabilities of the software. Models may be viewed from any viewpoint, inside or out, often in either perspective or parallel-line views. (Crosley, 1988:187)

**Three-dimensional projection:** A means of displaying two-dimensional drawings as three-dimensional images by stretching or extruding them along a third, perpendicular axis. 3-D projections cannot be used to create new drawings in planes that are not parallel to the original (e.g., sections from projected plans). (Crosley, 1988:187)

**Time-sharing:** A method of operation whereby a computer automatically shares its central processor with one or more input devices, output devices and storage devices so as to make the optimum use of the central processor unit. Since the peripheral devices operate relatively slowly compared with the speed of the central processor unit, this mode of operation allows the latter to keep the peripheral devices busy while still having spare time itself to carry out other parts of the current program which do not require the use of the peripheral devices; the effect is that many operations are able to proceed in parallel. (Compion, 1968:311)

**Time-sharing:** The technique of sharing a piece of computer hardware in rotation between two or more concurrent users; the switching between one user and another is so fast that each appears to have continuous use of the hardware. (Gero, 1977:405)

**Time-sharing:** The use of a computer system by more than one user at the same time. (Howard, 1998:136)

**Touch screen:** An input device. Touching the VDU screen can be used for the selection of menu items. (Howes, 1989:138)

**Two-and-a half-D drawing**: See Three-dimensional projection.

**Two-dimensional drawing:** Drawing with points, lines, arcs, circles, and complex objects in a single plane. (Crosley, 1988:187)

**Unblock:** To break up a defined block into its constituent elements. Synonymous with "explode". (Crosley, 1988:187)

**Updating:** The correction of information (data) held in computer-compatible form involving variously additions, deletions and/or changes. (Gero, 1977:405)

**Updates:** software development provided under a maintenance contract. (Woodward, 1997:150)

**User-friendly:** An interface, which gives the user instructions. (Howes, 1989:137)

**User-friendly:** A term, which describes software that is intuitive to use, quickly learned and easily retained. (Kronenberg Bsc, 1987:116)

**User-friendly:** an interface, which is easy to use. (Woodward, 1997:150)

**User interface:** The means by which the user controls and operates the computer system, consisting of hardware and software. An effective and intuitive user interface is of central importance to efficient system operation. (Kronenberg Bsc, 1987:116)

**Utility:** A small program that enhances the capabilities of the operating system. Utilities are used for tasks such as disk repair, file compression, or searching. (Cohen, 2000:273)

**VC:** Abbreviation of *Virtual Communities*. (Cicognani, 1996)

**VDU:** Abbreviation of *Visual Display Unit*, usually a cathode-ray tube capable of displaying output also used as an input device; it often has graphic display capability. (Gero, 1997:405)

**VDS:** Abbreviation of *Virtual Design Studio*. (Cicognani, 1996)

**VE:** Abbreviation of *Virtual Environment*. "VE is closely related to VR but often refers to different things to different people. Some people consider VE as computer-based visualisation environments employing components of VR technology, while others may mean the computer models of some existing or fictional built environments as the end products of using VR technology. One of the most distinctive developments of VR or VE is the innovative display and interactive technologies such as head-mounted data glove-based 3D(Three-dimensional Modelling) immersive display or desktop panoramic viewing". (Peng, 2001:5)

**Vector:** The format in which CAD systems retain the positions of lines and other entities. Co-ordinates are used to specify the endpoints of lines. (Kronenberg Bsc, 1987:117)

**Videoconferencing:** A system that supports geographically distributed group discussion with video and sound. Videoconferencing on the Internet requires a high-bandwidth connection between participants. (Cohen, 2000:273)

**View:** The storage of a specified view of part of a drawing at the selected zoom level, enabling rapid return to that screen view during the drawing session without the need for time-consuming zooming and panning. (Kronenberg Bsc, 1987:117)

**Viewpoint:** A user-selected point in space from which a three-dimensional image will appear to be seen. (Crosley, 1988:187)

**Virus:** A destructive program, which attaches itself to a file frequently used by the operating system. Contagious and self-replicating, and can be 'caught' from unauthorised software and from floppy disks of dubious origin. (Howes, 1989:139)

**Virtual:** from virtus, meaning potential essence or force. The virtual has superseded the real. (Zellner, 1999:10)

**Visualization:** modelling (or enhanced draughting) programs that allow models to be viewed from many directions and lighting effects and other physical attributes to be applied. (Woodward, 1997:151)

**Visualization:** A graphical presentation of a design idea. (Szalapaj, 2001:225)

**Voice recognition:** a combination of hardware (e.g. microphone) and software that can recognize digitise human speech. (Woodward, 1997:151)

**VR:** Abbreviation of *Virtual Reality,* the simulation of real or imagined environment that can be explored interactively on a computer using the mouse or keyboard. (Cohen, 2000: 273)

**Virtual reality:** software systems that allow the user to interact with a computer environment. (Woodward, 1997:151)

**Virtual reality:** computer-created environment, which closely imitates the real world in terms of effects used: it is three-dimensional, it is immersive, it allows things to be picked up and dropped, it gives haptic feedback, for more applications, a special helmet is needed with a display attached to the eyes, to 'disconnect' from the real world. (Schmitt, 1999:88)

**VRAD:** Abbreviation of *Virtual Reality Aided Design*. Computer Aided Design using virtual reality methods. (Donath et al., 1999:453)

**VRML:** Abbreviation of *Virtual Reality Modelling Language*; a language for describing three-dimensional, interactive space. (Cohen, 2000: 273)

**WAN:** Abbreviation of *Wide Area Network*; a geographically dispersed network. Typically connects the various locations of a single organization. (Cohen, 2000: 273)

**Web page:** A single HTML document, usually part of a larger Web site. (Cohen, 2000:274)

**Web site:** A collection of Web pages, or HTML documents, together with their associated graphics and other media, and a system that links these elements together. A web site resides on a server, from which a browser can make requests for pages. (Cohen, 2000:274)

**Whiteboard in CSCW:** allows users to sketch directly or to comment on the work of others. (Schmitt, 1999:31)

**Window:** In computer-aided drawing, an area outlined on the display screen for the selection of drawing elements or for zooming in or out, Synonymous with box and fence. (Crosley, 1988:187)

**Window (drafting and modelling):** A variable size box on the screen, which can be used to select portions of drawing for editing, or an area of the screen where another program can be run at the same time as the main program. (Howes, 1989:139)

**Window:** A variable sized box which appears on screen and is used to select objects for editing, zooming and, in some systems, panning. (Kronenberg Bsc, 1987:117)

**Wireframe:** A three-dimensional projection or model in which the edges or outlines of objects are displayed as lines. Usually all lines are displayed, unless hidden lines are removed. (Crosley, 1988:187)

**Wire-frame model/ Wire-line model:** (modelling) a 3D(Three-dimensional Modelling) model built up of lines representing the intersection of planes. (Woodward, 1997:151)

**Wire-frame:** The presentation of a 3-D CAD in terms of lines in 3-D space. (Szalapaj, 2001:225)

**Word processor:** A computer program that manipulates text. Generally used as a typewriter with editing capabilities; some can also be used for combining text and graphics. (Crosley, 1988:187)

**Word processor:** A system used to create and modify text files. (Reynolds, 1987:210)

**Workstation:** Arrangement of computer peripherals suitable for the user/machine interaction. (Gero, 1977:405)

**Workstation:** The complete hardware and software package necessary for use as a dedicated CAD system. Typically consisting of personal computer, screen, pointing device and plotter. (Kronenberg Bsc, 1987:117)

**WWW:** Abbreviation of *World Wide Web*, one of the Internet services, the Web has become the leading gateway to the Internet because of its support for multimedia and hypertext. (Cohen, 2000: 274)

**WWW*:** Abbreviation of *World Wide Web*, a global, interconnected system of Internet servers that support specially formatted documents, commonly known as Web pages. Web pages are formatted in HTML and support links to other documents, as well as graphics, audio and video files. Users accessing a Web page can jump from one page to another by clicking on hyperlinks. (Jolliffe et al., 2001:320)

**WWW:** Abbreviation of *World Wide Web*, one of the services offered by the Internet. The WWW is a global publishing medium for texts, audio and video. It is organized into single documents called pages. A WWW browser is needed to look at WWW pages. (Schmitt, 1999:88)

**WYG:** Abbreviation of "What *You Get"* on the printer. (Woodward, 1997:151)

**WYS:** Abbreviation of "What *You See"* on the screen. (Woodward, 1997:151)

**Zoom:** To expand or contract an image on a computer display; the effect is much like changing scale in drafting, but the user views a drawing in real units, regardless of the zoom magnification. (Crosley, 1988:187)

**Zoom:** The ability to focus in on an area of a drawing and reproduce it at full screen size to allow detailed information to be seen or added. (Kronenberg Bsc, 1987:117)

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# Appendix III: UK Schools of Architecture

This part contains useful information about Schools of Architecture in UK whose courses and examinations are recognised by RIBA or exempted from examinations (RIBA Part I) and (RIBA Part II), followed by information about important association related to architecture education relating with CAAD. The following information on each category is given: full name, address, telephone number, fax number, e-mail and website. The words between brackets indicate the former name.

**England Region**

Department of Architecture & Civil Engineering
Faculty of Engineering & Design
University of Bath
Bath, BA2 7AY

Tel: 01225 386357
Fax: 01225 386691
E-mail: ace.adm@bath.ac.uk
Website: http://www.bath.ac.uk/ace/

Birmingham School of Architecture and Landscape
Faculty of the Built Environment
University of Central England in Birmingham
(City of Birmingham Polytechnic)
Perry Barr
Birmingham, B42 2SU

Tel: 0121 331 5130 / 0121 331 5100
Fax: 0121 331 5114
e-mail: architectureandlandscape@uce.ac.uk
Website: http://www.uce.ac.uk/

School of Planning & Architecture
Faculty of the Built Environment
University of the West of England, Bristol
Coldharbour Lane,
Bristol, BS16 1QY

Tel: 0117 344 3218
Fax: 0117 344 3308
E-mail: Mary.Allen@uwe.ac.uk
Website: http://www.uwe.ac.uk/fbe/pa/

School of Architecture and Design
Faculty of Arts & Architecture
University of Brighton
(Brighton Polytechnic)
Mithras House, Lewes Road
Brighton
East Sussex, BN2 4AT

Tel: 0127 360 0900
Fax: 0127 364 2348
e-mail: D.W.Baker-Brown@brighton.ac.uk
design@bton.ac.uk
Website: http://www.bton.ac.uk/structure/soad.html
http://www.brighton.ac.uk/design/

Department of Architecture
University of Cambridge
1-5 Scroope Terrace, Trumpington Street
Cambridge, CB2 1PX

Tel: 0122 333 2958
Fax: 0122 333 2960
e-mail: arct-info@lists.cam.ac.uk
Website: http://www.arct.cam.ac.uk/

Canterbury School of Architecture
Kent Institute of Art and Design
(Canterbury College of Art)
New Dover Road
Canterbury
Kent, CT1 3AN

Tel: 0122 776 9371
Fax: 0122 781 7500
e-mail: asadler@kiad.ac.uk
Website: http://www.kiad.ac.uk/

School of Architecture Technology
University of Huddersfield
Queensgate
Huddersfield, HD1 3DH

Tel: 01484 473 813 / 01484 472 064
Fax: 01484 472 940
e-mail: j.c.walker@hud.ac.uk s.l.beverley@hud.ac.uk
Website:http://des-tech.hud.ac.uk/des_tech/index.html

Hull School of Architecture

Tel: 0152 288 2000 / 0148 246 2067

(The Lincoln School of Architecture)
Faculty of Art, Architecture& Design
University of Lincoln
(Humberside College of Higher Education)
Brayford campus, George Street
Hull, HU1 3BW

Fax: 0152 288 2088 / 0148 246 2048
e-mail: HSA@lincoln.ac.uk
mbaker@lincoln.ac.uk
Website: http://www.lincoln.ac.uk/arc/

School of Architecture
Faculty of Professional Studies
Kingston Polytechnic
Knights Park
Kingston Upon Thames
Surrey, KT1 2QJ

Tel: 020 8547 7194
Fax: 020 8547 7186
e-mail: e.hilides@kingston.ac.uk
Website: http://www.kingston.ac.uk/

School of Art, Architecture & Design
Faculty of Health and Environment
Leeds Metropolitan University
(Leeds Polytechnic)
Brunswick Building
Leeds, LS2 8BU

Tel: 0113 283 2600 ext 4070
Fax: 0113 283 3190
e-mail: j.howes@lmu.ac.uk
Website: http://www.lmu.ac.uk/hen/aad/

Leicester School of Architecture
Faculty of Art and Design
De Montfort University
(Leicester Polytechnic)
The Gateway
Leicester, LE1 9BH

Tel: 0116 257 7507
Fax: 0116 250 6281
e-mail: artanddesign@dmu.ac.uk
Website:
http://www.dmu.ac.uk/faculties/art_and_design/

Liverpool School of Art and Design
Liverpool John Moores University
68 Hope Street
Liverpool, L1 9EB

Tel: 0151 231 5083
Fax: 0151 231 5096
e-mail: artadmissions@livjm.ac.uk
Website: http://cwis.livjm.ac.uk/artschool/

The School of Architecture and Building Engineering
Faculty of Social& Building Studies
The University of Liverpool
(Liverpool University)
Leverhulme Building, Abercomby Square
Liverpool, L69 3BX

Tel: 0151 794 2603/2608
Fax:0151 794 2605
e-mail: archweb@liv.ac.uk
Website: Http://www.liv.ac.uk/abe

Architectural Association
School of Architecture
36 Bedford Square
London, WC1B 3ES

Tel: 020 7887 4000
Fax: 020 7414 0782
e-mail: info@*aaschool.ac.uk*
Website: http://www.aaschool.ac.uk

School of Architecture and Construction
University of Greenwich
Mansion Site
Avery Hill Campus
London, SE9 2PQ

Tel: 0208 331 9000 / 0208 331 9108
Fax:
e-mail:
Website: http://www.gre.ac.uk/schools/a-and-c/index.html

Department of Architecture
School of Architecture and Built Environment
The University of Westminster
(Polytechnic of Central London)
35 Marylebone Road
London, NW1 5LS

Tel:020 7911 5020
Fax:0207911 5703
e-mail: mrdmark@wmin.ac.uk
Website: http://www.wmin.ac.uk/sabe/

School of Architecture& Interior Design
Environmental and Social Studies
University of North London
(The Polytechnic of North London)
(London Metropolitan University)
40-44 Holloway Road
London, N7 8JL

Tel: 020 7753 5134
Fax: 020 7753 5764
e-mail: admissions@unl.ac.uk
Website: http://www.said.unl.ac.uk/

School of Architecture
University of East London
(North East London Polytechnic)
Holbrook Road
London, E15 3EA

Tel: 020 8223 3295
Fax: 020 8223 3296
e-mail: c.wade@uel.ac.uk
Website: http://www.uel.ac.uk/architecture/index.htm

Division of Architecture
Faculty of the Built Environment
London's South Bank University
(Polytechnic of South Bank)
Wandsworth Road
London, SW8 2JZ

Tel: 020 7815 7102
Fax: 020 7815 7330
e-mail: crackns@sbu.ac.uk
Website: http://www.southbank-university.ac.uk/

Department of Architecture and Interiors
School of Architecture and Design
Royal College of Art
Kensington Gore
London, SW7 2EU

Tel: 020 7590 4444
Fax: 020 7590 4500
e-mail: admissions@rca.ac.uk
Website: www.rca.ac.uk/architectureandinteriors/

Bartlett School of Architecture
Faculty of the Built Environment
University College London
Wates House
22 Gordon Street
London, WC1H 0QB

Tel: 020 7679 7504
Fax: 020 7679 4831
E-mail: architecture@ucl.ac.uk
Website: http://www.bartlett.ucl.ac.uk/architecture/

The Manchester School of Architecture
Tele: 0161 247 6950 / 0161 275 6923 (Admission)
Fax: 0161 247 6810
e-mail: msa@mmu.ac.uk
Web site: www.msa.mmu.ac.uk

Department of
Architecture, Landscape &
Three Dimentional Design
Faculty of Art and Design
Manchester Metropolitan
University
(Manchester Polytechnic)
Chatham Building
Cavendish Street
Manchester, M15 6BR

Tel: 0161 247 2905
Fax: 0161 247 6393
e-mail: artdes.fac@mmu.ac.uk
Website: www.mmu.ac.uk

School of Architecture
Faculty of Art
The University of
Manchester
(The Victoria University of
Manchester)
Architecture and Planning
Building
Oxford Road
Manchester, M13 9PL

Tel: 0161 275 6923
Fax: 0161 275 6935
e-mail: mfksthg@fs1.ar.man.ac.uk
Website: www.msa.mmu.ac.uk/

School of Architecture, Planning and
Landscape
The University of Newcastle Upon
Tyne
Newcastle upon Tyne, NE1 7RU

Tel: 0191 222 7634 / 0191 222 5831
Fax: 0191 222 8811
e-mail: info@apl.ncl.ac.uk
Website: http://www.apl.ncl.ac.uk/

Institute of Architecture
School of the Built Environment
The University of Nottingham
University Park
Nottingham, NG7 2RD

Tel: 0115 951 3134
Fax: 0115 951 3159
e-mail: sbe@nottingham.ac.uk
Website: http://www.nottingham.ac.uk/sbe

Oxford School Of Architecture
Oxford Brookes University
Gipsy Lane
Oxford, OX3 0BP

Tel: 01865 483200
Fax: 01865 483298
e-mail: arch@brookes.ac.uk
Website: http://www.brookes.ac.uk/schools/arch/

Plymouth School of Architecture
University of Plymouth
The Hoe Centre
Notte Street
Plymouth Devon, PL1 2AR

Tel: 01752 233 600
Fax: 01752 233 634
e-mail: drushton@plymouth.ac.uk
Website: http://www.tech.plym.ac.uk/soa/arch/

Portsmouth School of Architecture
Faculty of the Environment
University of Portsmouth
(Portsmouth Polytechnic)
University House
Winston Churchill Avenue
Portsmouth
Hampshire, PO1 2DY

Tel: 023 9284 8484 / 023 9284 8288
Fax: 023 9284 3082
e-mail: env.admissions@port.ac.uk
Website: http://www.port.ac.uk/departments/arc/

School of Architecture
Faculty of Architectural Study
University of Sheffield
The Arts Tower
Western Bank
Sheffield, S10 2TN

Tel: 0114 222 0399
Fax: 0114 222 8276
e-mail: n.j.lewis@sheffield.ac.uk
Website:
http://www.shef.ac.uk/uni/academic/A-C/archst/f_y2.html

**Northern Ireland Region**

School of Architecture
Faculty of Engineering
Queen's University of Belfast
2 Lennoxvale
Belfast, BT9 5BY
Northern Ireland

Tel: 028 9027 4198/4214
Fax: 028 9068 2475
e-mail: architecture@qubac.uk
Website: http://www.qub.ac.uk/arc/

**Scotland Region**

Mackintosh School of Architecture
Glasgow School of Art
University of Glasgow
167 Renfrew Street
Glasgow, G3 6RQ

Tel: 0141 353 4590
Fax: 0141 353 4703
e-mail: architecture@gsa.ac.uk
Website: http://www.gsa.ac.uk

The Scott Sutherland School Architecture
The Faculty of Design and Technology
The Robert Gordon University
(Robert Gordon's Institute of Technology)
Garthdee Road
Aberdeen, AB10 7QB

Tel: 01224 263 524/500
Fax: 01224 263 535
e-mail: i.ramsey@rgu.ac.uk
Website: http://www.rgu.ac.uk/sss

School of Architecture
Faculty Duncan of Jordanstone College

Tel: 01382 344 000
Fax: 01382 201 604

University of Dundee
Nethergate
13 Perth Road
Dundee, DD1 4HN

e-mail: school@architecture.dundee.ac.uk
Website:
http://www.architecture.dundee.ac.uk/

School of Architecture
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**Notes**

[i] The areas in the black shadowed blocks are emphasised during this dissertation.

[ii] Since 1969 the Department of Architecture and Urban Planning, in Tripoli-Libya, have been members of the Faculty of Engineering.

[iii] The Higher Education Quality Council in UK (HEQC, 1995), has set specific themes that can be used for examining institutions (see QaQish, 1997: 418), and these are: Management Issues, Curriculum Development, Teaching and Learning, Staff Issues, Student Issues, Assessment and Examine, and Links between Levels.

[iv] Mitchell, W. (1977), ***"Computer-Aided Architectural Design"***, USA: Mason/Charter Publishers, Inc.

[v] Longman Dictionary of Contemporary English (2000), Longman Group Ltd., P917.

[vi] Unpublished Research at Mackintosh School of Architecture by John Boutsioukis- Sep. 2002.

[vii] The Joint study Program Report, is an annual report organize and supports by *auto•des•sys, Inc.,* to evaluate students use of Form•Z software package as a 3D(Three-dimensional Modelling) tool at Universities and Colleges worldwide.

[viii] Mitchell, W. (1977), ***"Computer-Aided Architectural Design"***. USA, Mason/Charter Publishers, Inc., P.13

[ix] Reference: **www.pattosoft.com.au/.../HistoryOfComputers/ 1990s.html**. 05/05/2003, 24:00

[x] Reference: Zampi, G. &Morgan, C. (1995), ***"Virtual Architecture"***, B. T. Batsford Ltd.: London, UK, P.20

[xi] IESNA Software Survey, *LD+A*, July 1994 (Hanna, 1996:184)

[xii] 14$^{th}$ eCAADe Conference, Lund, Sweden, 12-14/09/1996.

[xiii] CATIA "from Dassault systems-was originally developed for the design of complex surfaces, such as aircraft fuselage or automobile bodies" (Sanders, 1996:78)

[xiv] Lindsey (2001:43) notes that there is argument within architecture practice about the accuracy of translation from physical to digital model.

[xv] http://www.culture.net/ArtandArch/Bilbao.htm [15/04/2003, 13:02]

[xvi] Funded project jointly carried out by the Department of Civil Engineering at University of Paisley, the Mackintosh School of Architecture, and Lamp Software (MacCallum & Hanna, 1996)

[xvii] A case-based reasoning tool for teaching structural design developed at Key Centre of Design Computing, Department of Architectural and Design Science, University of Sydney (Maher, 1997)

[xviii] ABACUS: An urban modelling software package has been developed at University of Strathclyde (Grant & Paterson, 1994:136)

[xix] TRIM & TUMMS: Software packages being written at the Centre for Landscape Research, School of Architecture and Landscape Architecture, University of Toronto (Danahy, 1990:365)

[xx] URBIS: "A computer program built for AutoCAD environment, which propose to help in urban planning's education and practice, and is the result of the collaborative effort of the Faculty of Architecture, the Belgrade University and the IMS Institute" (Simovic, 1991:98)

[xxi] "CSCW offers the possibility of working together in spite of being separated spatially " said Gerhard Schmitt (1999:30)

[xxii] Alan Turing: English mathematician and logician who pioneered computer science.

[xxiii] http://members.tripod.com/~MalusMan/AI/ChrisEssay.html [08/03/2003, 16:34], Mind [Journal], Vol. LIX, No 236, October 1950, Pp.433-460.

[xxiv] Reference:http://www.sun.com/960710/feature3/sketchpad.html#sketch [08/03/2003, 16:34]

[xxv] Present at 1964 Fall Joint Computer Conference (Mitchell, 1977:15)

[xxvi] The Scottish Central Institutions Committee for Educational Development.

[xxvii] Maver, T & Schijf, R (1983),***"International Implementation of a CAAD Project in Schools of Architecture"***, BoCAAD, No. 47, February1983, Pp. 3-8.

[xxviii] The Committee for the Built Environment of the Council for National Academic Awards. (see, Bridges, 1986:335).

[xxix] This approach to pedagogy in the CAD studio is offered by Flemming, U. & Schmitt, G. (1986), "The Computer in the Design Studio: Ideas and Exercises that Go Beyond Automated Drafting" ACADIA Proceeding 86. (See, Akin, 1990:302-303)

[xxx] Marla Smith is a full-time instructor, and has taught in the design studio at The University of Texas at Austin, since 1994.

[xxxi] According to Schmitt (1990:80), Generic tools include word processing, spreadsheets, painting, drafting, three-dimensional modelling, and hypermedia.

[xxxii] The National Architectural Accrediting Board (NAAB) is the sole agency authorized to accredit US professional degree programs in architecture, and was established in 1940. (http://www.naad.org/information1725/, 01:19 pm, 25/06/03)

[xxxiii] Strojan et al. (2002:17) and Wojtowicz et al. (1995a: 22) state that the term *Virtual Design Studio* (VDS) was used for the first time by William Mitchell in 1993.

[xxxiv] The literature shows that the early test of CSCW or VDS used in architectural education date back to February 1993[xxxiv] between five separate institutions MIT with Harvard Graduate School of Design, The University of Hong Kong, University of British Columbia, and Washington University (Wojtowicz, 1995) (Schmitt, 1999:31), followed by 1994 virtual design studio between six separate institutions: Escola Tecnica Superior d'Arquitectura de Barcelona, MIT, Harvard Graduate School of Design, University of British Columbia, The University of Hong Kong, and Washington University (Wojtowicz, 1995:190).

[xxxv] The University of Huddersfield awards BSc (Hons) in Virtual Reality Design, BSc (Hons) in Architectural Computer Aided Technology, and BA/BSc (Hons) in Multimedia Design, under Architectural Foundation Programme. (Building Design [newspaper] 28/5/1999,p.17)

[xxxvi] Yeung, Cheung, Yen & Cheng (1998:95)

[xxxvii] Building Design [Newspaper], May 28/1999, P.17.

[xxxviii] This approach is used in Tampere department of Architecture-Tampere University of Technology-Finland (see Penttilä, 1996)