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ORIGINAL ARTICLE

Architectural education in the digital age Computer applications: Between academia and practice

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KEYWORDS

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Abstract Architecture is a technology-intensive discipline. It uses technology, both in the process of design and also in production. It is believed that digital computer technology has a strong impact on architectural design, architectural teaching as well as in practice. Image architecture, digital simulation and virtual scene among other applications have gradually become progressive architectural design phrases. There exists a necessity that architectural teaching should adapt to such transformations.

With the rapid development of computer applications in the architectural profession, the need to find a framework to integrate the computer applications with architectural curriculum has increased. Hence, it became mandatory to examine the computer integration's impact on architectural schools, at the same time explore the architecture profession's needs in order to help find an efficient framework for architectural education.

This paper studies the integration of computer applications in the top 20 international architecture schools as well as in eight architectural departments in Egyptian universities, with the aim of understanding the current educational status nationally and internationally. A survey was conducted on a sample of architects in order to investigate the profession needs in various architectural fields. The study is carried out to bridge the gap between architectural education and architectural profession.

1. Introduction

Computer technology has provided architects with new affordances and has begun to displace traditional design technologies. It is obvious that the efficiency, control, and intelligence became possible by computational tools; these methods are increasingly considered essential to architectural practices. However, it is less obvious how this technology has begun to influence the practice of architecture, the society they serve, and therefore the education of architects. According to Qaqish and Hanna [27], Computer technology includes all computer applications whether they are integrated within the design studio, or are stand-alone courses; both in architectural design as well as in urban planning courses.

In the 21st century, architectural education has witnessed an increase in the digital technologies that have been involved

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in the design studio curriculum. These various technologies of computer aided drafting, enumerating, modeling, and analysis became not only key pedagogical nodes in the design studio, but also started to shape the overall curricular structure of architectural education. They also needed to be implemented as support courses in order to balance the learning curve and the number of software available to architects. Traditional architectural education tools are mainly based on 2D sketches as well as on physical 3D models. This situation has been changed through the 90's. According to an experiment in architectural education by Angelil [4], computer technologies have been involved in the education process to replace traditional tools of teaching at least in the three final years of the educational schedule.

Nowadays, integrating complete digital teaching became the main subject of educators and researchers. Their main aims are using computer applications as a tool for design as well as improving students' skills and abilities. However, until now there exists neither a framework nor a fundamental structure for the use of computer in architectural education, most of architectural schools and departments, especially in developed countries, have developed their criteria in the educational schedules by integrating more computer courses [39].

A proper understanding of architecture schools pedagogies can be a start to discover when, where and how the computer applications should be implemented in architectural education. Hence at first, the current status for the architectural education should be examined and analyzed through a theoretical and analytical investigation of the architectural schools. Then, understanding the architectural profession needs is the second step towards an ideal framework to integrate the computer applications with architectural curriculum.

2. Historical background

The advance of the information computer technology revolution with the accompanied digital technologies has changed the traditional context of architecture as a profession and in education [20].

Computer applications have been used in the profession over the past three decades to enhance existing practices by facilitating the production of vast quantities of drawings with high accuracy and over less time. A study prepared by Andia [3] suggested that digital technologies have been used in architectural schools to challenge the modernizing view of architectural practice [29]. Andia indicated that computer application has affected both practitioners and students in terms of their skills and the setting of educational and professional culture. Simultaneously, combining traditional design approaches with digital technology is effectively improving architectural practice. Computer application has been used by schools of architecture to transform architectural imagination and architectural practical possibilities.

However, architectural schools are becoming laboratories for various digital design media, and the architectural studio itself has become a space to examine the role of computers in architectural design. Students have increasing tendencies toward computer applications and are becoming more skilled and involved in using various design media in their design processes, which, in turn, has affected the traditional design studio culture. Al-Qawasmi emphasized that digital media, as used in the e-studio, can bring important changes to the architectural design process but might have unintended restricting effects [2].

In contrast, Achten [1] warned that this transformation towards digital architecture should be reconsidered whether in term of practice or education. First, digital tools could replace, the traditional design tools, such as manual sketching that often provides the necessary direct physical link between the hand and the brain. Second, digital tools has provided an alluring, easy, and inexpensive alternative to physical architectural models and has replaced them with a set of seducing graphics that are usually designed to impress the audience (juror/client).

According to Guney [25], the disadvantage of using computer applications is to make the students addicted and design their projects without creativity. The use of computer application tools by students came as early as the conceptual stage in the investigation of specific formal themes [1]. However, many educators and practitioners have called for a combination of both physical and digital design methods rather than the use of either method separately. Breen [20] indicated that the combination of both techniques gives the designer added insights and more "real" approaches to develop, reconsider and refine any design. Breen also emphasized that the combination of both techniques should be actively incorporated in the educational curriculum to prepare the students as they move toward practice [2].

3. Objectives

The study aims to:

a. Bridge the gap between academia and practice of architecture
b. Compete with the international architectural status; the national post graduate architect should be entitled in full equality with the international post graduate.

4. Methodology

4.1. Study 1: Academia

After reviewing the history of computer applications' integration in architectural education, a sample of top 30 international architectural schools are chosen, in order to state the contemporary architectural education status. The sample is chosen according to Quacquarelli Symonds (QS) World University Ranking by Subject (2017) and Times Higher Education University Ranking (2017). Then it is summarized to the common top 20 schools in both ranking systems. Also eight architecture departments from top Egyptian universities are added to investigate the current national status.

The survey examines 20 international schools from 9 different countries; 9 architectural schools from USA, three from England UK, two from Australia and a single school from each China, Singapore, Italy, Netherlands, Germany and Canada, aside to eight national universities.

4.1.1. Data gathering tools

1. For the national architecture schools' curriculum, interviews were held for the architecture department professors of national universities to collect the data.
2. While for international schools, the researcher depended on emailing the university administration or contacting students if the published handbook didn't occupy the needed information.

The study focuses on bachelor architecture programs for undergraduate students. As the number and the content of general education courses vary from school to school, a common classification has been adopted to set the factors of the study. The years of undergraduate study programs were classified into three main phases:

- Preparatory year(s)
- Sophomore year(s)
- Final year(s)

These three phases were set as 75% of the chosen architecture schools study the bachelor of architecture through three years; as for example University of Hong Kong, National University of Singapore, Columbia University, University of Melbourne, Harvard school of Architecture while national architecture departments along with 25% of the international schools tend to use a four years curriculum; as Cornell University, University of Toronto, Architecture study in the first two years is usually limited to introductory topics. Non-professional students do not have to make a firm commitment to the architecture program until the end of their second year. Specialist coursework in architecture usually begins in the third year. Therefore the first two years were considered as a preparatory year while the third was the sophomore year and then the fourth for the final year.

To evaluate computer integration in the architecture school, their curriculum is studied and analyzed. The different computer application courses in the curriculum are classified into eight categories that represent the function of the computer application as the software vary from school to another and can be changed every year while the researcher is concerned about the function not the software. These are all the categories that are included in the 20 schools' Curriculum.

- 2D&3D representation
- BIM
- Parametric design
- GIS
- Digital fabrication
- Simulation
- Environmental technology
- Building technology
- Communication
- Programming, Coding and Scripting

The collected data has been conducted through a matrix that states which category of computer application is being studied by each school in different phases, and whether those applications are integrated within the design studio or are studied as stand-alone courses for both the international architectural schools as well as the national departments (Fig. 1).

Thus, the contemporary status for the national architectural education, regarding integrating computer applications into the curriculum, is stated and analyzed.

4.2. Study 2: Practice

A survey questionnaire is held to study the contemporary national architectural profession needs. A sample of post graduated architects is chosen from various architectural fields. The main objective of the study is to bridge the gap between the computer applications teaching and the profession needs. The study seeks to reach that objective through identifying the recent computer application approved in the national architectural profession, providing an insight into the recent computer application trends turning up in the architectural profession fields.

The questionnaire was carried through an online, web and mobile application. A random stratified sample of national architects is chosen. 65 successful results are chosen out of a 100 sample of national architects. The survey is targeting the newly graduated architects rather than the older ones. About 63 percent of the responses are from female architects, while only 37 percent are from male architects. The survey is only for the graduated architects either master degree holder, candidate or post graduated. From national architectural departments, 45 percent of responses for architects graduated from Faculty of Engineering, Alexandria University, about 45 percent as well from Arab Academy for Science and Technology, while only 8 percent are from Faculty of Fine Arts, Alexandria University and one from Ain Shams University and Tanta University.

Six principle areas of analysis are developed to examine the contemporary computer use in architectural profession:

- The first area examines the role of computer applications in architectural profession fields within areas of architecture, science and research, namely: interior and exterior architectural design, urban planning, landscape design, execution drawing, site supervision as well as the academic field. So, the role of computer applications utilization in architectural profession is an important variable used by this study to better understand architectural computing. Also it identified the areas in architectural fields that computer is likely to have an impact on.
- The second area examined whether there are any differences in attitudes and perception between the ages of the architect towards the importance of computer applications in the design process.
- The third area explored the stages of computer applications employment in the architectural phase. This analysis intended to explore whether there are any trends in teaching computer applications.
- The fourth area investigated the use of software in work field (low use and high use).
- The last area tends to know the new up-coming trends and technologies in the architecture field.

Therefore, as the factors that affect the computer applications' integration are studied and analyzed, the output of the research seeks to help finding an efficient frame work for computer applications' integration in architectural education.

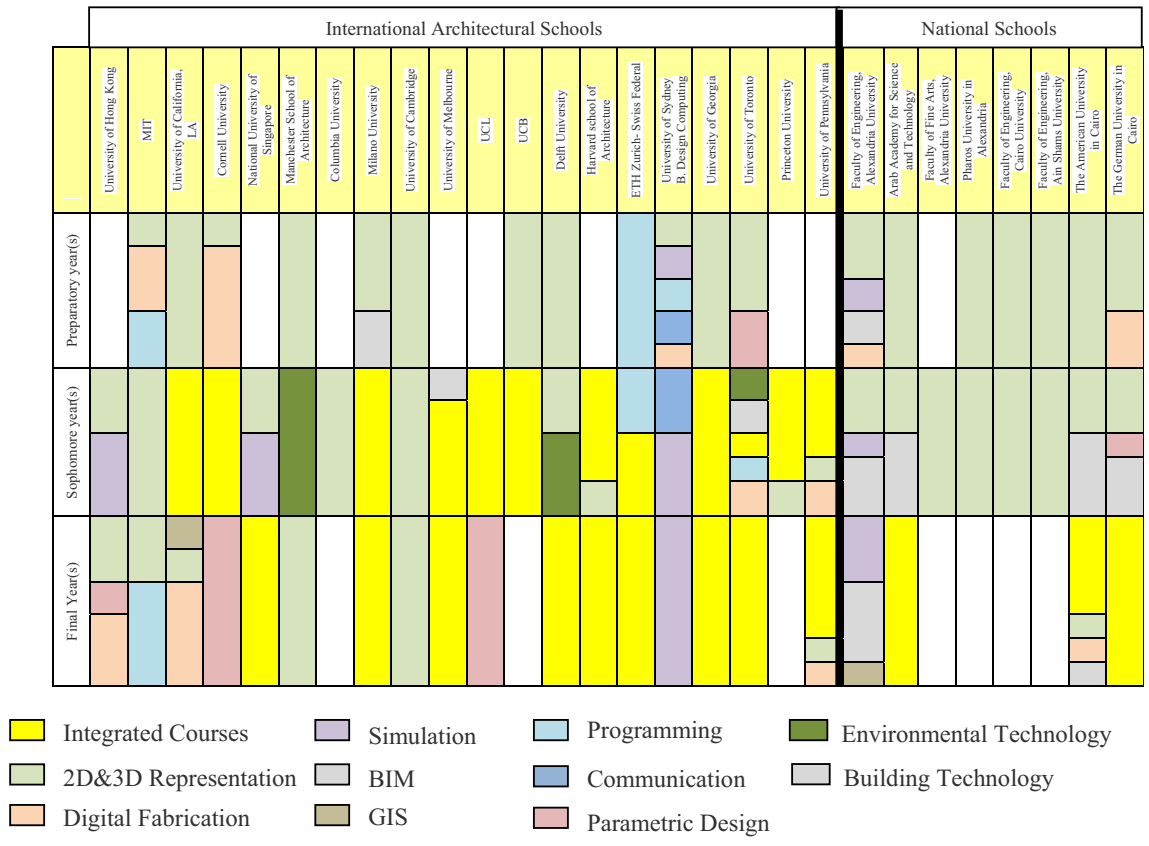

Fig. 1 Matrix for computer applications in architectural schools. (See above-mentioned references for further information.)

5. Results

5.1. Study 1: Academia

The matrix is analyzed to investigate the current status of architectural education through examining the intensity of integrated and stand-alone courses, their category as well as their phase of teaching. Computer application courses records total 71 courses from 20 international schools among 31 courses in eight national schools (Fig. 1).

- Type &Intensity of integration

Based on the 20 international schools, the study finds that 68 percent of the computer applications are integrated within the design studio while only 32 percent are taught as stand-alone courses.

On the preparatory year in international architecture schools/ departments, it is noticed that, 38% of the courses are taught as stand-alone courses. While by time, computer courses decrease on sophomore years to 30 percent, and to 31 percent in the final year (Table 1).

On the other hand, in national departments, 50 percent of computer application courses take place in the preparatory, followed by the sophomore years with 39 percent, while only 11percent of courses are taught in the final year (Table 1).

As noticed in the matrix (Fig. 1), in the final year in both, Alexandria University and the American University in Cairo, only have separate computer application courses, unlike other departments who rarely have course even integrated ones.

Finally, it is noticed that national as well as international schools integrate computer courses in the final year, unlike stand-alone courses which are concentrated in preparatory year(s). National departments differ from the international

Table 1 Type & intensity of integration, by researcher.

	Total courses	Integration type		Integration intensity		
		Integrated courses	Stand-alone courses	Preparatory year(s)	Sophomore year(s)	Final year(s)
International	71	68%	32%	38%	30%	31%
National	31	10%	90%	50%	39%	11%

ones in the sophomore year as they lack integrated courses, while international schools have most courses in sophomore year(s) (Fig. 2).

- Computer application disciplines

On the international level, it was found that the 2D&3D representation applications stand for 50 percent of all computer application courses all over the threephases (Fig. 3). Digital fabrication courses take 13 percent from the architecture curriculum followed by nine percent for programming, seven percent forsimulation courses and five percent for environmental technologies. While parametric design, building technologies and communication take four percent. Finally GIS and BIM courses account for the least computer application courses in the curriculum.

While on the national level (Fig. 4), the Egyptian departments focus mainly on the 2D&3D representation courses with 39 percent, followed by BIM courses that take 31percent of the curriculum. Digital fabrication and simulation courses take only 13 percent, as digital fabrication ones take place in Alexandria University, the American University in Cairo and the German University in Cairo (Fig. 1), while Alexandria University's architecture department is the only department that put simulation courses in their curriculum. Parametric design courses are placed in four percent of the national curriculum as it is taught only at the German University. Finally programming, coding and scripting courses among parametric design, environmental technologies and communication courses are not included in the national curriculum.

On the international level, it is noticed that parametric design and digital fabrication courses are needed in the final year(s) (aside to the 2D&3D representation) more than in sophomore or preparatory years unlike the simulation and building technologies which take place in sophomore years as the matrix shows (Fig. 1). But 2D&3D representation is found in the three phases, mainly in the preparatory year (Fig. 5).

While on the national level, the departments follow the international schools in focusing on preparatory and sophomore year with 2D&3D representation courses as well. But unlike international schools, they lack the presence of computer applications in the final year (Fig. 6).

5.2. Study 2: Practice

The survey of computer applications usage in architectural profession invigorated esteemed interest and the response

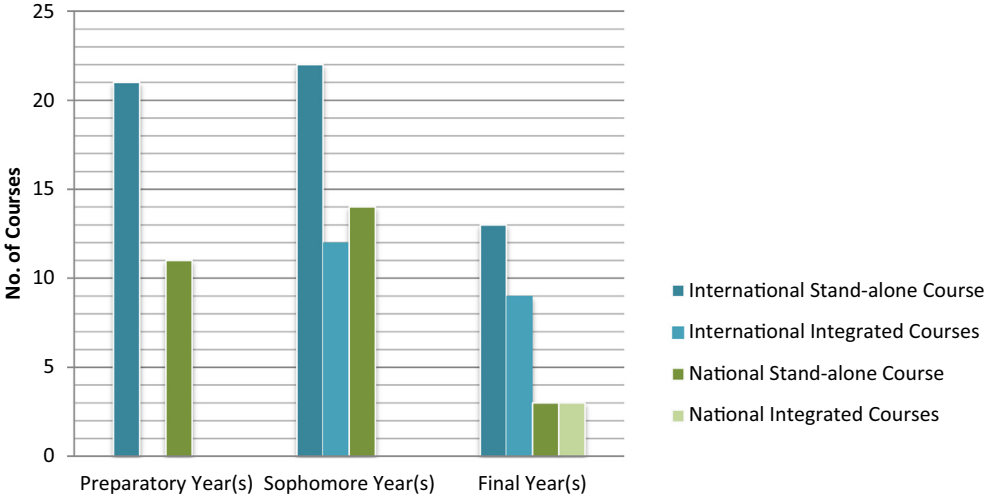

Fig. 2 Computer courses in study years, by researcher.

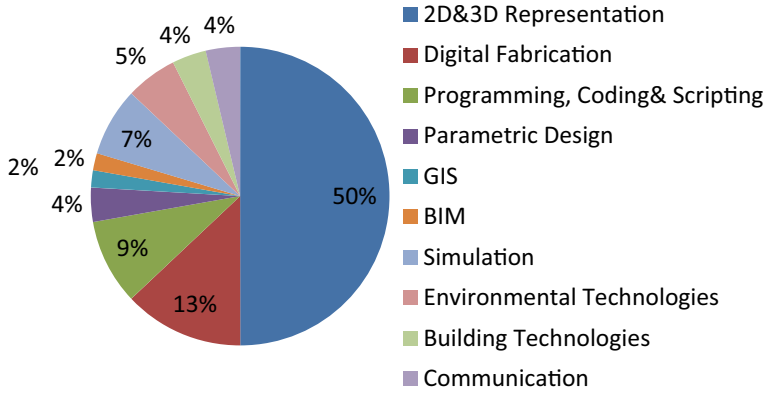

Fig. 3 Computer application disciplines in the international level, by researcher.

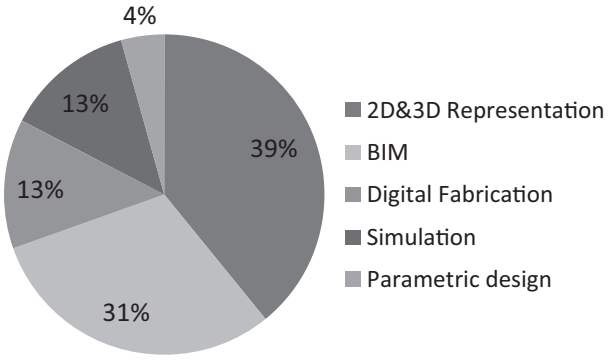

Fig. 4 Computer applications disciplines on the national level, by researcher.

was much greater than the authors had originally anticipated. A genuine interest in computer applications and architectural profession was noted amongst all respondents.

From the online questionnaires, sixty-five (65) positive responses were received. The answers were analyzed to find out the following:

- Architectural Profession Fields

The respondents were asked to identify their work field; it is found that about 71 percent of responses are for architects who work in the interior and exterior design field. While 35 percent work on execution drawing. Followed by, 18 percent of the responses are working in the urban planning field. Then site supervision as well as academic field has only 17 percent of the responses (Fig. 7).

- Computer Applications (software) in Architectural Profession Fields

The analyses carries out that (Fig. 8), on the top, 97 percent of the respondents are working with the Autodesk AutoCAD software, as well as 92 percent are working with Adope Photo-

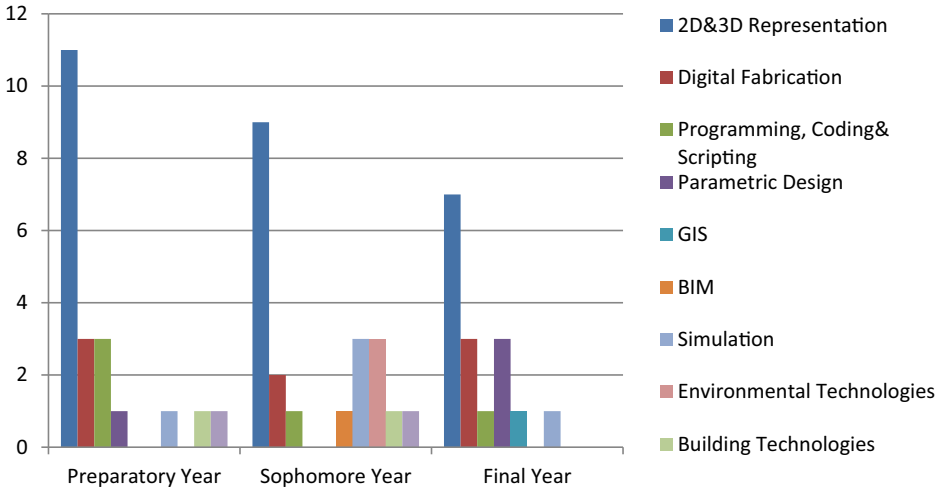

Fig. 5 International computer applications courses in study years, by researcher.

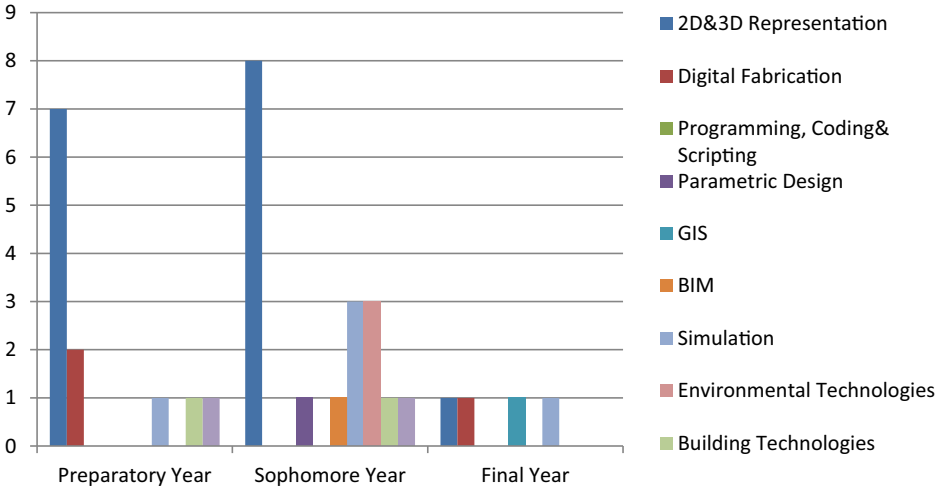

Fig. 6 National computer applications courses by year, by researcher.

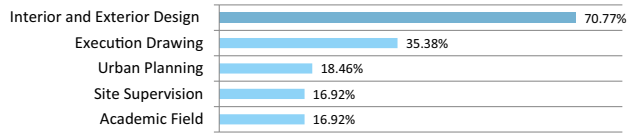

Fig. 7 Respondents' architectural profession fields, by researcher.

shop. Followed by, 74 percent are using Autodesk 3Ds MAX and 63 percent are using Microsoft Office. While Sketch-up is used by 46 percent, Autodesk REVIT by 40 percent, Lumion by 22 percent and GIS by 12 percent of the respondents. Adope Illustrator as well as Rhinoceros is used by about five percent and Grasshopper by three percent of the respondents. Finally, about two percent of the respondents are working with Indesign, Blender 3D, Coral Draw and Design Builder. And none of the respondents is using any Processing software.

- The Most Used Computer Application (Software)

The respondents were asked to identify the most computer application used in their profession field (Fig. 9); it is found the Autodesk AutoCAD software is most computer application used by respondents as, 50 percent of them considered it the most used software. While only 22 percent considered Autodesk3Ds MAX, followed by, Adope Photoshop, Autodesk REVIT and Microsoft Office. And the end, the least used software are Sketch up, GIS and Indesign by 1.5 percent of the respondents.

- Architectural Phase

It is found that in the phase of Design Development, 75 percent of the respondents are using computer applications. While 46 percent use it in the Schematic Design, 43 percent use it in the Conceptual design and 40 percent in the Execution and Fabrication. Then about 28 percent of the respondents use computer applications for preparing the construction documents. In the end, the least respondents use computer applications in Construction Administrations as well as for Academic Research (Fig. 10).

- Undergraduate Computer Applications Courses

The respondents were asked to identify the computer applications studied within their undergraduate courses, the analysis finds that, 95 percent studied Autodesk AutoCAD, 88 percent studied Adope Photoshop and 69 percent studied Autodesk 3D studio MAX. While 46 percent studied Autodesk

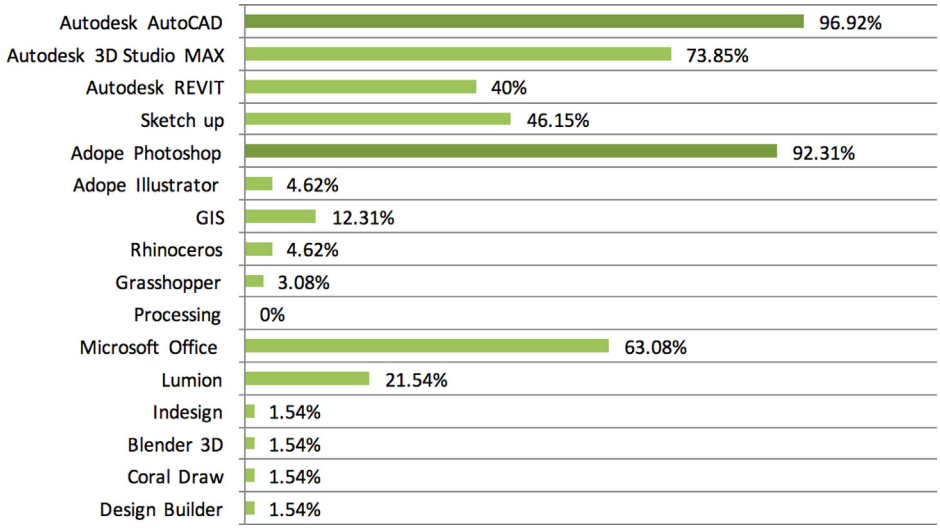

Fig. 8 Computer applications used by respondents, by researcher.

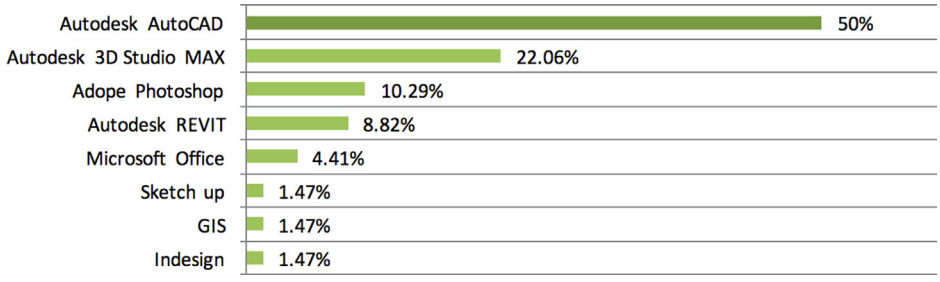

Fig. 9 The most used computer application (software), by researcher.

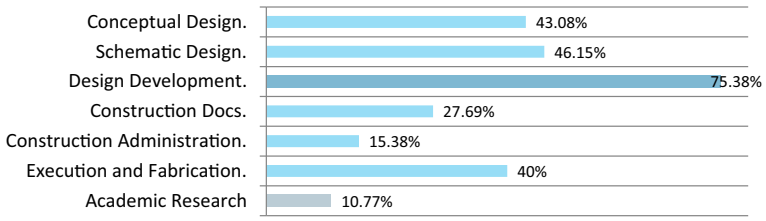

Fig. 10 Architectural phase responses rate, by researcher.

REVIT, 32 percent studied Sketch up and 14 percent studied Microsoft Office.

GIS was studied by about 8 percent of the respondents. And Finally 3 percent studied Grasshopper as well as Ecotect and only 1.5 percent studied Lumion and Rhinoceros (Fig. 11).

- Targeted Computer Applications

The respondents were asked about the computer applications they are willing to learn/improve. 31 percent of the respondents are willing to learn/improve Autodesk REVIT. Autodesk 3Ds MAX is targeted by 25 percent of the respondents. It is found that, 12 percent of the respondents are interested in learning Grasshopper. About 9 percent of the respondents are willing to learn Lumion, as well as, Adope Photoshop and 7 percent for GIS. Only 3 percent are interested in Rhinoceros and Sketch up (Fig. 12).

- Purpose for Computer Application Improvement

The Analysis finds that (Fig. 13), 81 percent of the respondents want to learn computer applications in order to improve their profession field. However, only 16 percent are willing to learn computer application out of their interest not for profession. 1.5 percent of respondents intend to learn computer applications to help them as they are struggling with another computer application. Researching purpose as well is targeting 1.5 percent of the respondents.

6. Recommendations

It could be helpful to develop a global structure for computer applications' education to be a guide for architectural schools in teaching this tool especially for architectural schools in developing countries.

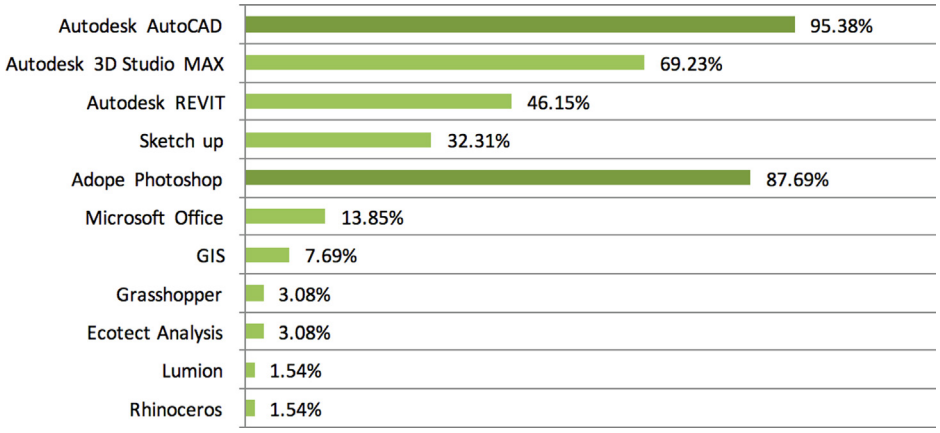

Fig. 11 Undergraduate computer applications courses, by researcher.

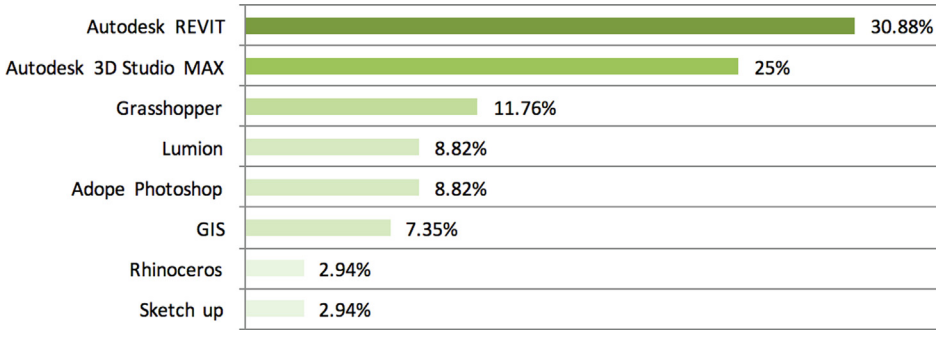

Fig. 12 Targeted computer applications, by researcher.

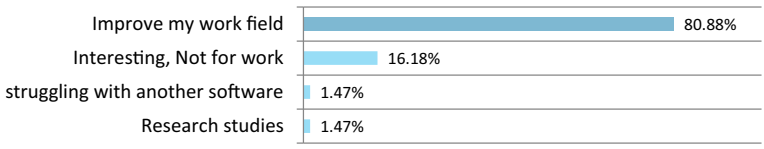

Fig. 13 Purpose of computer application improvement, by researcher.

In order to bridge the gap in national architectural education, the researcher recommends the following considerations:

- The national departments should consider developing their curriculum, as it depends mainly on stand-alone courses, while this is not found in the top international schools.
- Although Autodesk REVIT and Autodesk 3Ds MAX are being mostly used in the national architectural profession, but still shows an interest by architect to be more learned. Other specialized computer application disciplines should be considered in the national curriculum, As International schools started introducing those technologies like parametric design, digital fabrication and scripting while there is no presence for those disciplines in the national level. While algorithmic applications like Grasshopper are started recently to attract national architects. So it is recommended to introduce applications like Grasshopper into the curriculum.
- The 2D&3D representation computer applications discipline is the most integrated application both in national and international level. As well, Architects admit that the national undergraduate curriculum is focusing on 2Dand 3D representation applications as Autodesk AutoCAD, Photoshop and Sketch up as well as Autodesk 3Ds MAX in addition to Autodesk REVIT. Hence, it is better to be taught in the preparatory year and it can get more advanced in the next years as noticed in MIT, Manchester University among other top architectural schools.
- The various national architectural profession fields are mainly using 4 computer applications; Autodesk AutoCAD, Adobe Photoshop, Autodesk 3Ds MAX and Autodesk REVIT. Thus, these applications should be considered in the architectural curriculum.
- Computer applications like Lumion, Rhinoceros and Grasshopper, are recommended to be introduced to the architectural curriculum, as well as Indesign, Blender 3D, Coral Draw and Design Builder, as they have a presence in the architectural profession.
- Computer applications are recommended to be used in the design development rather than the conceptual design and the schematic design as the architects finds it more useful in that phase according to their architectural profession.
- As computer applications are particularly integrated in the execution and fabrication phase, the computer applications used in those fields is recommended to be more integrated in the curriculum and preferably as integrated courses within the design studio to be implemented with the design problem.

7. Conclusion

Professional practice of architecture requires considerable training in the use of CAAD techniques. There is a need to explore ways of improving the use of CAAD among undergraduate students.

It is useful to evaluate and reevaluate the education process to ensure that it goes in a parallel way with the practice field and to be informed of up to date computer applications.

It is important to share experience and latest concepts in digital implementations and integrating of computer applications in architectural education. As The main reason for developing the computer applications' practice is improving their profession field, so architects prefer to learn new computer applications in order to have an advanced work rather than being interested in new trends.

It can be more efficient if computer applications are integrated in all the phases among different discipline; as noticed in the international level unlike the national curriculum that focus on the preparatory phase.

And finally the study indicates the further need for more research into how to increase students' interaction with CAAD.

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