Assessing The Impact Of Caad Design Tool On Architectural Design Education

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ABSTRACT

The current concept of architectural design education in most schools of architecture in Jordan is a blend between manual and digital approaches. However, the disconnection between these two methods has resulted in the students' failure to transfer skills learnt through traditional methods to the digital method of CAAD. The objective of this study is twofold: to first compare students' attitudes toward using both methods and to then assess the impact of CAAD use on the quality of architectural design final product. An open-ended questionnaire was designed to measure variables related to students' preferences toward CAAD and traditional methods. The quality of sixty graduation projects at three Jordanian universities was investigated. The results appear to support the assumption that CAAD tools are used largely as visual means and thereby cause a marked decline in design quality. These findings call for a reconsideration of the status quo and a rethinking of perhaps the entire architectural educational model.

Keywords: *CAAD; architectural design education; design methodology; Jordan*

INTRODUCTION

In the last few decades, revolutionary developments in the field of Information and Communication Technology (ICT) have significantly impacted everyday life. The internet, advanced illustration tools and) software are obvious examples of this digital revolution that has affected the very process of teaching architectural design. Thus, the development of such digital tools over a relatively short time and their continuous advancement and refinement had, and continues to have, an inevitable major impact on many key pedagogical aspects of architectural education and curricula design.

Although CAAD was introduced into most, if not all, the architectural design departments in the Jordanian universities, but students are not allowed to use it unless they finish their first two years of the architectural education program as they must, due to their curriculum, to learn the basic hand sketching and other hand communication skills in order to apply it in their designs.

However, in the third to the fifth years they are encouraged to us both methods in design, that are the traditional and the CAAD. Although this transition is not clearly addressed, thus students are left unable to implement this blend of methods when needed. Moreover, some students are not able to employ CAAD tools in design different processes, for example, they cannot use CAAD to better understand their projects' different components and systems, for example the structure, electro-mechanical, heating, ventilation, and air conditioning, etc. CAAD tools and software are not taught as design or analysing tools or programs, thus students are not able to analyse the environmental aspects of the site. As a consequence, students are not able to implement their learned skills in CAAD to their design projects in practical manner to deliver integrated designs.

The purpose of this research is to study number of architectural design projects for students in the last year, the fifth year, to explore and examine the role of CAAD in the design process from conceptual phases to final product as it is the case in different departments of architecture in Jordan.

This paper presents a framework to assess the impact of CAAD on the architectural design process and the quality of its product. This framework focuses on a group of indicators that were investigated: architectural program; site analysis; conceptual design development; buildability; and design presentation. This assessment may reveal certain indicators that can help educators and practitioners to understand the impact of this rapid and radical transition on the architectural design process and thus help to redirect the future of architectural education into a more adaptive and qualitative.

Definition of the Problem

The current concept of architectural design education is a blend of the traditional method of drafting on paper and the modern method of using CAAD in the design process. This paper argues that the transition to the new digital media has been vague and largely ill-defined, which causes several serious pedagogical problems. The introduction of these new tools into design teaching has been combined with a dysfunctional relationship between the tools and the intended end tasks (Yehuda, 2008). Consequently, this dysfunction has resulted in a separation between architectural design and the context of the project, specifically its sense of scale and proportion, and has led to a marked decline in the spatial quality experience and a disproportionate dependence on illustrative techniques. The inappropriate use of the digital tools and the heavy reliance on them, the lack of integration among different digital tools and, more importantly, the absence of effective coordination between theoretical courses and design projects has resulted in a relatively poorer overall architectural design product.

Aims of the Study

The aim of this study is twofold. First, this study quantitatively explores students' preferences and attitudes toward the use of CAAD tools. Second, this study assesses the potential impact of these digital tools on the quality and creativity of architectural design final product by examining design projects. The main objectives of this paper can be summarized as follows.

- What motivates the student to use CAAD software in the design process?
- What is the importance of the role of CAAD in an architectural curriculum?
- What impacts do CAAD tools have on the overall quality of architectural design in all of its stages (conceptual, design development, presentation)?

The overall aim of the study is to examine the impact of caad design tool on Architectural design education.

Theoretical Framework

Architectural Design

Architectural design is a complex process of creating a coherent structure or system that comprises many unified elements. During the last few years, many theoreticians and practitioners have attempted to define the word "design". Archer (1964) defined it as: "A goal-directed problem-solving activity". Others defined it as "a creative activity that involves bringing into being something new and useful that which display new physical order, organization, form, in response to function" (Alexander, 1961). However, the authors prefer the broader definition of Suh, (1989), which we believe captures essential aspects of architectural design while also accommodating other kinds of designing too. Namely: "... the creation of a synthesized solution in the form of products, processes or systems that satisfy perceived needs through mapping between the functional requirements (FRs) in the functional domain and the design parameters (DPs) of the

physical domain, through proper selection of the DPs that satisfy the FRs."

During the last two decades, architecture has been influenced by the increasing use of digital technology—both in the process and in the final outcome of design—to meet certain functional, cultural, aesthetic, environmental, and socio-economic needs. Thus, digital technology became the mediating factor between design theory and architectural theory. Accordingly, architectural design has become engaged in the exploration of complicated forms that depend heavily on the use of sophisticated "generative" computational programs. This transformation has begun to show a significant influence on architectural design theory, concepts and approaches (Zellner, 1999). Much of the earlier basis for design methodology, such as the study of typological precedents and contextual setting, has now been replaced by emerging digital tools, such as generative modeling, animation and performance-based indicators (Zellner, 1999).

Architectural Education

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 (Breen, 2004).

ICTs 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 (2002) suggested that digital technologies have been used in architectural schools to challenge the modernizing view of architectural practice (Andia, 2002; Schenk, 2005).

Andia indicated that ICT 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. ICT 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 (i.e.,Ataman and Lonnman, 1996; Bermudez and King, 2000; Ataman, 2000; Al-Qawasmi, 2004, 2005; Schenk, 2005). Students have increasing tendencies toward ICT 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 (Al-Qwasmi, 2005).

In contrast, Achten (2003) 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 (2015), the disadvantage of using CAAD tools is to make the students addicted and design their projects without creativity. Salman et al. anticipated that the use of CAAD tools by students came as early as the conceptual stage in the investigation of specific formal themes (Achten, 2003). 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 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 (Al-Qwasmi, 2005).

The State Of Cad Education In Architecture Schools In Jordan

CAAD has been used in Jordan since the mid-1990s. Several engineering firms and contracting

companies were interested in the potential of digital technologies as drafting and modeling tools. As an educational tool, CAAD software was installed as an introductory course for undergraduate architectural programs in 1994, but there were only a few faculty members who could teach it then. Several years later, CAAD courses became obligatory (i.e., CAAD I, CAAD II) over two semesters, typically for second-year students (Abu Ghanima, 2006). Moreover, most schools of architecture in Jordan attempted to update their curricula through software and digital technologies to bridge the gaps between design theory and practice. Since 2014, however, some schools have begun to re-think the use of digital software as an analytical, generative and constructive tool. Consequently, software such as "Revit" and "Introduction to BIM" were installed in their curricula.

Generally, schools of architecture in Jordan combine the physical method with the digital method to ensure that students enjoy the benefits of both methods. Thus, most, if not all, schools of architecture prohibit the use of CAAD tools in design for students in their first two years. Design teaching for first- and second-year studios emphasize on the importance of developing manual graphic communication skills, sketching, and the experience of making physical models. However, the current curriculum of architectural design education in most schools suffers from a lack of synchronization and integration between computer courses and design projects. The prevalent tendency at present is to treat each course as a separate entity with its own distinct particularity, which prevents the necessary coordination between theoretical and design courses and applied computer courses. Moreover, although the structure of the curricula remains relatively flexible to manage new digital technologies, integrating these technologies with design courses is highly advisable and will ensure a more holistic and creative environment and not to use this software only as drafting tools.

RESEARCH METHODOLOGY

The present study focuses on studying the impact of the CAAD use on architectural design projects in schools of architecture in the Jordanian Universities. Three universities in Jordan, namely, Al-Ahliyya Amman, Petra, and Philadelphia, were selected as the study cases. The following figure illustrates the CAAD use assessment Approach Framework that is used throughout this research.

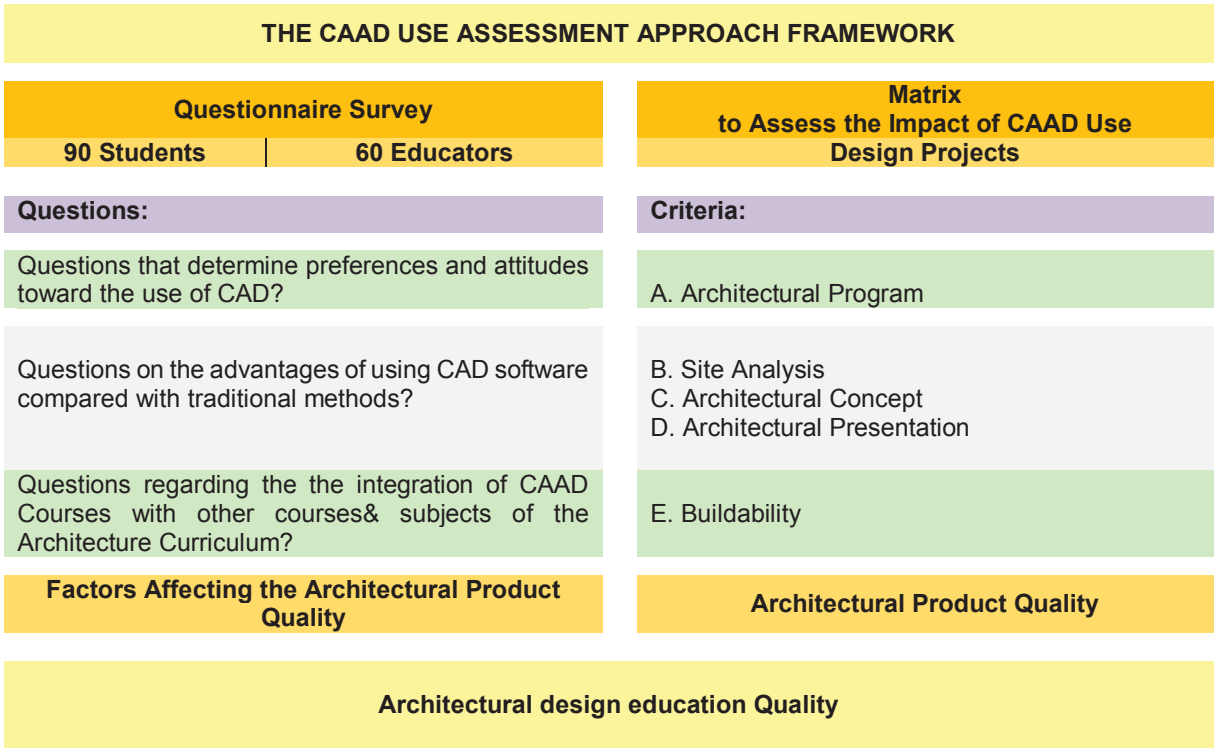


Figure 1. The Caad Use Assessment Approach Framework

This study was completed in two distinct stages. This study used a case-study approach to assemble the main data through the following:

1. **Interviews and Questionnaire Surveys**

(a) Qualitative in-depth interviews: The data used for evaluation were based on qualitative in-depth interviews that were conducted with a sample that comprised the following:
- 90 fifth-year architecture students, who have acquired and developed various design skills and practices and whose studio work incorporates traditional and new architectural design methods; and
- 60 educators from three universities in Jordan.

(b) A paper-based questionnaire survey: an extensive survey questionnaire was completed by the 90 fifth-year students and 60 educators in the study area.

The conducted interviews and questionnaire involved open ended-questions based on collected qualitative data from the students, such as students' preferences and attitudes toward the use of CAAD, the types of CAAD software used by students, CAAD learning methodology, proficiency level in CAAD, the frequency of using CAAD in different design phases, and the advantages of using CAAD software (table 1.).

Table 1. Questionnaire to measure variables related to students' preferences toward CAAD and traditional methods

Main questions		Sub-questions
Part one:	Questions that determine preferences and attitudes toward the use of CAD?	Q1. Attitudes toward the importance of CAAD compared with traditional methods
		Very Positive
		Positive
		Neutral
		Negative
		Very Negative
		Q.2 Superiority of using CAAD over the traditional method of sketching
		CAAD
		Traditional
		Both
		Others
		Q3. Type(s) of CAAD software used by students?
		AUTOCAD
		REVIT
		3D-MAX
		PHOTOSHOP
		GRASSHOPPER
		Q4. CAAD learning methodology?
		Self-learning
		Departmental courses
		Private classes
		Departmental courses + Self-
		Self-learning + Private classes
		Q.5 Frequency of using CAAD in different design phases?
		Conceptual
		Schematic design
		Design development
		Construction drawings

		Detailing & specifications
		Q6. Proficiency level in CAAD?
		Very High
		High
		Average
		low
		Very low
Part two:	Q.7 Questions on the advantages of using CAAD software compared with traditional methods?	accuracy
		neatness
		speed
		Save money
		Help to visualize end product
Part three:	Q.8 Questions regarding the the integration of CAAD Courses with other courses& subjects of the Architecture Curriculum?	structural
		Environmental
		Electrical
		Mechanical
		Heating, ventilation, and air conditioning

Note: The survey was prepared and conducted from January to June 2016.

The questionnaire comprised a number of questions with 5 different scores for each answer. The students evaluated each of the standardized answers on a 5-step scale from very high to very low (each of them had an assigned numeric value to calculate the sum for each answer). To compare the answers, each sum was divided by the number of times that a specific answer was chosen.

2. **A well-structured matrix** to assess the impact of CAAD use on the design projects: Sixty graduation projects in the study area were examined through the matrix that has five suggested indicators (i.e., architectural program, site analysis, concept, presentation, and buildability) to assess the architectural product quality (Table 3). The gathered data of graduation projects was important in providing evidence of the benefits that the respondents mentioned in the questionnaire survey and interview.

Assessment Criteria

Five essential criteria were chosen to assess the quality of the graduation projects with differing score weights that totalled 100. These criteria were architectural program (15 points), site analysis (15 points), architectural concept (30 points), presentation and illustration (25 points), and buildability (15 points). The criteria are basically self-explanatory, but the architectural concept criterion needs some elaboration. Section A-Table 3 shows that architectural program was subdivided into 3 main considerations: First (1), projects' adoption to interrelated values, goals, facts, and needs of users and the surrounding community. A well-conceived program leads to a high quality design, (2) projects' adherence to the functional relationships of the main components of the projects. Finally, (3) the projects' adherence to standards and binding codes and regulations.

Regarding the site assessment, and as shown in section B-table 3, projects were examined according to their responsiveness to their: (1) direct urban context, (2) environmental context, i.e., climate, topography, etc.; (3) plot's shape, area and location, and finally Appropriateness of the use of CAAD to develop the overall site design.

Section C -Table 2 shows that architectural concept was subdivided into 6 main considerations. First (1), a philosophical and intellectual basis is adopted to explain the concept and conceptual development and shows how students arrived at their final solution and whether any design reference or precedent was

adopted. Second (2), aesthetic and creative considerations refer to the overall formal, spatial and sculptural aspects of the project, including proposed materials, colors, patterns and textures. Third (3), regional and cultural factors refer to how the student responded to the sense of place and whether cultural influences such as local and/or regional architectural heritage had any role in the overall design or architectural trend that was adopted. Fourth (4), environmental considerations include the student's response to the question of sustainability, energy consumption, climatic factors, such as orientation and solar shading devices, etc. Fifth (5), the appropriateness of the adopted trend refers to what degree the design approach has succeeded in being relevant and workable with the overall function of the project. The final Sixth (6) consideration is the degree of use of the CAAD tools, including generative design software, to develop the final solution.

Architectural Presentation in section D was subdivided into 5 main considerations revolved around quality and quantity of visualization. Finally, the Buildability was assessed by measuring the role that CAAD software and courses played into delivering integrated designs, through using structural design software to provide technical details.

Table 2: Matrix of main criteria assessed for the impact of CAAD on the quality of architectural design product. (scores 1 poor to 5 high)

A. Architectural Program [15 points]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
1. Analysis of the needs, values and main goals of the client, tentative cost analysis of the proposed project and its feasibility					
2. Provision of detailed inventories, required facilities, functional relationships of main components of the project.					
3. Compliance with local and/or international space standards and binding codes and regulations					
Total A					
B. Site Analysis [15 points]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
1. Response to urban context, surroundings and accessibility					
2. Site layout, topography and overall landscape design					
3. Appropriateness of plot's shape, area and location					
4. Use of CAAD to develop the overall site design					
Total B					
C. Architectural Concept [30 points]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
1. Philosophical and intellectual basis adopted to explain the architectural concept to client					
2. Quality of conceptual development and evolution of main design theme					
3. Aesthetic and artistic considerations					
4. Regional/cultural/environmental considerations					
5. Appropriateness of adopted design approach to overall function and context					
6. Appropriate use of digital software in generating design?					
Total C					
D. Architectural Presentation [25 points]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
1. Overall poster design theme and clarity					

2. Compliance to 2D minimum submission requirements (plans, elevations, sections, site plan, etc.)					
3. Compliance to 3D requirements (3D perspectives (exterior & interior), details, etc.)					
4. Physical modeling: Compliance to submit several study models showing design development at different stages					
5. Appropriate use of digital software?					
Total D					
E. Buildability [15 points]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
1. Use of appropriate structural system(s)					
2. Submission of technical services & details					
3. Appropriate use of digital software?					
Total E					
Total Score					

Findings from the Analysis

Part one, Question 1: Attitudes toward the importance of CAAD compared with traditional methods?

Figure 2 shows that the majority of respondents (85%) described their attitudes positively toward the importance of CAAD compared with traditional methods. However, 5% of the respondents were indifferent, and 10% had negative attitudes regarding the use of CAAD.

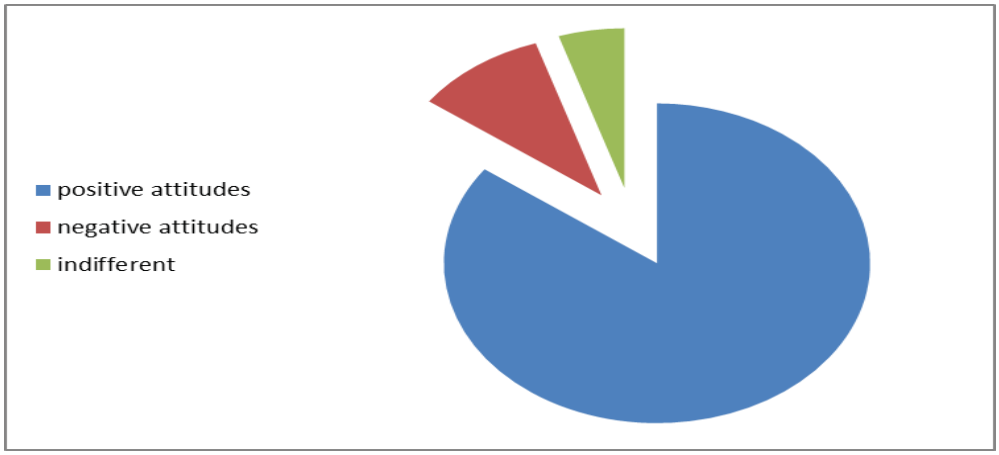


Figure 2. . Attitudes toward Using CAAD among architecture students

Question 2: On the superiority of using CAAD over the traditional method of sketching, 80% of the students preferred to use CAAD media over traditional methods, whereas traditional-method users accounted for only 5% of the total (Figure 3). A great interest in CAAD was noted among all respondents. There seems to be a strong trend for architectural students to convert from traditional methods to CAAD. The dramatic increase of CAAD users suggests that there should be a serious reconsideration of the current curriculum to adapt to the new CAAD trends.

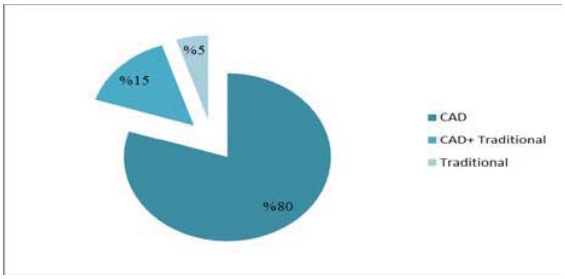


Figure 3. Superiorty of CAAD over traditional method

Question 3: Type of CAD software used by students: The respondents were asked to identify the type of CAAD software used in their graduation design project. Among the 60 respondents, 52 used AutoCAD, 3D-MAX and Photoshop, which are the most widely used software in education. However, the results revealed that the highest response rate was reported in Revit (7%), followed by Google Sketch-up (4.5%), ArchiCAD (4.5%), Grasshopper (2.1%), Maya (1.1%), and Vasari (1%) (Figure 4). None of the respondents used Heliotrope. Nevertheless, students employ various CAAD software to produce the best graphical representations with minimum cost, maximum functionality, and the highest quality.

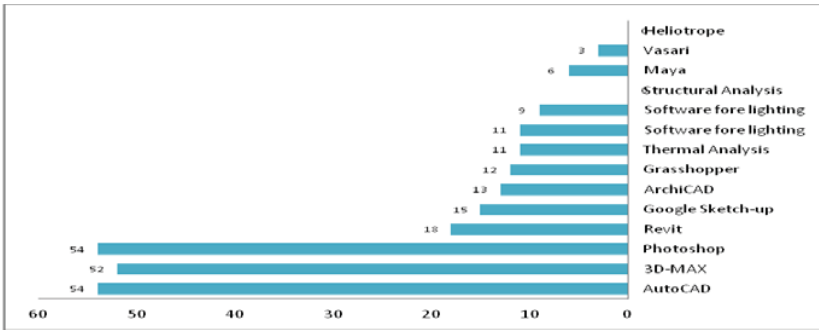


Figure 4. Type of CAAD Software Used among architectural Students

Question 4: CAAD learning methodology by students: The respondents were asked to describe how they gained CAAD proficiency based on the parameters of departmental courses, self-learning, and private classes. As shown in Figure 5, 30% of the respondents stated that they gained proficiency in CAAD by self-learning first, and 25% gained their CAAD proficiency through departmental courses. This result confirms the finding when students were asked about their preferences toward CAAD. As shown in Figure 5, the majority (85%) of the respondents had positive attitudes concerning the use of CAAD, which explains the percentage of the respondents who were interested (55%) in learning CAAD either by themselves or in the department. The least number of respondents (15%) learned CAAD through private classes.

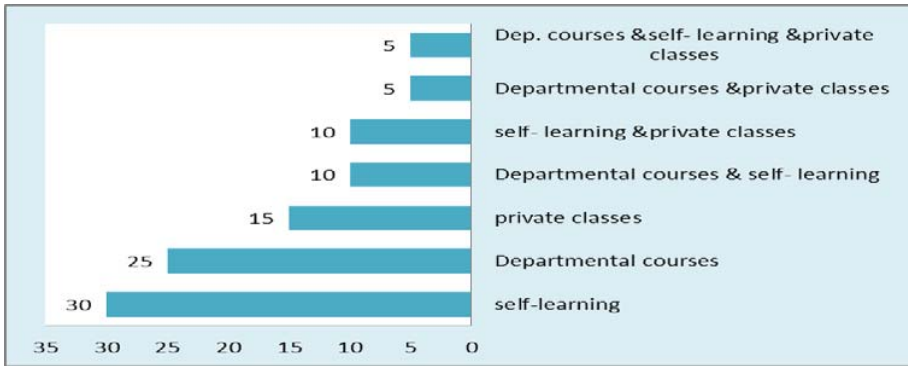


Figure 5. CAAD learning methodology among architectural students

Question 5: The students were asked to specify the design method that was used in each stage/stages of the design process. Interestingly, both design methods were employed in all design stages. However, Figure 6 shows that traditional methods were used the most (80%) at the initial or conceptual stage and were utilized much less in the schematic design stage (30%). CAAD was used mostly in the phases such as in: design development, construction drawing, and the detailing and specification phases at 55%, 80% and 90%, respectively. Few respondents may use CAAD in the conceptual stage because CAAD has not replaced the traditional method of manually sketching designs. Instead, CAAD acts as an extension of manual methods with a vast potential to advance various design that previously were impossible to develop with traditional methods.

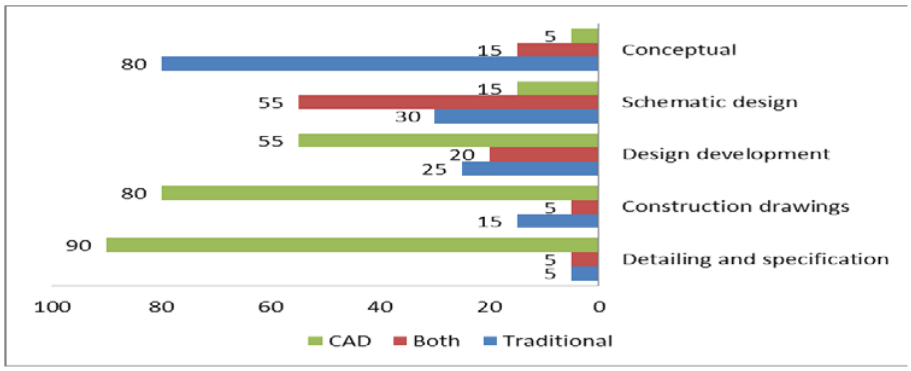


Figure 6. Design method used in each stage

Question 6: The students were asked to evaluate their proficiency level with CAAD applications. Figure 7 indicates that 90% of the respondents had high proficiency in AutoCAD, 85% had high proficiency in Photoshop, and 70% had moderate proficiency in 3-D MAX. In total, 40% and 35% of the respondents reported proficiency in Revit and Sketch-up, respectively. Moreover, 10% of the respondents used ArchiCAD, and 10% used Grasshopper. In contrast, regarding the use and performance of CAD environmental software, the results revealed that a very low response rate was reported for Heliotrope (0%), Vasari (1%) and software for lighting (3%) (Figure 7). This result can be explained by the lack of competent tutors in different CAAD areas.

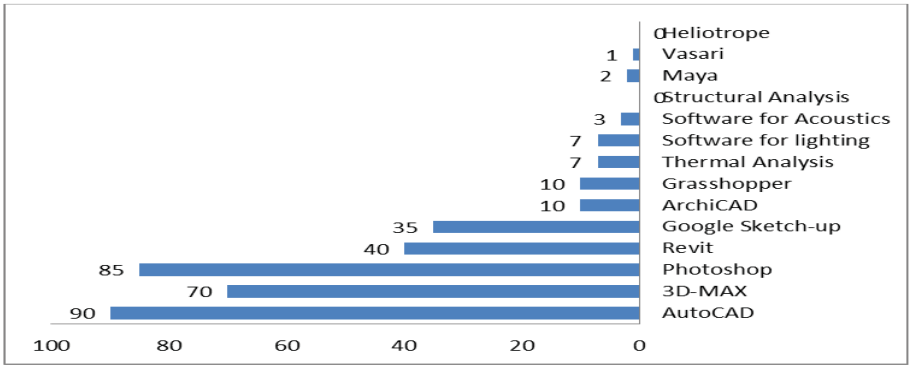


Figure 7. CAAD applications proficiency levels

Part Two: Questions about the Advantages of Using CAAD Software

As shown in Figure 8, 90% of the respondents preferred to use CAAD for its various advantages, such as accuracy, neatness, speed and lower cost. Interestingly, 70-90% of the students stated that using the combination of CAAD with traditional methods typically helps them to visualize the end product better than using the CAAD method alone.

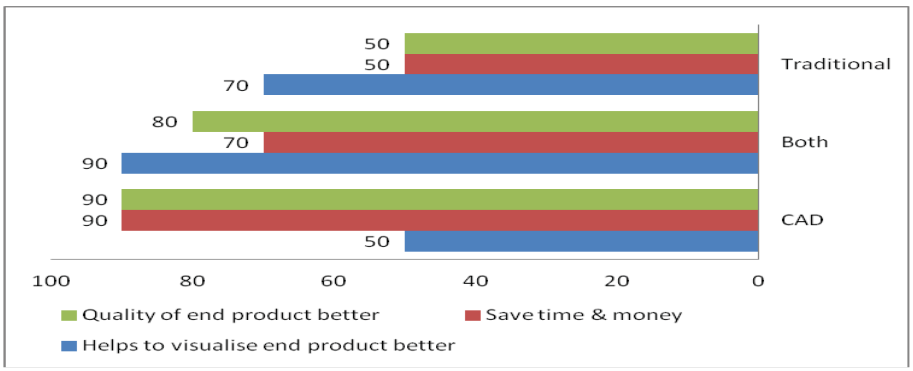


Figure 8. Advantages of using CAAD software, traditional methods and combined methods

Moreover, majority of the respondents, of 90%, considered the quality of the projects that used CAAD to be higher than the quality of the projects that used traditional methods. However, 5% of the respondents are indifferent, and another 5% considered the design that is generated by CAAD to be of lesser quality than the design that is generated by traditional drafting (Figure 9).

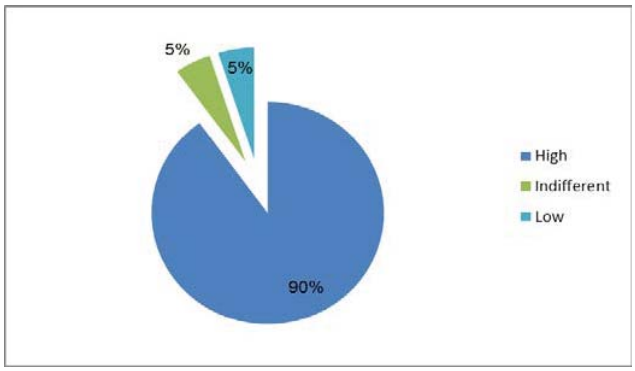


Figure 9. Responses to Questions Pertaining to Quality of Designs Created with CAAD

As shown in Figure 10, respondents indicated that CAAD has an important role in three central areas in the architectural curriculum, namely, design, urban design, and building technology, according to 90%, 85%, and 80% of the respondents, respectively. However, CAAD has a weak role in other areas, such as theoretical courses (45%), engineering systems (35%), and project management (25%).

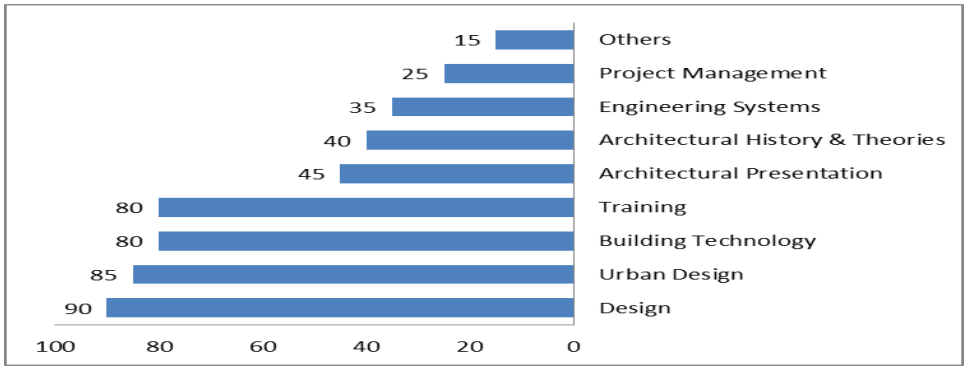


Figure 10. The Role of CAAD Course across the Curriculum of Architecture Schools

Part Three: A. Graduation Project Analyses

Figure 11 shows that about 60% of the graduation projects demonstrated that their designers were

unaware of the projects' needs, values, main goals and tentative cost estimate. It is interesting here to notice that the same ratio of the projects had problems with the functional relationships of the main components of the project. Finally, 55% of the projects' designs did not adhere to local or international standards.

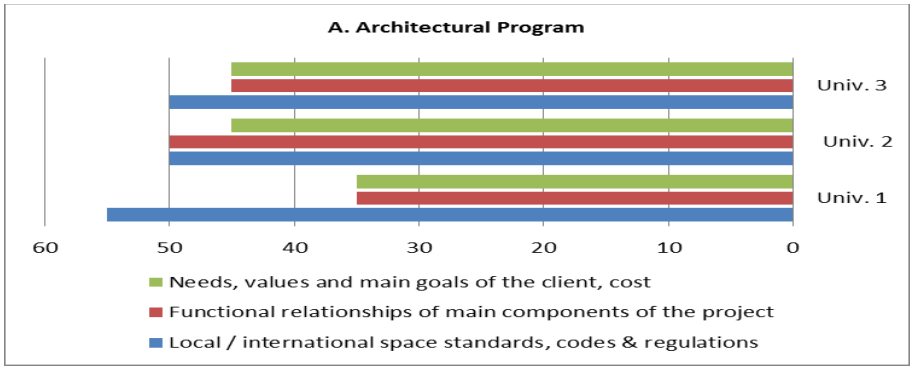


Figure 11. Architectural Program

B. Site Analysis

A very interesting finding here was the low number of projects that employed CAAD or any other digital software in analyzing the site. Figure 12 indicates that only 5% to 15% of the graduation projects had used digital applications in analyzing or planning the site. This result accords with the findings in part 2, question 2, regarding the types of CAAD software. The majority of respondents were having a good command of traditional AutoCAD. Moreover, the absence of specialized software to analyze or plan the site obviously caused the wrong design decisions. About 60% of the examined projects had no or low responses to the urban context, surroundings and accessibility. Finally, 50% of the projects in the study area did not respond to the projects' given land in terms of shape, area and topography.

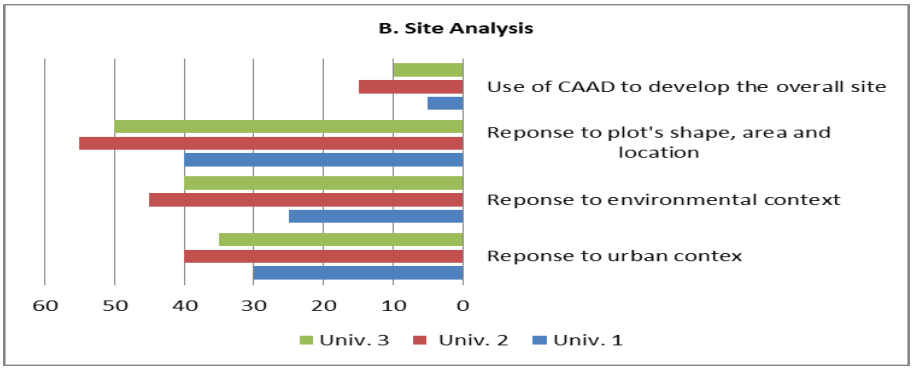


Figure 12. Site Analysis

C. Architectural Concept

As shown in Figure 12, the majority of the students showed a tendency to use CAAD even at the conceptual stage for drafting or site planning. Meanwhile, only 5% to 15% of the projects showed a tendency to use “generative” software to investigate a specific conceptual theme and its formal potential, such as Grasshopper, Maya, and Vasari. The interviews also revealed that because generative design software is not taught at the 3 schools, few students used this software by learning it on their own. Consequently, the projects were largely developed by using CAAD for drafting and illustrative goals and lacked the necessary basis to comply with the required criteria to generate rational and creative designs, with little or no attention paid to regional, cultural and environmental or artistic considerations.

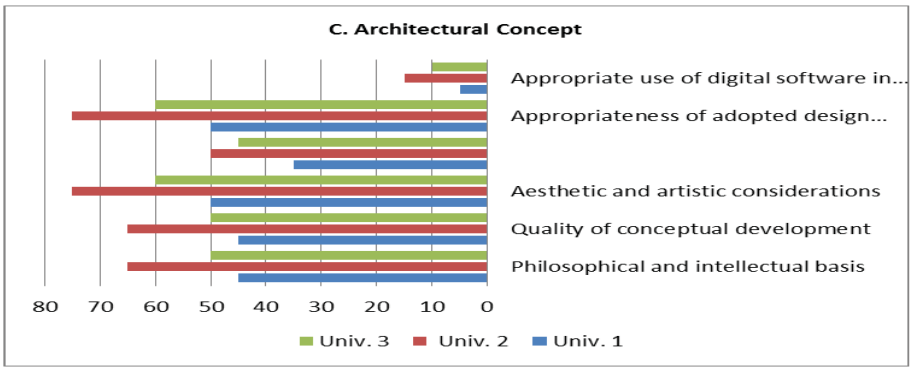


Figure 13. Appropriateness of CAAD use by students

D. Architectural Presentation

As shown in Figure 14, the majority (90%) of the analyzed graduation projects were mainly concentrated on the poster design theme. Regarding "3D presentation", a higher use was reported; 85% reported that they used it in their graduation projects, whereas only 35% responded that they employed the traditional methods of physical modelling in their projects. Furthermore, the 3D presentations were delivered as seductive conceptual images that were incompatible with the 2D drawings and in some cases, with the physical models. This result means that the students are concentrating on images rather than on content, which leads to irrational and unrealistic projects. This result confirms our findings from the questionnaire survey, part 3, where most respondents indicated that CAAD would guarantee a higher quality project. Certainly, there is no integration between CAAD and other courses in the curricula.

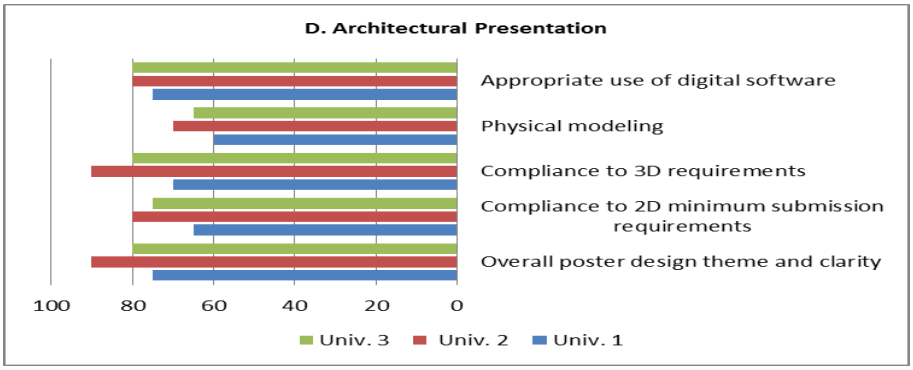


Figure 14. Architectural presentation in a Sample of Architectural Graduation Projects from Three Different Jordanian universities

E. Buildability

The survey revealed that no digital software was used to achieve a certain level of buildability (see Figure 15). The overwhelming majority of graduation projects lacked the necessary information regarding the structural and constructional aspects of the proposed design and with no meaningful impact on the architectural concept.

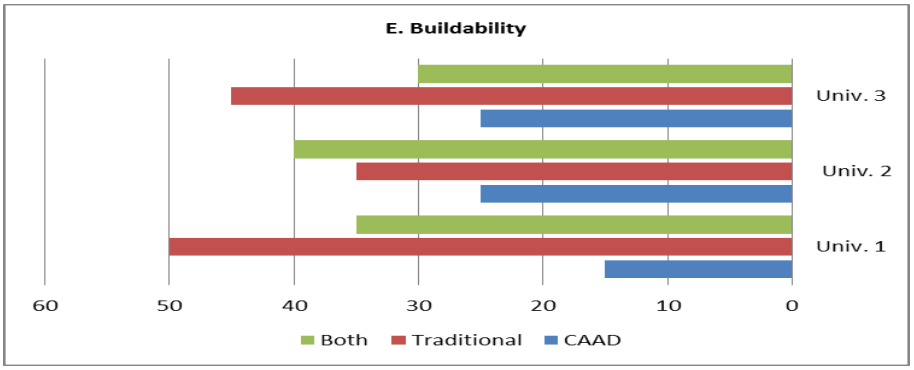


Figure 15. Buildability of projects by method used

As shown in Figure 16, the evaluation of 60 graduation projects from three architectural schools in Jordan according to criteria of program, site analysis, concept, presentation and realization revealed relatively similar results for the three schools. As expected, the architectural presentation criteria consistently scored the highest; ranging from 75% to 61.3%, and the site analysis and concept criteria presented the next highest scores, ranging from 67.7% to 59.1% and from 59% to 55.1% respectively. However, the architectural program and buildability criteria had the lowest scores, in the ranges of 59.7% to 48% and 32% to 30.5% respectively. These disappointing results reinforce the notion that the overall quality of design has declined significantly due to the misuse of digital visual tools.

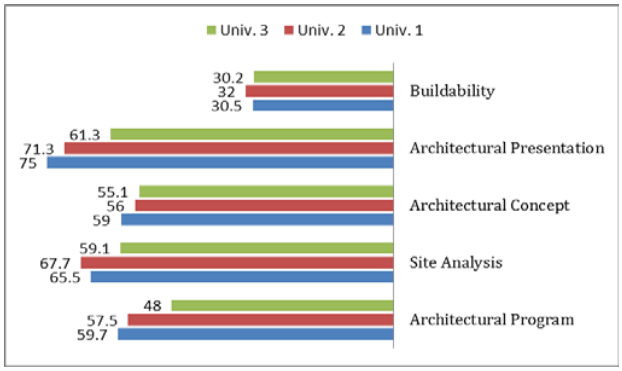


Figure 16. The Impact of Using CAAD Design Tools on Design Projects

DISCUSSION AND CONCLUSIONS

This paper assessed the impact of CAAD tools on the design process and on the quality of the architectural end product at three schools of architecture in Jordan. The findings revealed that all three schools have almost the same architectural design educational approach that mixes traditional design methods with digital methods.

Analyses revealed that although majority of students were found to have a strong tendency to use

CAAD software programmes for its various advantages, such as: accuracy, neatness, speed and lower cost, etc.

Presently, the mode of teaching CAAD in most, if not all, of the architectural departments in Jordan does not encourage the use of CAAD in early phase of the design, just like in the conceptual stage.

The study shows that CAAD tools have not been integrated into the creation processes of the conceptual architectural design and the influence of the CAAD tools in the conceptual design phase is still very minor. Moreover, all interviewees agreed that the creation procedure has not been influenced by the adoption of digital tools (see Figure 17). At the same time, findings from the analyzed design projects showed that the presented projects are seductive graphic more than realistic architecture.

CAAD is still being considered, perceived and utilized as drafting, modelling, and rendering tool rather than as a problem-solving strategy. Simultaneously, this restricts the potential use of CAAD to develop already created designs, but not to use it as a tool to generate new design. Very few analysed projects showed the use of CAAD as medium to create an innovative form in the geometrical formation and conceptual phase. And this can be explained according to:

- A basic curricular split between architectural education and the digital world. This assures Botchway et al. (2015) findings, when he assessed the impact of CAAD Design Tools on Architectural Design Education, as he found out that CAAD is taught in isolation of other design courses in the department.
- Marginal balance between creative and technical courses.
- Split between CAAD courses and other multi- and inter-disciplinary disciplines (e.g., structural, environmental, urban courses, etc.)
- The transformation of students' design trends from traditional methods to CAAD is still not clearly defined. And this affects students' ability to transfer their skills that are learned through traditional methods to the more complicated CAAD method.

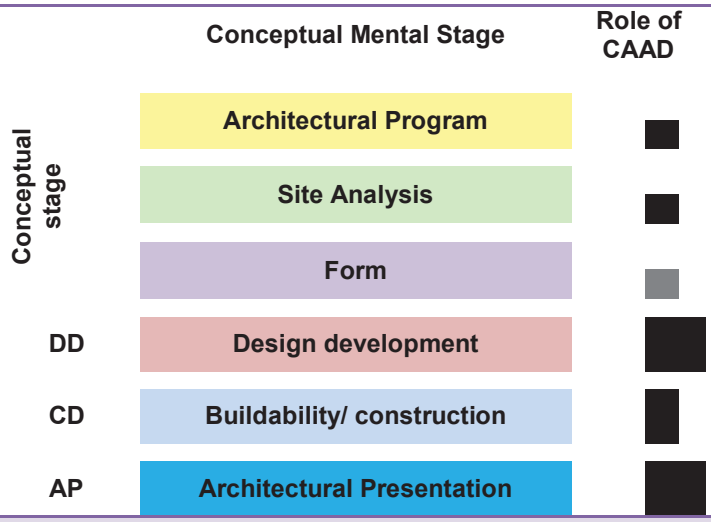


Figure 17. The Role of CAAD Tools in Architectural Design Stages

Therefore, this shift in students' preferences toward CAAD systems has resulted in a dramatic change in the study context together with other various shifts in design media, design thinking and design theory.

Analyses of design projects showed that digital media has become very essential, so that other physical media, such as scale-models and sketches that address better sensible aspects of design, are excluded. 3D CAAD modelling and virtual animation in most of the analysed projects were replacing the physical model. Thus, students' designs were neither realistic nor comprehensive and there were no compatibility between the different set of drawings. Drawings are more seductive artistic and graphic rather than buildable (see Appendix A1, A2, A3). This should be resolved by integrating both: physical and digital tools in design. This integration would increase students' experience of inquiry, discovery and representation (Achten, 2003) and this leads to creativity.

Furthermore, we as educators have the responsibility to teach CAAD courses in creative way, as extension to our creative possibilities. So that, CAAD tools can be used in developing a responsible, responsive and integrated architecture that meets society needs and adhering to the surrounding environment as well.

So far, our case study confirms Schenk (2005) findings in terms of how to integrate CAAD into the drawing curriculum not the opposite. This gives another example of how students' tendency to apply visual media to any other conventional design skills need to be reconsidered (Salman et al, 2006; Breen, 2004; Schenk, 2005).

Finally, CAAD and other digital technologies shall be engaged within the architectural design in early stages so that such tools would be used to provide creative design. Moreover, digital technology should be utilized as an essential part of the new design studio culture that integrates with other design subjects and courses in the architectural education curriculum. Integrating digital technology into architectural design education curricula help to create more responsive designs in terms of: structural, environmental, urban, and other components. Thus, understanding and employing these new technologies in proper ways could afford us with more innovative, responsible, effective, and more integrated designs. Thus, we must reconsider the potential of computers and communication technology to orient the entire institutional infrastructure and pattern of behavior for better architectural education and practice. There is also a crucial need to review the national accreditation criteria for architectural education postgraduates' program curriculum to make them more adaptable to these emerging and ever-changing digital technologies.

REFERENCES

Achten, H. (2003). “New Design Methods for Computer Aided Architectural Design Methodology Teaching,” International Journal of Architectural Computing 1, no. 1.

Alexander, Christopher (1961) "Information and an Organized Process of Design," in National Academy of Sciences, Proceedings of the Building Research Institute (Washington, D.C.: National Academy of Sciences, 1961), 115-24.

Abu Ghanima, Ali et al. (2006). “The Use of Computers in Architectural Research and Practice,” in Proceedings of the 4th FAE International Symposium “Creating the Future” (North Cyprus, Jordan, 2006), 453-458.

Al-Qawasmi, J. (2004). Reflections on e-design: the e- studio experience. 1st ASCAAD International Conference, e-Design in Architecture, KFUPM, Dhahran, Saudi Arabia, pp.177-193. Al-Qawasmi, J. (2005), Digital media in architectural design education: reflections on the estudio pedagog’, Art, Design & Communication in Higher Education 4(3), pp.205– 222.

Andia, A. (2002). "Reconstructing the Effects of Computers on Practice and Education During the Past Three Decades," Journal of Architectural Education 56, no. 2 (2002): 7-13.

Archer L.B. (1964) Systematic Method for Designers, (Council for Industrial Design, London).

Ataman, Osman (2000) Media effect on architectural design, College of Architecture, Georgia Institute of Technology. Retrieved from http://cumincad.scix.net/cgi-bin/works/Show?83c4

Ataman, Osman and Lonnman, Bruce (1996) Introduction to Concept and Form in Architecture: An Experimental Design Studio Using the Digital Media, Design Computation: Collaboration, Reasoning, Pedagogy [ACADIA Conference Proceedings / ISBN 1-880250-05-5] Tucson (Arizona / USA) October 31 - November 2, 1996, pp. 3-9. Tuscan , AZ: ACADIA.

Bermudez, J. and King, K. (2000) Media interaction and design process: establishing a knowledge base, Automation in Construction, 9, pp. 37-56.

Breen, J. (2004). "Changing Roles for (Multi) Media Tools in Design: Assessing Developments and Applications of (Multi)Media Techniques in Design Education, Practice and Research," in the 22nd eCAADe Conference Proceedings (Copenhagen, Denmark: Architecture in the Network Society, September 2004): 530-539

Botchway et al., J Archit Eng Tech (2015). The Impact of Computer Aided Architectural Design Tools on Architectural Design Education. The Case of KNUST.J Archit Eng Tech, 4, 145. (http://dx.doi.org, accessed 2016.12.02)

Guney, D. (2015). "The importance of computer-aided courses in architectural education," Procedia-Social and Behavioral Sciences, 176, 757.

Salman, H., Laing R. and Conniff A. (2006, September 6-9). CAAD Visualization Techniques Mediate the Conceptual Design Process as a Thinking Tool: Reflection on action study, in Communicating Space(s) [24th eCAADe Conference Proceedings / ISBN 0-9541183- 5-9] Volos (Greece) 6-9 September 2006, pp. 700-708.

Salman, H., Laing R. and Conniff A.(2006). THE CHANGING ROLE OF CAAD AT THE ARCHITECTURAL DESIGN STUDIO. (http://www.irbnet.de/daten/iconda/CIB16586.pdf, accessed 2016.12.03)

Schenk, P. (2005), Reflections on the teaching of drawing in the digital age: attitudes of senior academics in the United Kingdom to the place of drawing tuition on the design curriculum in higher education, Art, Design & Communication in Higher Education 4(3), pp. 189–203.

Suh, N.P. (1989) Principles of Design, (Oxford University Press, London).

Yehuda, E. Kalay (2008). The Impact of Information Technology on Architectural Education in the 21st Century. computer-assisted construction technologies, computer-controlled buildings, and InternetFirst International Conference on Critical Digital: What Matter(s)?, (http://papers.cumincad.org, accessed 2016.12.02)

Zellner, P. (1999). Hybrid space: new forms in digital architecture (London: Thames and Hudson).

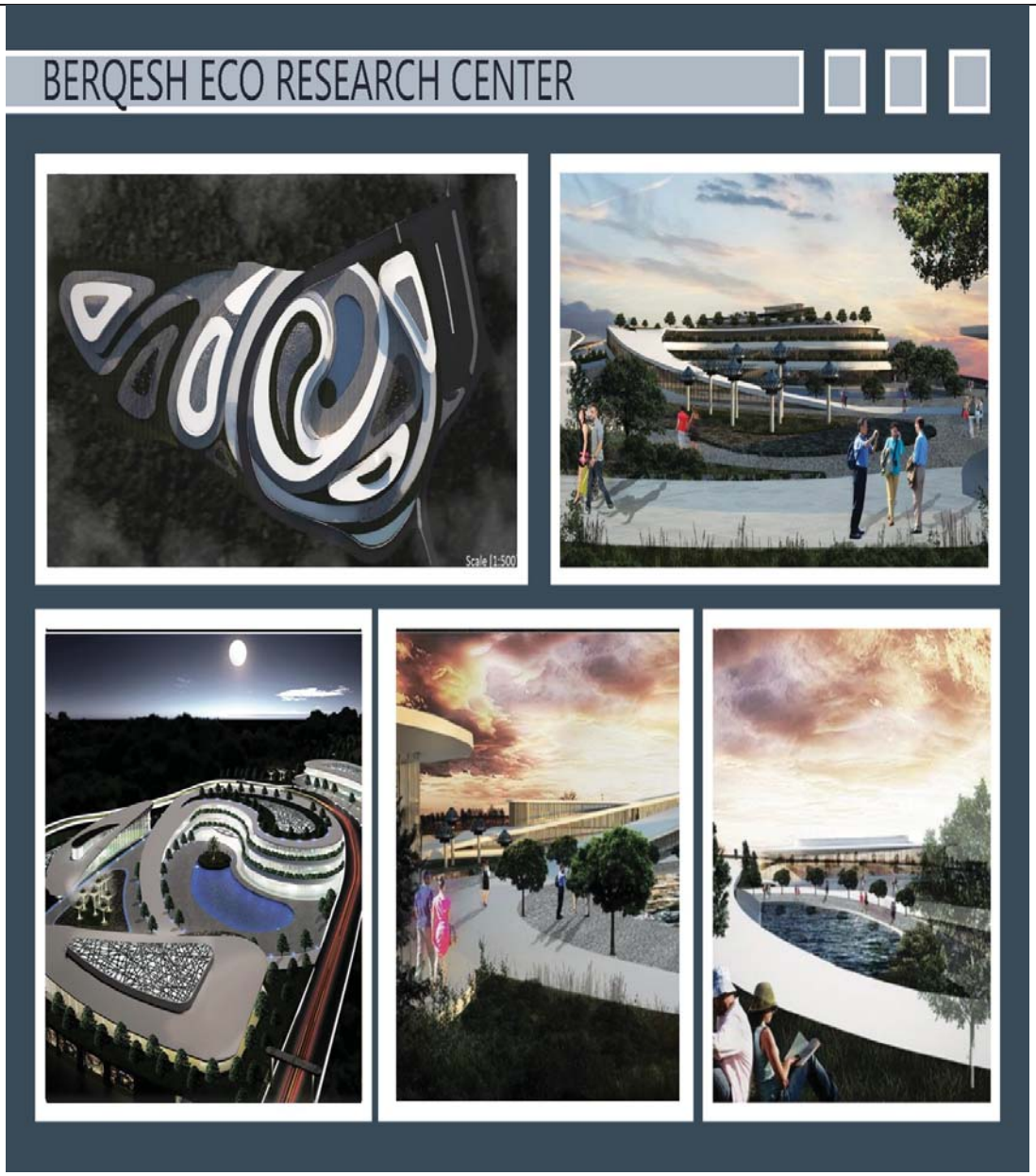
APPENDIX A

Sample No. A1	**Architectural Graduation Projects, Jordan Assessment Criteria**

Project Title: Cultural centre	Year: 2015-2016	University: AAU
Built up Area: 25,000 m2	Location: AQA- JORDANBA	

Sample No. A2	**Architectural Graduation Projects, Jordan Assessment Criteria**

Project Title: Cultural centre	Year: 2015-2016	University: AAU
Built up Area: 25,000 m2	Location: AQA- JORDANBA	



Sample No. A3	**Architectural Graduation Projects, Jordan Assessment Criteria**

Project Title: Cultural centre	Year: 2015-2016	University: AAU
Built up Area: 25,000 m2	Location: AQA- JORDANBA