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COMPUTER AIDED DESIGN (CAD) TECHNOLOGY VERSUS STUDENTS' LEARNING IN ARCHITECTURAL DESIGN PEDAGOGY – A CONTROVERSIAL TOPIC REVIEW

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ABSTRACT

Since the advancement of information technology and the development of computers in the 1960s, students' approaches to design education have been affected greatly in recent years. The current situation of using Computer Aided Design (CAD) in architectural practices through the aid of computer systems for visualisation presentation, communication, and information processing purposes define the future of architectural education in universities and graduates employment opportunities into small to mid-sized companies. Though several architectural schools have adopted these changes in architectural education by making it part of their curriculum to enhance CAD pedagogy skills. However, a large number of studio educators still find it impractical in the design process. This paper examines the studies related to the augments among architectural studio educators regarding CAD utilisation in architectural design studio, as well as its effects on students' learning. The challenges, controversies, divergent views and best practices are presented. Even though, an in-depth enquiring to adopt a more dynamic approach to addressing the future field of architectural design education that has been engulfed by digital technologies and its developments is essential.

INTRODUCATION

Advances in digital technology and design have affected student approaches over design education chiefly in recent years. The developments in information technology (IT) and electronic design is re-shaping the practice of both architectural profession and its educational patterns. Several investigators have shown that developments in CAD, visualisation, and digital modelling together with advanced technology to communicate data, images and live action design know-hows, have enabled virtual dimension in studio instruction (Salama and Wilkinson, 2007). Virtual reality (VR) has been used within the construction industry for design applications, for collaborative visualisation and as a tool to improve construction processes (Bouchlaghem and Thorpe, 1996). Recently, among other software in use for design, Computer Aided Design (CAD) tools are the most widely used computer applications and has become a skill that is increasingly used in most architectural offices or firms nowadays. Several investigators have shown that practicing architects value competency in the production of digital presentations, effectiveness in the production of construction drawings and the capability of working together through digital media (Tasli, 2001; Pektas and Erkip, 2006).Several investigators have pointed out that Computer Aided Design (CAD) are now implemented by professionals in most architectural school curricula to enhance CAD teaching skills, such as 3D modelling and digital presentation, consequently grabbing academia to impromptu develop pedagogy for a digital practice (Pektas and Erkip, 2006). Similarly, Wang (2009) stressed on the need for instructors to be aquatinted with the use of digital tools so that prospective instructors not only gain skills in working with equipment and software, but also experience how technology can be used to explore, organize, and communicate knowledge by emphasizing discovery approaches to learning in a technologically astute environment. Zoller and Donn (1993) averred that students and instructors attitudes toward digital technologies can often be distinguished. A similar study by Smith (1986) revealed that instructor computer efficacy scores are significantly and

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negatively related to that of students. Moreover, students' self-confidence increases with more exposure to computer lessons, while on the other hand instructors' self-assurance decreases. Basa and Şenyapili (2005) concluded that in the past studio instructors are not willing to use digital tools in their professional studies and were also loath to accept digital tools in design courses. Studies have demonstrated that not only has CAD technologies reduce the production time required for completing a certain task, but also has enabled design students and other individuals to process digital visual information faster. These technologies also make students' ideas and creativity, operational decision making, or other design-related activities more productive.

Visualisation on the other hand, is a new aid tool also for the design of different infrastructures. For advertising and presentation purposes, visualisation becomes important when 3D object is created. Visualisations show how a created object will be in real life without the need for expensive external resources (Pilkaite, 2010). It is evident that students can detect certain errors in the initial stages of their design process. Furthermore, CAD system and designed objects visualisation help students to understand the different stages of the design process. It also assists them to get a deeper understanding of how an object works before they are built (Pilkaite, 2010).

Structure of the Article

In this article, the school of thought for the positive effect of CAD pedagogy in architectural discipline was first discussed. Followed by the negative effect of CAD pedagogy on student learning in architectural education. Next, how CAD visualisation affects the students' design process. Instructors and students' attitude toward a digital era was highlighted. The article also addresses the augments among architectural studio educators regarding CAD utilisation in architectural design studio, including its effects on students' learning. The challenges, controversies, divergent views and best practices are presented. The concluding part articulated lesson learned and implications for further investigation and practice.

MATERIALS AND METHODS

Methods and Search Combination

Relevant English language articles and references was sourced using the ISI Web of Knowledge and electronic database resources, which includes Elsevier Science Direct, IEEE Xplore Database, ASME Digital Collection, Springer Link, SAGE Journals Online, Wiley Online Library, Springer Link, and Taylor and Francis. The search was completed in December 10, 2014. Articles published between 1986 and 2014 were searched using the keywords and search term combinations: "Design Education", "Computer Aided Design (CAD)", "Digital Presentation", "CAD Visualisation", "Computer Mental Attitude", "Jury Assessment", "Computer visualisation", "Computer generated images", "CAD impact on student learning". All the related papers from the databases were printed out to intensively study the arguments and impacts of CAD technologies on student learning, perceptions/attitude of students to student, instructor to instructor, and instructor to students.

RESULTS AND DISCUSSION

The School of Thought for Positive Effect of CAD Pedagogy

When digital tools were made known in architectural education; the reflection on building practice was obviously understood (Reffat, 2005). A glanced at historical developments of computer use in architectural education; we realised that computers were used as a tool primarily for the following purposes, such as information processing, communication tools, and visualisation tools during the design process and presentation. Computer use has a prime purpose of improving the quality and efficiency of the building design process through the development of advanced 3D visualisation tools including Virtual Reality (VR) techniques (Reffat, 2007). According to Ley (2007) there is no general agreement among design educators on the role of computers within design education and similarly no existing base solid pedagogical for their effective use in developing design skills.

On the other hand, Brown (2009) advocated that the introduction of CADs to architectural education have ease students with limited literacy by giving them the chance to explore design fields, which in turn reduces students fatigue aspects of design and has provided added time for them to explore broader fields of study. A research has found that CAD serves as an adaptive medium to design students for creating, refining, and appraising multifaceted models, which successively could be expeditiously transformed into actual products (Scales and Sneider, 1999). Considerable preference has been given to CAD visualisation for heightening students' ability to present, represent, develop, and communicate ideas efficaciously through assorted formats (Robertson and Radcliffe, 2009). A number of similar studies have elucidated that the advent of the internet and omnipresent connectivity has essentially contributed to the positive impacts of CAD, easing sharing and partnership of design thoughts (Ley, 2007; Shniederman, 2007).

As may be evident, Cil and Pakdil (2007) concentrated on the use of CAD, particularly in 3-Dimensional formats, and concluded that it can aid the development of perceptual skills in design students, as well as in the development of spatial abilities. Investigators have argued that CAD visualisation can contribute or improve the creative thinking skills of students by providing them with effective communication, presentation skills, and evaluation tools (Bonnardel and Zenasni, 2010).Considerable support exists that when CAD is used in an early design process, in association with other media can lead to an effective educational tool (Robertson and Radcliffe, 2009). Christie and Ferdos (2004) contended that educational and digital technology tools cannot be separated, thereby concluding that a good pedagogy can be inform and supported with good information technologies, whereas poor pedagogy can undermine the very point of using good information technologies. An experimental conducted study to measure the impact of technology-based instructional environment on student learning shows that computer mediated discussion can be a valuable component of any traditional course (Irvine *et al*., 1990). A study conducted by Döngela *et al*. (2009) on design education disclosed that there are a number of underlying advantages over disadvantages in using CAD for

design rather than classical drawing teaching methods. Moreover, one of the significant benefits of CAD is the ability to transform drawings to drawing exchange format (DXF) and transported to the Computer Numeric Controlled (CNC) machines for automated production. Furthermore, with CAD, it is likely to modify drawings in the future with little alteration (Döngela *et al*., 2009).

The School of Thought for Negative Effect of CAD Pedagogy

Reffat (2005) indicated that in the late 1980s computer and other digital tools were still inadmissible to a very great degree by huge amounts of traditional design studio instructors. Their claims were based on the fact that computer drawing is taking away the nature of hand drafting and hand modelling which was very significant elements in developing rationalizations and the design process. Andia (2002) on the other hand, states that over a century old, studio approaches of developing design rationalisation through plans, section, elevation, and models have been hardly touched by the new tools. In a normal circumstance, the initial drafting and modelling is done manually when most design rationalisation occurs, and later developed fully with computer drawings and rendering for final presentations and project documentation. However, evidence has proven CAD to be a significant aid in the development of design skills in design education (Lawson, 2002). Brown (2009) argued that the penetration and the emphasis on CAD visualisation in design education have dominated the manual way of drafting by undermining the beneficial aspects of student to student and student to instructor partnership and fundamental interaction.

Robertson and Radcliffe (2009) also claims that the most vital aspect of design education is the student to student or face-to-face social interaction which CAD has taken away. According to Wang (2010) for the last century, assessment of design skill development traditionally has centred on studio critique. Even though, “awarding of formal grades in respect to students' achievements are centred on behavioural psychology, physical processes of social interaction, engagement, constructive dialogue, collaboration and reflection embrace many positive elements of social constructivism” (Wang, 2010; Beecher, 2006). Brown (2009) criticizes CAD usage by students, arguing that especially in the initial stages of design development cut down the volume of materials available for discussion, hereby weakening the potential value of any constructivist engagement. Evidence has shown from many design educators that CAD is simply a tool for improving good design (Unver, 2006).

The use of CAD has been discouraged by many for hindering further exploration of design ideas and criticized for creating the illusion of completeness and precision (Robertson *et al*., 2007). Research carried out by Robertson and Radcliffe (2009) confirmed that design exploration can also be limited to the software's ability rather than the ability of the mind to create mental images. Another odd aspect of CAD on design education is the challenge it poses to new design students. Design students are often faced with challenges in translating the unacquainted and multifaceted command language of CAD software, which consequently, has shown to undermine other subject areas (Lang *et al*., 1991; Bonnardel and Zenasni, 2010). Research conducted by Robertson and Radcliffe (2009) also indicated that student CAD applications can perhaps lead to over use of it even when more appropriate tools are available. Fig. 1 – 4 provides sketches, perspectives and rendering by Moustafa Elshindidy, indicating that architectural design students still have the potentials to design and render drawings with hands.

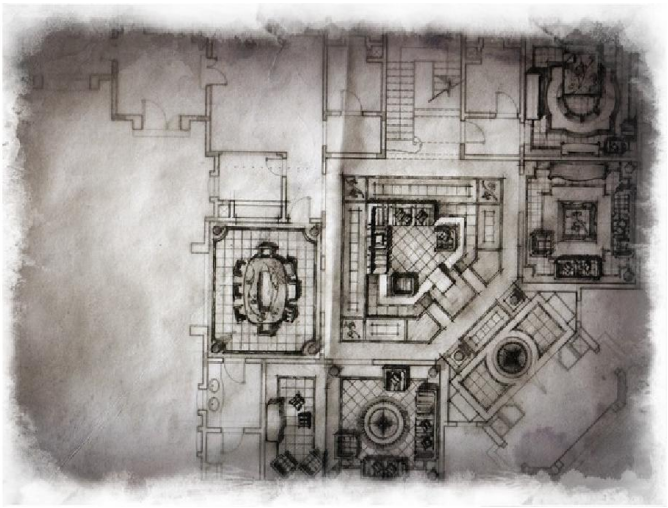

Fig. 1. Hand rendered floor plan [by Moustafa Elshindidy – Ace Rendering Company (2006a)]

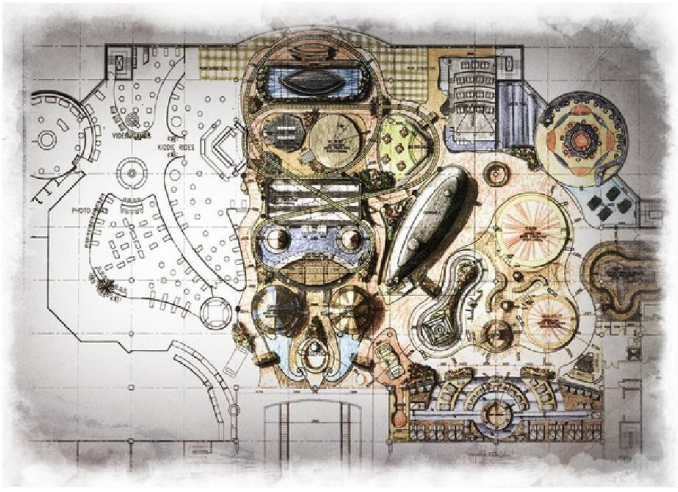

Fig. 2. Hand rendered site plan [by Moustafa Elshindidy – Ace Rendering Company (2006a)]

Fig. 3. Hand rendered elevation drawings [by Moustafa Elshindidy – Ace Rendering Company (2006a)]

Fig. 4. 3D urban setting hand rendering [by Moustafa Elshindidy – Ace Rendering Company (2006a)]

CAD Visualisation and the Design Process

Since when computer became widespread in the 1960s, investigators have tried to use information technology to improve learning. Even though, there is still underlying proves that whether these technologies improves learning. However, previous research literatures have indicated that the product development begins with the design process. Murthy and Mani (2012) identified that a technology used in the design process must be flexible so as to accommodate effective communication within a group comprising diverse designers, encourage generation of diverse ideas that carry potential for new and better ideas, retain contradictory thoughts and unexplored ideas (even those that might appear illogical or unproven), and integrate logic and science to aid in the synthesis of design solutions. CAD is one of these technologies that are used in generating ideas, making drawings in project management and presentations. An increased use of CAD will lead to improved product reliability, standardization, and profits. CAD's critical role is to connect the designers to the suppliers and manufacturers in the necessary design phase (Murthy and Mani, 2012).

The CAD systems and designed objects visualisation on the other hand, help students to comprehend diverse phases of the design process, and equally help them to get a profounder understanding of how an object works before they are built in real life. Students can actually see how the three dimensional objects they are designing will fit in its appropriate real space. Popescu and Haffmann (2007) advocated that visualisation is a significant tool in CAD, which is used in all phases of the life of a product. Visualisation allows designing, debugging, validating, and marketing, maintaining, repairing, updating, and recycling products effectively and efficiently. Furthermore, declared that Graphics and visualisation techniques have reached a great level of sophistication that remains unmatched by the visualisation modules of CAD software systems. It was concluded that visualisation modules of CAD systems are typically one or more steps behind the state-of-the-art in graphics and visualisation, and the gap continues to widen. Lynn (1998) demonstrated that visualisation effects can be tested immediately, and decisions can be made on the spot. Moreover, reported the critique from scholars about the use of digital tools, which states "architects who espouse the virtues of digital space must not only engage the formal issues, but must also address how human activity spans the real and virtual worlds". Over the few last decades, digital tools have been created with special visualisation products, including VIZ, 3ds Max, Maya, Sketchbook Pro, Autodesk Freewheel, Sketchup, Revit, etc., and has proven to be effective, fast and enhance good presentation. Animation systems or tools have obtained a stage where they can render complex 3D scenes to produce images that can be straightforwardly mistaken for photographs or real object. It is significant to communicate with an audience effectively, using contemporary presentation tools, which are coming into the standard CAD system and are used for product design (Vidmantas and Nomeda, 2009). Another study has shown that new technologies often allow people to do new things, as well as doing old ones better (DeGregori, 1989). Fig. 5 – 8 illustrates the potentials of CAD drawings and rendering in the information and digital technology era that has greatly influenced students' approaches to design education in recent years.

Fig. 5. Interior design 3D modelling and rendering [by April Wang -Ace Rendering Company (2006b)]

Fig. 6. Urban design 3D modelling and rendering [by April Wang -Ace Rendering Company (2006b)]

Fig. 7. Exterior design 3d modelling and rendering [by April Wang - Ace Rendering Company (2006b)]

Fig. 8. 3D Landscape planning modelling rendering [by April Wang - Ace Rendering Company (2006b)]

For instance, Pilkaite (2010) indicated that AutoCAD and Mechanical Desktop (MD) systems allow design students to perform the visualisation process of creating an object using two ways, such as shading of an object and its rendering. Moreover, these special digital or animation system tools offer design students the opportunities to define lighting, camera angles, animation parameters and background style, as well as to create images that best present ideas. It is apparent that these tools presents the possibilities to create both still and animated renderings of parts and assemblies to envisage the appearance and motion of a design before it is being built. Other beneficial characteristics of these tools are their ability to specify the geometry and settings for background, lights and cameras to create a scene for a rendering or animation, create and save multiple animations in one assembly file, reuse constraints or parameters between animations in one assembly file (Pilkaite, 2010). The 3D models or views improves the student's imaginary experience, lightens learning process in classes, and promotes a project realistic visualisation or appearance, without the need for expensive external design resources. It is apparent that visualisation and animation are becoming more and more significant in many of today's student design projects and presentation.

Generating and presenting accurate and realistic images of the finished product can be essential for approval of the project (Pilkaite, 2010). However, the final design jury, which declares a closing remark on the design project, has a solid influence in design education. The way the design projects are presented graphically, affects how jury instructors comprehend and evaluate the projects (Gürel and Basa, 2004). Investigators have evidently shown that digital tools hugely influence their positive contribution to visual presentation in design education (Hanna and Barber, 2001). However, the argument among studio educators have indicated that entirely encouraging computer aided visual presentations in design education is feared to lead to the loss of hand drawing skills hereafter (Shu, 2000). Basa and Şenyapili (2005) inquiry on design jury and computer generated presentations demonstrated that a tension is actually created within the integration between conventional hand drawn and computer generated presentation techniques. After investing other scholars work, Hanna and Barber (2001) concluded that conventional drawing methods are still preferred for design creation and development phases, even though, empirical verification are still needed.

Instructors versus Students' Attitude in a Digital Era

Pektas and Erkip (2006) showed that the relationship between students and instructors' attitudes toward computer generated visual presentation is one of the controversial issues in computer attitude research. Some pedagogues have suggested a relation between the student and teacher attitudes toward computers. For example, Downes, (1993) described that a good role model classroom instructor who uses computers for educating have a more positive attitude toward computers for students. On the other hand, Basa and Şenyapili (2005) elucidate that evaluating computer generated visual presentations in student juries can be composed of two parts. The positive attitude and sometimes exceeding the impact of the design project, while the other aspect is an insecure attitude, endangering the conception of the design, which results to instructors arguments for presentation.

An observation by Zoller and Donn (1993) revealed that there is often a distinction between students and instructors in their attitudes towards design presentation with digital tools. In a similar study, Akalın (2003) acknowledged that even when a student is a beginner in using digital tools and architectural software, the visual presentation reflects same spirit and character of the student. Besides that, a demonstration of hand skill in the visual presentation fetches a positive quality of the student. Basa and Şenyapili (2005) on the other hand, declared that students are anticipated to present virtuous drawings in the final jury, and at the same time possess ownership on these drawings. Moreover, students need to demonstrate skills in drawing techniques throughout the design development phases. The authors also demonstrated that student conventional or hand generated drawings can be detected by their instructors easily, compared to computer generated visual drawings. They argued that instructor's proficiency in the drawing technique is an added advantage to trace student identity in a drawing. The proficiency of the instructor over the covered subjects (including design, content, structure, materials, and presentation technique) in a design jury puts the instructors in a secure position, and within this secure position instructors evaluate and criticize the designs (Basa and Şenyapili, 2005).

In line with this framework, Ochsner, (2000) states that the instructor in the design jury identifies with the student unconsciously, and this identification have an impact on the instructor's behaviour. Laiserin and Linn (2000) explains that computer generated presentations may shift the instructor's secure position. Possibly, the most common and biased disagreement may be the expectation of a gap between the instructors with hand drawing backgrounds and students skilled in digital tools techniques. Again, Basa and Şenyapili (2005) explicates that the best presentation medium, which expresses student identity is the hand drawing, or the combination of both conventional and digital design tools rather than employing only digital design tools in their design process. Irrespective of the jury profile, students' ideas and identity are often portrayed in hand drawn visual presentations and are invariably appreciated more. Pektas and Erkip (2006) supported this augment by indicating that students' attitude toward digital tool application in design was highly related over their general attitude toward computers. However, result shows no correlation with instructor's attitude toward the use

of computers in design. Robertson *et al*. (1995) unfold that the concept of digital tools is becoming so much a part of a culture that most young people expect to be able to understand them and enjoy using them. Considerable studies have shown that gender difference in digital tool attitudes among students is found in males having more positive attitudes than females. In addition, the level of expertise, professional education, and age might alter the perception of the visual simulation content (Mahdjoubi, 2001; Pektas and Erkip, 2006). An educator has shown that research and computation professors who were close to the design methods community considered commercial CAD a frivolous instrument, which ignored the informational potential of software design. In the early years, a great number of established studio professors worried that students would not acquire traditional drafting and design skills, and this resulted to the banned of commercial CAD from their design studios. In later times, professors and students developed an attitude of practical realism as they drew from the developments in practice. In this era, the use of computers and digital technologies have become so rampart in architectural schools, most students bring their own individual computers, raising the ratio still further (Andia, 2002).

Conclusion

Lessons Learned and Implications for Further Investigation

With the advancement of information technologies, there is no doubt digital culture has altered the way that projects have been designed and presented by students in architectural education. This has tremendously affected the architectural practice and will be more apparent in the future. Therefore, for a future architect to withstand the recent trend of digital technologies, evolving with the global world advancement of information and communications is now essential. Not with standing, most architectural educators today, admitted that the process of design should kick-off manually with hand sketch drawings and modelling. Moreover, it is more natural and realistic to draw whatever that comes to mind with hand sketching at the initial stage of a design process, acknowledging that digital programs are limited to certain shapes and tools in comparison with a human mind at the first instance. Sometimes starting the design phase with hand sketching perhaps can lead students to better design ideas or thoughts. After which, the ideas and sketches are transferred into digital formats for further development.

However, some schools of thought, consents with the potentials of digital tools, as it has caught them impromptu to work with the technology of today, believing that students can feel the space better and see how it look like in real life with 3D programs. A student that knows how to manipulate these digital tools can add colour, texture and lighting to the space at a glance. To an extent, most instructors in various architectural schools agree that hand sketching should be used in the initial design phase to create the idea and digital tools to improve the final presentation of the project. On the contrary, some educators believe that all can be done with digital technology, since creativity is from the mind not the hand. For instance, it is apparent that nowadays in America, and some part of Europe, the traditional system are eliminated, and students start working with computer digital programs for the first year. Which call for all educators in such region to evolve with these different technological tools and programs to survive students with Hi-tech digital awareness. Human scale will be better considered while working with digital tools. In line with this augment, the study supported that CAD tools or technologies are having the potentials to facilitate better communications in multifaceted problem solving conditions, although the traditional method of drawing (hand sketching/ drawing) is required in the initial stage of the design process. However, many architectural studio educators do not yet accept this curricular change, and this debate is still ongoing in several architectural schools. Investigators need an in-depth enquiring to adopt a more dynamic approach to addressing the future field of architectural design studio that has fully been modulated by digital technologies (including CAD) and its emergences.

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