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The Impact of using Computer-Aided Design (CAD) on the Creativity of Architecture Students

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ABSTRACT
The architectural design process is based on imagination where creativity is highly valued. Contemporary goals in higher education and particularly architectural design education include giving students tools to stimulate the search for creative solutions to problems. One of those tools is the Computer-Aided Design (CAD) tool. The use of CAD in the latter stages of the design process for efficiency purposes has become common. However, the integration of CAD into the early, schematic stages of the design process has initiated some debate where empirical evidence regarding the impact of CAD on the creativity of architectural design solutions and the influence on the creative mental process of students is lacking. The aim of this paper is to determine whether the use of CAD effectively enhances students' creative concepts. Other than descriptive-analytic methodology, the study was divided into two stages: an experimental study and a questionnaire. The first stage aimed to examine the effect of using pencil-based and computer-based methods on the creativeness of architectural solutions in the preliminary design phases. The second stage aimed to gather rich descriptions of how CAD is used in architectural design education. The respondents of these two stages were students of the Department of Islamic Architecture, Umm Al-Qura University, KSA.The study concluded that the use of CAD did not significantly inhibit, nor did it enhance creativity in the preliminary design stage compared to the pencil-based design method.

Keywords: creativity, architectural education, computer-aided design, CAD

INTRODUCTION

Architectural design is a process that is required to address the plethora of complexities, ranging from tangible aspects like the articulation of space and geometry to intangible aspects like the multisensory nature of the architectural experience and ambiguousness and metaphorical nature of conceptualization. These inherent contradictions in the very fiber of architecture make teaching and learning architecture so challenging.

Architecture today is undergoing paradigm shifts at a rapid frequency never seen before in the history of mankind. The mind of a student of architecture, therefore, needs to be systematically trained to think in an ‘assumptions-breaking manner’, not just from the aesthetic point of view, which is the more extrinsic expression of architecture, but from the perspective of conceptualization, which is the intrinsic core of the architectural design. Hence, the architectural design could be defined as a creative activity in its essence as it mixes information, ideas, drawings, and many other ingredients to create something where nothing was before.

Contemporary goals in higher education and particularly architectural design education include giving students tools to stimulate the search for creative solutions to problems (Kowaltowski, Bianchi and de Paiva 2010). Right here, an essential question arises: Does the computer really help? (Lawson, 2002).

The development of digital and emerging technology creates the perfect opportunity to enhance architectural education “in terms of methodologies, strategies and tools” and deliver more effective learning processes. (Aydin and Aktas, 2020; Ceylan, 2021: (Hajirasouli et al., 2023). The history of using information and communication technologies in architectural design is very short when compared to the development of methods in practical design. Information and communication technologies have had a revolutionary impact on the field of architectural design and have necessitated the improvement of existing pedagogical approaches and educational tools. On one hand, the use of Extended Reality has evolved to engage in architecture design and education. It allows the students to experience their design project in real scale (Darwish et al., 2023). Virtual reality technologies, one of the Extended Reality classifications, having made a technological breakthrough in the field of architectural visualization and providing opportunities to realistically demonstrate architectural objects, have become a promising and effective tool for improving the environment of architectural education

(Holubchak, 2021). Furthermore, integrating augmented reality technology into architectural design education creates a more rewarding educational environment that provides an interesting learning atmosphere and deepens students' knowledge of the architectural design process (Hussein, 2022). On the other hand, Knowledge of parametric modeling is crucial for finding a new way to solve design problems and help with creativity and innovation in design (Gallas, et al., 2015). While a high level of parametric modeling skill means using computational power in the design process, custom Computer-aided design (CAD) tools are examples of the lowest algorithmic level in design (Ali, 2022). (CAD) has now been with us in a practically useful form for more than a quarter of a century. This has generally been seen as progress towards a better way of designing architecture, and the exponents of CAD have often argued that it improves the architectural process and product. Sadly, remarkably little empirical evaluation of such claims has been carried out.

Creativity in Architecture

Although it is a common, everyday term, it is difficult to define creativity scientifically (Robertson & Radcliffe, 2009). Amabile (2006) has provided the field with one of the most simple and yet comprehensive frameworks for creativity. As illustrated in Fig. 1, creativity arises through the confluence of the following three components: (a) Knowledge (expertise): All the relevant understanding an individual brings to bear on a creative effort; (b) Creative Thinking: It relates to how people approach problems and depends on personality and thinking/working style; and (c) Motivation: Motivation is generally accepted as key to creative production, and the most important motivators are intrinsic passion and interest in the work itself.

In architecture, creativity is the cornerstone of this realm (Danaci, 2015). Fig. 2 shows the process through which a designer creates an architectural space. As can be seen, creativity is one of the primary requirements for the creation of architectural space (Daemei& Safari, 2018).

In this paper, apart from the complexity in defining creativity, "creativity" is used as shorthand for creative ideas or concepts in architectural design education, where aesthetics, usability, stability, and above all novelty, are important to produce unique and useful results (Park & Lee, 2022).

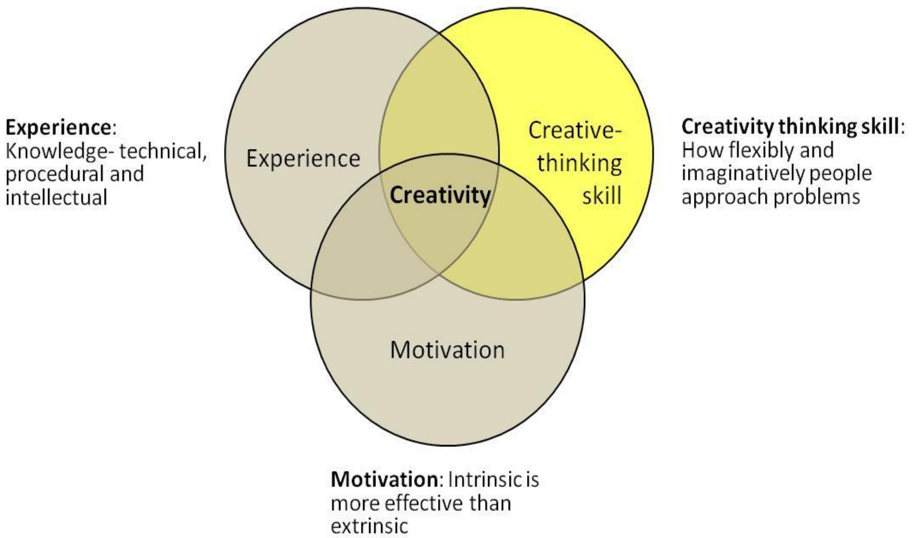

Fig 1: The three components of creativity (Amabile, 2006) illustrating creativity thinking skill, the focal point of this study.

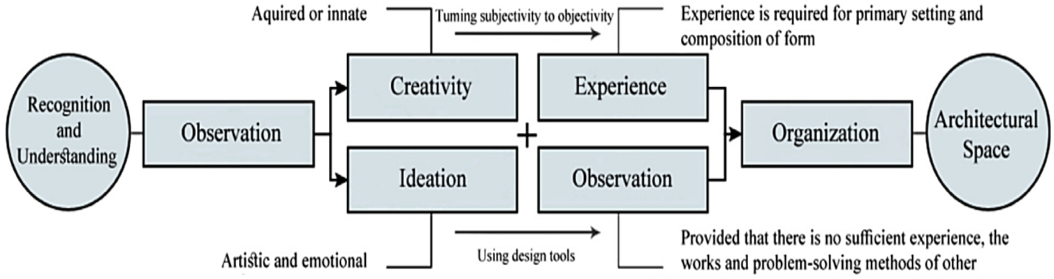

Fig 2: Proposed model of the architectural design process (Daemei& Safari, 2018).

Creativity Theory

Categories of creativity

The literature on creativity could be divided into three major categories, which are known as the "three Ps": the creative person, the creative process, and the creative product (Kahvecioglu, 2007) (Garcês et al., 2016). These three categories were adapted to the field of architectural design as followings:

The creative person (Architecture student)

Researchers have shown that there are certain personality traits associated with creative people, especially architects (e.g., Stein, 2014; Yalçın&Ulusoy, 2015). One such list of traits was comprised by the researcher and is summarized as:Creative architect has: (a) The ability to change undesirable habits into desirable ones, (b) A positive curiosity about the unknown, (c) A positive attitude towards new architectural experiences, (d) The ability to take negative criticism and turn it into constructive action, (e) The ability to take risks fully knowing that architectural concepts may be attacked by others, (f) A good sense of humor, (g) The motivation to solve architectural problems on his/ her own, (h) High self-esteem and self-confidence in one's abilities, and (i) The ability to focus full attention on a particular problem for an appropriate length of time.

This is only a guide to help identify an architect's creative potential. Because all people are creative (Maslow, 2021), it is reasonable to expect that each possesses some measure of these characteristics. Nevertheless, highly creative architects tend to exhibit more of these traits and to a greater degree of intensity (Stein, 2014).Though personality traits play an important part in understanding creative ability, an equally important area of creativity theory lies in the identification of the creative process itself.

The creative process (Architectural design process)

A more comprehensive description of the creative process is captured within a definition offered by Torrance (1966): Creativity is a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficult; searching for solutions, making guesses or formulating hypotheses about the deficiencies, testing and re-testing these hypotheses and possibly modifying and re-testing them, and finally communicating the results. The design process involves three interconnected essential activities of imaging, presenting, and testing. According to Zeisel (2006), "Imaging is the mental process of fabricating, fantasizing, and otherwise creating ideas and concepts" and the ability to "go beyond the information given".

In architectural design, images are often visual; they provide a larger framework in which pieces of a problem fit together as they are resolved. Architects use their early images of eventual solutions to improve the definitions of the design problems or challenges they work on and to guide their search for answers. Early images are referred to as "pre-representations" as if the mind sketches out images it holds. Creative imaging involves making connections between elements that already exist in novel ways.

Presenting is another fundamental activity in the process of architectural design. Preliminarily sketching, drawing plans, building models, and taking photographs are some of the many ways architects externalize and communicate their images. It takes skill not only to present an idea well but also to choose the mode of representation best suited to a particular time in the design process. There are many purposes for presenting, including communicating, exploring, experimenting and testing, among others. Creativity in presenting lies in the skill and refinement with which the architect senses the world, perceives it, and communicates the work to others. Architects express their creativity in the finished products that others appreciate.

Appraisals, refutations, criticisms, judgments, comparisons, reflections, and reviews are all types of testing, which is the third fundamental activity in the design process. After presenting an architectural design idea in any form, architects step back with a critical eye and examine the products, sometimes in groups and sometimes alone. Without testing, there can be no improvement. While reviewing, criticizing, and analyzing any form of presentation, architects are preparing the way for the next creative leap or conceptual shifts necessary for design development.

The creative product (Architectural project)

The product may be a physical object, article, patent, theoretical system, equation, new technique (Lyne, 2020), or sketches for buildings or structures under contemplation. Olson (1973) remarks: The project represents human creative achievement with materials and ideas and results in an experience of self-fulfillment. The continuing student input causes immediate, real, and meaningful feedback enabling him to assess his achievement at any one time or point in the project. A student's project is nothing less than a creative product. Besemer and O'Quin (1993) believe that the creative product is unique in that it combines both the creative person and process into a tangible object representing the "true" measure of a person's creative ability.

Criteria for evaluating the creative product

Evaluating creativity presents a unique challenge in higher education. Although there are tools on the market for assessing creativity, most are designed for young children, and all tend either to lack sufficient validity and reliability or to assess only rather trivial aspects of creativity (or, in many cases, both). On the other hand, most research on creativity has focused on the creative person and process, not the creative product. This lack of interest in the product has resulted in little progress toward defining attributes of the creative product.

Creative Product Analysis Matrix (CPAM)

The most extensive review of literature establishing criteria for evaluating the creative product was conducted by Besemer and Treffinger (1981). The researchers grouped the evaluation criteria into 14 general categories or sub-scales that were placed under three general dimensions. The researchers' work resulted in the establishment of the Creative Product Analysis Matrix or CPAM (Besemer&Treffinger, 1981), a theoretical model by which the creative product could be identified and measured. Below is a summary of the model's three general dimensions and sub-categories that are adapted to architectural design concepts:

1. The Novelty Dimension (New): This dimension defines the extent of newness an architectural design concept possesses in terms of the number of new concepts, new techniques, and new materials. It also includes the influence the project has on future creative projects. Associated with this dimension are the following sub-categories and their definitions: (a) Germinal: The concept is likely to suggest additional future creative projects, (b) Original: The concept is unusual or infrequently seen in other concepts designed by architects with similar experience and training, and (c) Transformational: The concept is so revolutionary that it forces a shift in the way that architecture is perceived by users and viewers.
2. The Resolution Dimension (Useful): This dimension defines the degree to which the architectural design concept fits or meets the needs of the problematic situation. Associated with this dimension are the following sub-categories and their definitions: (a) Adequate: The concept answers enough of the needs of the problematic situation, (b) Appropriate: The solution fits or applies to the problematic situation, (c) Logical: The concept or solution follows accepted and understood rules for the discipline of architecture, (d) Useful: The concept has a clear and practical application, and (e) Valuable: The concept is judged worthy by users or viewers because it fills physical or psychological needs and because it responds to social, economic and environmental aspects.
3. Elaboration & Synthesis Dimension (style): This dimension defines the degree to which the concept combines unlike elements into a refined, developed, coherent whole, statement, or unit. Associated with this dimension are the following sub-categories and their definitions: (a) Attractive: The concept commands the attention of viewers and users, (b) Complex: The concept or solution contains many elements at one or more levels, (c) Elegant: The solution is expressed in a refined, understated way, (d) Expressive: The concept is presented in a communicative, understandable manner, (e) Organic: The concept has a sense of wholeness or completeness about it, and (f) Well-crafted: The concept has been formulated and reformulated with care to develop it to its highest possible level for that point in time.

The Creative Product Semantic Scale (CPSS)

The CPSS (Creative Product Semantic Scale) is a reliable, valid instrument that measures novelty, resolution, and style (O'Quin&Besemer, 2006). It is an objective descriptive assessment measure that provides measurements of the component qualities of creativity in products. The CPSS, based on the CPAM model, has undergone substantial conceptual and psychometric development over a 30-year period. The theory underlying the development of the CPSS adopts the three dimensions of CPAM. In operationalizing the major elements of this underlying theory into measurements, the CPSS provides three scales or factors and nine subscales or facets. This assessment measure was developed over years of scientific empirical validation studies including reliability, exploratory and confirmatory factor analysis, and other multivariate statistical measures to be sure that it measures what we want to know: how people perceive the new concepts. The CPSS consists of 55 items, contrasting adjectives, on Likert-type scales from 1 to 7.

The Consensual Assessment Technique (CAT)

First proposed by Teresa Amabile in 1982 and further developed by her and other researchers (Amabile, 1982, 2019; Baer, 2016, 1994a, 1994b; Baer, Kaufman, & Gentile, 2004; Kaufman, Baer, Cole, & Sexton, 2008), the CAT is now a well-validated tool for assessing creativity. The CAT is based on the rather simple idea that the best measure of the creativity of a work of architecture, art, a theory, or any other artifact is the combined assessment of experts in that field. The experts work independently and do not influence one another’s judgments in any way. No attempt is made to measure some skill, attribute, or disposition that is theoretically linked to creativity; instead, it is the actual creation of things that subjects have produced that is assessed. The focus is therefore on creative products, not creativity-relevant talents or attributes that are hypothesized to influence creativity. Because (a) it is based on actual creative performances or artifacts; (b) it is not tied to any particular theory of creativity and (c) it mimics the way creativity is assessed in the "real world", the CAT has sometimes been called the "gold standard" of creativity assessment (Carson, 2006) (Kaufman, 2017) (Baer,2020).

CAD and Creativity

In the early 1990s, computers and the internet were becoming widespread in developed countries (Radić et al., 2021). With the introduction of the graphical user interface, increase in processing speed, and affordability, educational computing had finally come of age. (Depcik&Assanis, 2005). CAD has had a radical impact on the teaching, learning, and practice of architectural design (Brown, 2009). While the evolution of architectural design education and practice advanced slowly, the introduction of CAD sparked a rapid shift in all aspects of design over a very short period of time (Lawson, 2017). Before the introduction of CAD, architectural design was essentially a hands-on process involving a variety of physical media and manual tasks. Throughout a few hundred years' primitive tools were replaced by a succession of technological advancements, which culminated in the invention of the computer in the mid-1900s. With the introduction of workable CAD applications in the early 1980s, architectural design education and practice underwent immense change (Brown, 2009); And what began life as a technical drafting tool rapidly become integral to all stages of design practice and education (Tai, 2003; Musta'amal, Norman & Hodgson, 2009; Chester,2006). The swift uptake and increasing importance of CAD were, and continues to be, driven by one key factor: CAD's ability to meet architectural demands. (Brown, 2009). Taking the previous into account, Reffat (2007) notes that despite the pervasive infiltration of CAD into both design education and practice, and its increasing importance in both spheres (Brown, 2009), some architectural design schools still rely upon manual techniques of sketching and drawing in several design studios; this reluctance is attributed to the general perception that manual drawing skills are fundamental to underpinning good architectural design education (Akalin&Sezal, 2009).

MATERIALS AND METHODS

The qualitative study was divided into two stages: an experimental study and a questionnaire. The aim of the first stage was to assess creative concepts using manual sketches in comparison to CAD methods to determine if it fosters students' creativity in the preliminary design phases. The second stage aimed to gather rich descriptions of how CAD and other computer tools are used in architectural design education. The participants were students of the department of Islamic architecture, Umm Al-Qura University, KSA.

Stage One

In the first semester of 2022, forty students constituted the population for the generation of the design solutions that were rated by the educator judges. They used two design methods-- pencil-based and computer-based-- and generated design solutions for a small bus stop project. The students had about six hours in which to complete this experiment. Half of this time was allocated to thinking about the project manually and the other half to thinking about the project using CAD. All students were enrolled in at least two CAD course. Prior to the completion of the project for this study, the students had experience in applying both design methods through their required courses.

Following the scale of CPAM, a panel of judges experienced in assessing architectural design projects was asked to rate the design solutions. According to Barnard (1992), six judges were needed in order to reach the minimum reliability criterion of .70 when using the rating scale. Therefore, five faculty members from Architectural Design Studio 5 participated in addition to one from another design studio. The statistical procedure used in this portion of the study was a univariate analysis of variance (ANOVA) performed on each of the variables. Figure 3 illustrates different categories of the bus-stop projects using the two methods.

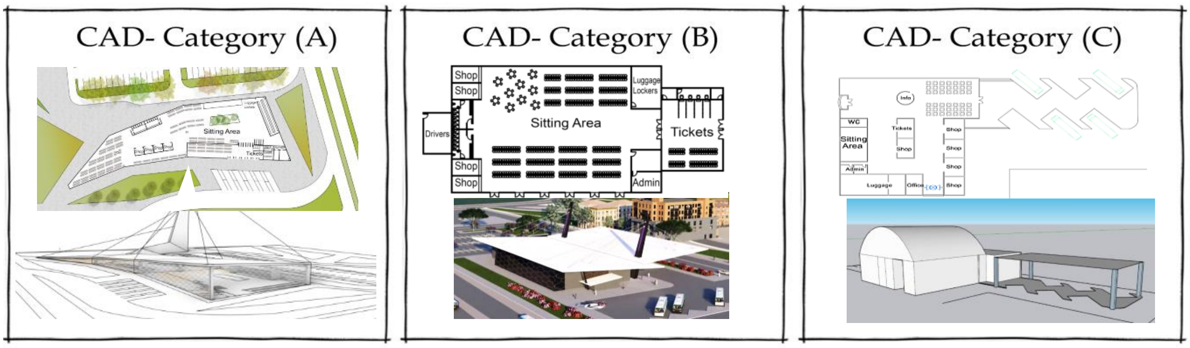

Fig. 3 (a). Different categories of bus stop projects using CAD method

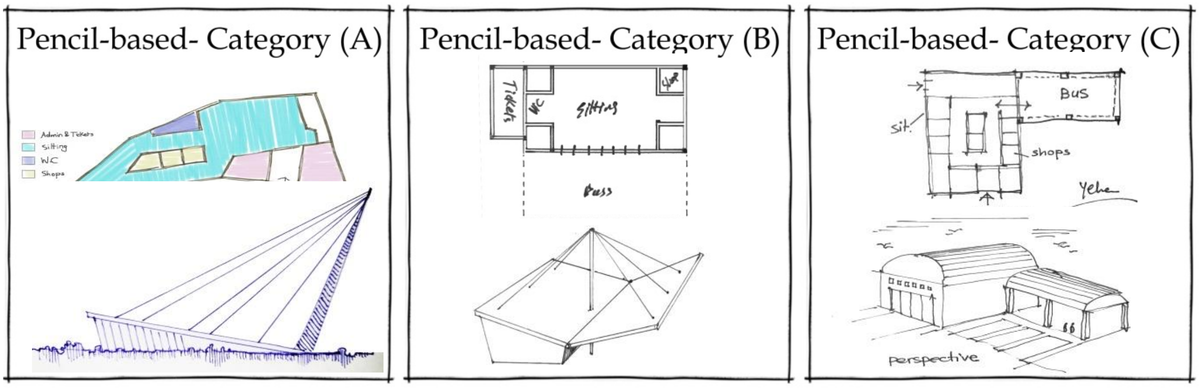

Fig. 3 (b). Different categories of bus stop projects using pencil-based method

Stage Two

A number of students, including participants of the first stage and students of studios 6 to 10, were administered a questionnaire to assess their attitudes and perceptions regarding the use of the two design methods. This instrument examined the process of creativity that could not be measured by the CPAM rating scale, which measured the products of creativity.

The survey consisted of statements and open-ended questions regarding the generation of design solutions. A pre-trial of the survey was conducted with a small number of respondents (n = 10) to try to identify any problems with the survey instrument before it was released to a wider audience. Several minor changes were made before the final survey was released, but no major problems were found.

RESULTS

Univariate Analysis of Variance (ANOVA)

A total of 40 students participated in this experimental part of the study. The analysis illustrates that the degree of novelty, resolution, and elaboration and synthesis in the design solutions was equivalent using either design method (Table 1). This means that architectural design educators rating the projects did not indicate that the design solutions generated by one method were more creative than the solutions generated by the other.

Table 1:Detailed Results of the Univariate Analysis

SOURCE OF VARIATION	df	SS	MS	F	Ᵽ
Novelty Dimension					
Design Method	1	6.2	6.2	3.34	0.08
Within	38	71.7	1.89		
Total	39	77.9			
Resolution Dimension					
Design Method	1	2.5	2.5	1.83	0.18
Within	38	52.7	1.39		
Total	39	55.2			
Elaboration & Synthesis Dimension					
Design Method	1	3.7	3.7	1.89	0.18
Within	38	74.1	1.95		
Total	39	77.8			

* DF: the degrees of freedom in the source. SS: the sum of squares due to the source. MS: the mean sum of squares due to the source. F: the F-statistic. P: the P-value.

RESULTS AND DISCUSSION

A total of 170 students responded to the survey, 2 of whom did not complete the whole survey. The remaining 168 responses were used for the analysis. The students participating in the first stage of this study were involved in this survey (Table 2).

There was a much higher percentage of students (24.5%) prefer to use the Revit1 program in their designs. This higher rate was not expected, as they begin computer application courses by studying Revit. The vast majority of respondents (92.8%) indicated that they use CAD either constantly or most of the time. The reason could possibly be due to the frequent requirements of architectural design, execution, and other computer courses.

Table 2:Detailed Results of the questionnaire

		Total	%
Programs that were taught	AutoCAD	94	15.5%
	Revit1	168	27.7%
	Rhino	91	15.0%
	Rendering & animation	62	10.2%
	SketchUp	85	14.0%
	Revit2	63	10.4%
	Other	44	7.2%
Preferred CAD programs	AutoCAD	86	20.7%
	Revit1	102	24.5%
	Rhino	81	19.5%
	Rendering & animation	41	9.9%
	SketchUp	66	15.9%
	Revit2	35	8.4%
	Other	5	1.2%
How often do you use CAD in your design work?	Constantly	82	48.8%
	Most of your working time	74	44.0%
	About half of your working time	9	5.4%
	Occasionally	3	1.8%
	Very rarely	0	0.0%
I can generate a larger number of early design ideas using:	CAD	20	11.9%
	Mixed methods	26	15.5%
	Pencil-based	122	72.6%
The tool that better enhances by ability for creativity in developing a design solution is:	CAD	37	22.0%
	Mixed methods	81	48.2%
	Pencil-based	50	29.8%
I believe that the capability for modifying or changing designs is better using:	CAD	23	13.7%
	Mixed methods	111	66.1%
	Pencil-based	34	20.2%
I feel that the projects in my portfolio that are of better quality are the ones I completed:	CAD	153	56.3%
	Mixed methods	4	1.5%
	Pencil-based	11	4.0%
One thing you like the most about using CAD.	Reduction in time for editing	66	39.3%
	Make corrections easily	53	31.5%
	Accuracy of the drawings	47	28.0%
	Other	2	1.2%
One thing you do NOT like the most about using CAD.	Loss of creativity in early stages	47	28.0%
	Bounded ideation	61	36.3%
	Circumscribed thinking	51	30.4%
	Other	9	5.4%

For preliminarily designs, there was a lower level of CAD preference (11.9%) and more use of pencil-based mode (72.6%). The percentage of students who preferred mixed methods for enhancing the ability for innovativeness and creativity in design solution development (48.2%) was larger than the number who preferred the pencil-based method (29.8%) or CAD only (22%). Regarding the capability for modifying or changing designs, there is a higher incidence of working with both CAD and freehand sketching (66.1%), and a corresponding lower incidence of using pencil-based method (20.2%) or only output from CAD (13.7%). The percentage of students selecting those preferable projects that were generated by the computer-based method (56.3%) was higher than those selecting the pencil-based method (4%) and mixed methods (1.5%).

The remaining items on the design survey requested information regarding the advantages and disadvantages of the CAD method. The advantages cited most often are the reduction in time for editing (39.3%), then the ability to make corrections easily (31.5%), and the accuracy of the drawings (28%). In addition, students cited some other advantages such as the ability to create three-dimensional modeling to enhance visualization of the proposed design and the ability to generate more architectural design solutions.

The most often listed disadvantages included bounded ideation (36.3%) and circumscribed thinking (30.4%). Furthermore, students indicated that loss of creativity in the early stages of design is one of the disadvantages of using CAD (28%).

It may seem inconsistent that there was no difference between the creativity ratings of the projects and the finding that the students preferred the pencil-based method for preliminarily stages of design. However, the rating was conducted on the product, not on the creativity process itself.

An explanation for the preference of the pencil-based design method for preliminary design development may be due to the manner in which the other method, computer-based design, has traditionally been introduced into the architectural design program. Typically, CAD has been used as the tool for producing precisely detailed final drawings than for conceptual design. If students are exposed more to computer-based design as a potential design tool that is introduced early in the design process, students' preferences for pencil-based design may decrease. Another possible explanation for this finding may be due to the difficulties of using computer modeling on CAD in three-dimension. In generating design solution ideas, it is necessary to visualize how the third dimension is affected by the changes made to the two-dimensional plan views and elevations. This visualization is not always an easy concept for students to develop as the mastery of this technique can be time-consuming and difficult. On the other hand, the pencil-based method may be easier to manipulate and use in the beginning stages of design. Another reason could possibly be due to the manner in which the students had taken their sequence of architectural design courses. These students had been taught pencil-based design prior to their instruction in computer-based design. An additional explanation for the preference for the pencil-based design method is that architectural instructors often prefer freehand sketching versus three-dimensional CAD. They often encourage students to use this traditional method in their designs.

The number of students who preferred mixed methods for enhancing the ability for innovativeness and creativity in design solution development was larger than the number who preferred CAD or pencil-based design only. This may indicate that with more exposure to and experience with computer-based design, a greater number of students may prefer the computer for generating creative and innovative design solutions.

The use of CAD in the project greatly enhanced the ability of the students to visualize and communicate their ideas. It is indeed true that CAD has created something of a revolution in the implementation and communication of new ideas. While this did not address the generation of these ideas in the first place, it did undoubtedly assist the creative process as a whole. However, there were some concerns about the modes of communication that were used with instructors and other students. It was observed that having several students crowded around a computer monitor was not the most ideal situation for brainstorming and idea evaluation.

The number of students selecting those portfolio projects that were generated by the computer-based method was higher than those selecting the pencil-based method. Although this was the case, the manner in which the students interpreted their "best work" may have more to do with perspectives, line quality, and the precision drafting available with CAD rather than those projects that more appropriately met the criteria of the design challenge.

The most often listed disadvantage included bounded ideation and circumscribed thinking. Bounded ideation can occur when the constant use of CAD under stressful conditions negatively affects the motivation, and hence the creative potential, of design students. The survey data indicates that most CAD users are affected by this phenomenon. The serious problem here is that the design ideas were limited not only to what is possible with a given tool, but what is easiest. In the case study, time pressures often forced the students to generate intended designs in the easiest way possible. At times, this pushed design decisions away from what best met the design criteria to what was easiest to generate with the tools available. Thus, the ideas and thinking of the student are circumscribed by the CAD tool's capability. This "negative" circumscribed thinking is potentially a barrier to the creative process (Lawson, 2005). Circumscribed thinking arises when a CAD program constraints or "circumscribes" the thinking and problem-solving of the designer. In the ideal situation, a designer is constrained only by the requirements of the task and is free to express their intent on the design. When the CAD tool interferes too strongly in the design process by limiting what can be created, or by encouraging the designer to over-reach the requirements of the task, this ideal is not achieved. Although a large amount of effort has gone into continuously improving the functionality of CAD tools, it is possible that they may never match the imaginative capabilities of designers.

Another disadvantage cited by students is that using a CAD tool for a large proportion of the whole day was not always the most conducive environment for idea generation. It was observed in architectural design courses that more ideas were generated by the students who did not use advanced CAD tools. Furthermore, the best environment for idea generation tended to occur away from computers, characterized by large amounts of sketching and discussion. It seems that the mundane nature of drafting on a computer, exacerbated by technical problems and software bugs, is a distraction from the actual process of designing, especially from idea generation and creative problem-solving.

CONCLUSION

Because of their educational potential, computers are becoming more abundant in architectural design education. In examining the products of creativity, the results of the ratings of the architectural design projects did not indicate a difference in the two design methods regarding the design aspects of the CPAM rating scale. Therefore, it can be concluded that neither design method was found to be superior in the generation of creative architectural products. The use of the computer-based design method did not significantly inhibit, nor did it significantly enhance creativity in the preliminary design stage compared to the pencil-based design method. However, in examining the process of creativity, the students indicated a preference for design methods regarding various stages in the design process. Although the students generally preferred the use of pencil-based design for the generation of early design ideas, computer-based design was preferred for the modification of design ideas and the final drafting of the project. Thus, a combination of design methods is preferred by the students for use throughout the design process. Finally, if implemented correctly, CAD may be an effective method for developing student creativity.

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CONFLICTS OF INTEREST

There were no conflicts of interest as declared by the authors.

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