A study for exploring student’s perceptions on the role and effect of CAD in conceptual design.

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ABSTRACT: The increasing popularity of Computer Aided Design (CAD) in architectural practice has produced a challenge for design education. The overall aim of this research is to understand the role and effect of CAD in architectural design and education, primarily within the conceptual design phase. Through focus group interviews, the research explores the impact of different approaches to CAD education on student’s perception regarding the role and effect of CAD in conceptual design. To achieve the aim a study was conducted with two accredited architectural schools in Australia. Two groups of universities, each adopting a very different approach to CAD education were identified and their enrolled student groups were interviewed. Although the two groups of students being interviewed have been educated in two very different approaches to CAD education, interestingly both groups have acknowledged the importance of traditional methods in conceptual design. The effect of CAD on architectural design and education is primarily seen as a positive and necessary move for the industry and education but more importantly CAD is not seen as a replacement for traditional methods of design, rather it should be part of an integrated ecology of software that facilitates a diverse range of design intentions.

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INTRODUCTION

Driven by the demands of practicing architectural professionals, schools of architecture are being pressured to develop a curriculum to produce graduates that possess high competency in digital technologies (Mitgang, 1999). Boyer and Mitgang (1996) proposed that architectural educators, critics and governing bodies have perceived that a disconnection exists amongst the individual fields of academia and professional practice. Amid the criticisms evident in architectural education there exists a claim that graduates appear to lack the necessary skills to shift from study to professional practice (Crosbie, 1995). Blame for the perceived shortcomings of free-hand sketch using traditional methods is commonly placed on the computer; however, the underlying skills in cognitive visualization also need to be addressed in architectural studies (Angulo, A. H., Davidson, R.J. and Vásquez de Velasco, G.P. 2001). CAD’s role within architectural practice has reached the stage where it is has become one of the standard prerequisites required by clients of architects (Green, 2002). Conversely, educators continuing the on-going debate surrounding CAD’s role in the curriculum put forward arguments emphasizing the importance of developing design skills and building a strong foundation in conceptual investigation. Karloff (1996) argued that the direction of architectural education should remain focused on cultivating life-long learning skills and instructing students to develop stronger technical resolution.

As technology encroaches further upon educational practice, the pressure placed on the adaptation of resources and curriculum could see traditional methods of representation used in conceptual design pushed aside to accommodate this growing trend. Research undertaken by Ostwald and Williams (2008) with the focus on understanding architectural education in Australasia produced key statistical data in the area of resources available to students. Part of the research focused on a thorough quantitative analysis on the teaching and learning environment. In this field the most problematic issue found was that of resources, “Academics identified a worsening situation in their schools in terms of model-making facilities, workshops, laboratories…” (pg. 159). Research also claimed that due to the current trend in technological advancement, and the pressures placed on students to become fluent with this technology for future practice as a professional, “this situation was expected to deteriorate in the future (19%)”(pg. 159). This information identified an area of research that required further investigation and attention, but should focus on understanding technologies impact on traditional media in conceptual design from the viewpoint of the student.

The set of criteria used by educators in the selection of suitable CAD packages and digital design tools for fulfilling a satisfactory academic curriculum is largely subjective. The literature in this field presents results and perceptions of how CAD is being used in the design process from the staff or academics viewpoint, as opposed to the viewpoint of the students themselves. As a result a possible research gap was identified, validating a study into the effectiveness of digital design mediums in conceptual design to providing a valuable insight into students learning and design behaviours. This study was conducted with two accredited architectural schools in Australia. Two groups of universities, each adopting a very different approach to CAD education were identified and their enrolled student groups were interviewed. This study has the potential to aid educators in choosing appropriate CAD and digital design interfaces, aimed at increasing the skill of the student and to facilitate their transition into professional practice.
1. BACKGROUND OF STUDY

The following background to the study is structured in four parts, each dealing with published trends in the field, conflicts in theory, and strengths/weaknesses of arguments and results. These sections include The Conceptual Designer: “Graphic Thinking”, CAD Versus The Sketch: Strength and Weakness, Tools of the Digital Medium: Rethinking the Design Process, and The Digital Interface: The Conceptual Design Environment. The research was aimed at understanding how technology influences a student’s conceptual design process in an academic setting and does not focus on the effects documented in the professional practice of architects.

1.1. The Conceptual Designer: “Graphic Thinking”

Traditionally in conceptual design, the ability to hand sketch has been a vital skill for a student of architecture to possess. Within the design process the sketch contributes to conceptual design as both an iterative tool and as a form of visual uncertainty. The technique of communicating an idea through sketching is discussed by Laseau (2000) who identifies the sketch as “graphic thinking”, a process that facilitates the progression of a “communication loop”. This continuous link between the active senses of the designer and the paper creates a cycle of information that informs and progresses the idea and this notion of “graphic thinking”. Referred to as a process of “lateral transformation” by Goel (1995), the sketch can be viewed as a series of symbols that allows the process of thinking to be visually displayed, showing the change from one conceptual approach to another. Goel identified the ambiguous role in advancing decisions made during the conceptual design phase claiming that the process of “lateral transformation” is required to take place throughout the course of the conceptual design phase. The capability of the system of symbols inherent within sketch methods allows the designer to utilize this cognitive function.

Literature in the field places significance on understanding the role freehand sketching contributes during the conceptual design phase. The sketch forms a dialogue between the designer and the design problem, opening the thinking process of conceptual exploration, the resulting diagram or illustration reflects a level of uncertainty or ambiguity. Won (2001) presented a case with regards to the process of hand drawing that designers demonstrated a “seeing behaviour”, coinciding with a focus on the non-literal elements of the subject allowing the designer to perceive the subject as an alternate form.

1.2. CAD Versus The Sketch: Strength and Weakness

The exponential increase of technological advancement in the field of architectural design has seen CAD develop as one of the principal tools for the generation of technical drawings in the professions associated with the built environment. The exploratory (as opposed to absolute) nature of the hand drawn pen or pencil sketch is now in question as to whether this form of visual communication can maintain its standing, primarily due to the level of implied subjectivity it conveys. Another recognized notion of sketching, as a key component to the conceptual design process, is further emphasized by the argument put forward that according to CAD’s “explicit rather than implicit representation” (Chastain, Kalay, and Peri, 2002) it becomes an unsuitable form of visual communication for early phases of design where focus should be placed on the intangible qualities achievable with a hand drawn medium.

In the field of computer generated image research, hand drawn sketches are recognised as formidable tools of design, having the advantage of low material cost and easy access to begin designing immediately (Jonson 2002). Jonson argued that freehand sketching conveys more substance than final presentation drawing, identifying that sketches have the potential to present the designer with more than one interpretation of the design problem, making the sketch an important investigative tool in the conceptual design process. In a similar way, computer-generated representations can be scrutinised for missing the ambiguous qualities required to deliver “…multiple interpretations and visual shifts in perception associated with design exploration in design processes…” (Won, 2001).

The “draw then modify” principle has been used to describe the process of computer driven software applications (Bilda and Demirken 2003). Research conducted by Bilda and Demirken concluded that during a conceptual design study subjects were more efficient in managing their time, perceiving the design issue, generating a range of solutions and distinguishing spatial components of design in a traditional form of media as opposed to a digital form of media. Limitations in computer-aided design have also been noted in other disciplines. Research undertaken by Stones and Cassidy (2007) examining the strengths and weaknesses of both pencil sketching and digital design (in the field of graphic design) found that student designers who created work using a computer lacked the confidence to produce a range of design alternatives, than those that utilized a drawing process based on traditional methods. In the conceptual design phase, the equipment available for students to interact and input information in CAD applications has been identified as a limitation through relevant literature. The standard tools available for interfacing include a keyboard, mouse and two-dimensional screen with research identifying the need to design and deploy “new computer interfaces for the CAD system... especially in support of conceptual design” (Ye, Campbell, Page, and Badni 2006)

1.3. Tools of the Digital Medium: Rethinking the Design Process

The implementation of digital media in the initial phases of design requires the design process itself to be revisited and conceptualized so that the process can be understood in its basic stage as a different process in which to learn. Researchers have proposed, despite the fact that digital media appears problematic for designers at a conceptual phase of design, that it is the individuals “designing habit” that effects the outcome (Bilda and Demirken, 2003). Abdelhamed (2004) proposes that the method of digital media has undertaken a process of transformation to become more than just a tool to aid the process of design, but to generate ideas and solutions to design problems. It can be seen that the argument surrounding the inefficiency of tools of digital design during the conceptual phase can be re-evaluated to a position that focuses on the incompatibility between traditional processes and digital processes.
of design.

The previously cited re-evaluation is conveyed through literature that frames digital technology as a type of design medium as opposed to a tool in the design process. Researchers have proposed that design using computational media needs to involve the designer in a “different form of input and level of formalization” (Oxman, 2006). Oxman also suggests that the division existing amongst paper-based design and digital representation are significant both in a theoretical and cognitive sense. Research also shows that computational input both in the conceptual and final design phase allows designers to undertake forms that require a degree of complexity that is beyond the scope of human achievement (Sequin, 2001). Sequin’s study found that, the unique characteristics found only within the design phase allows designers to undertake forms that require a degree of complexity that is beyond the scope of a theoretical and cognitive sense. Research also shows that computational input both in the conceptual and final design phase allows designers to undertake forms that require a degree of complexity that is beyond the scope of a theoretical and cognitive sense. Research also shows that computational input both.

The development of 2D and 3D representation made possible through the advancement in computer-generated modelling has greatly expanded designer’s scopes beyond the traditional forms of media. This notion principally relied on physical models, orthographic drawing and freehand sketching, and is supported by Abdelhameed (2004) who claims that developing a design idea through a combination of two and three dimensional representations, is the fundamental basis of exploring a visual design idea within the conceptual design process. In a paper by Simondetti (2002) the author examines the effects of applying physical model making through a computer-generated modelling program during the initial phase of conceptual design, incorporating a study of sketching, CAD modelling and rapid prototyping. Advantages of the study were noted:

“(1) understanding kinetic design, (2) understanding design involving complex geometry, and (3) understanding design at the interface with the human body.” (Simondetti, 2002)

In Bailey’s (2000) paper titled The Intelligent Sketch: Developing a Conceptual Model for a Digital Design Assistant, he uses a method of protocol analysis (founded in psychology by Eastman et al in the 1970’s) to extract information about design thinking in students. The study found that because sketches are driven by the possibilities of design rather than the end result (Laseau, 2000), energy should be directed towards the design of digital equipment that provides a responsive dialogue between designer and their drawing, ultimately “…enhancing the designers understanding of the design situation rather than automate it or transform it” (Bailey, 2000). Bailey empirically demonstrated that students responded well to an examination of their sketch by an expert in the field who provided feedback that made the design problem more comprehensible.

1.4. The Digital Interface: The Conceptual Design Environment

The cognitive nature of an idea formed within the concept stages of design is a significant precursor that evolves during the later phases of design development. Images and diagrams conceived at this level are not typically supported by digital design methods and applications (Schodeck, Becthold, Griggs, Koa, & Steinberg, 2005). For digital design methods to be used as an effective tool during concept stages the designer requires immediate response to input via digital sketching and adequate 3D visualization.

Schodeck, Becthold, Griggs, Koa, & Steinberg (2005) identify digital media applications that are intended for early conceptual design with a tablet based interface that seeks to be replicated in sketchpad design principles. These “stand alone” programs include sketching software applications, parametric modellers and rendering programs that make use of 2D line elements to make the conversion from the traditional hand drawn mediums of design to a system of digital render and modelling. Their research concludes that in order for this digital interface between designer and computer to be successfully achieved the interface must be easy to understand and provide an unrestricted ease of use. The proposed approach strengthens the previously discussed theories that during the conceptual phase computer-aided design is required to imitate or match hand drawn sketch methods.

2. RESEARCH AIM & METHODOLOGY

Within the current explored literature there are inconsistent views on the effect of CAD technologies for supporting conceptual design. The overall aim of the research undertaken was to understand the role and the effect of CAD software in architectural education, primarily within the conceptual design phase. To achieve the aim, a preliminary study was conducted on two accredited architectural schools in Australia.

The first group (Group 1) included universities that appeared to adopt a more traditional method of conceptual design where CAD is predominantly taught and used only for documentation and presentation purposes.

The second group (Group 2) included universities that appeared to teach and encourage the use of CAD in conceptual design.

The main focus of the research – from the perspective of the students – was on investigating how CAD is being used in their conceptual design phase, with interview questions designed to target different stages of the conceptual design process. This study reflected a goal to facilitate research that has the potential to benefit the field of architectural education.

To achieve the aim, a list of objectives was developed. These objectives were reflected in the interview questions posed to the participants and were as follows:
• To understand the participants pre design methods / mediums of design
• To understand CAD’s role in responding to a design brief and its application to contextual awareness
• To understand CAD’s role in generating forms and driving functional requirements in conceptual design
• To understand CAD’s role and effect in presenting a concept during the transition to the schematic design phase
• To understand any barriers evident in CAD’s application to conceptual design and understand current views towards CAD and its future role in architecture education.

A university from each of the invited groups, which first accepted the invitation, participated in the research. The criteria for these institutions to be selected were that they were Australian, geographically appropriate for the scope of the proposed research and must have a Bachelor of Design (Architecture) or Master of Architecture program available. The criterion for a student to be eligible to participate in the interview was that they must be currently enrolled in the Master of Architecture or their final year of the Bachelor of Design (Architecture) and currently undertaking a major design course.

The ‘distributor model’ of contact was employed. This method involved the researcher making phone calls to the participating universities’ Heads of School/Faculty, and asking them to agree to organise for the distribution of the Participant Information Statement/Consent Form to students who met the criteria to participate in the research. Student participants were then able to independently contact the student researcher if they were interested in participating. This process reduced the instance of coercion, as the Head of School is not nominating students to participate. The first 5-10 willing students to respond from each group were chosen. A series of 22 questions were posed during each focus group interview. These questions centered on different aspects and effects of teaching and learning technologically driven methods for conceptual design.

This research is significant, as it provides a comprehensive investigation and analysis of the roles and effects of CAD in conceptual design. The research also outlines areas where CAD was used within the education process, addressing the reasons that encourage the students or prevent them from using CAD products in design. As the information in the field of education was not adequately understood this research will contribute to the success of the architectural education system and in turn the profession itself.

This research provided the selected participants and universities an opportunity to understand and question the use of CAD within their institutions. This research serves to promote a dialogue and establish the links between the research community, students and staff members involved in the architectural education process. This research also provides CAD software developers with perceptions and needs analysis from the perspective of the student, ultimately improving the future development of CAD technology.

3. RESULTS

3.1. Group 1: Student Focus Group Interview

The preliminary questions targeted the level of computer aided tools and software available to the students by the university; ArchiCAD being the main CAD package taught. The data identified that the course curriculum does not promote the use of CAD in conceptual design and that CAD is generally a restriction and a diversity of mediums were necessary in this phase.

Pre-Design: Initial Interaction
It is apparent from the collected data that students tend to use traditional mediums (hand drawing, models etc.) when beginning the conceptual design phase. However, the data also indicated that a combination of traditional and digital mediums was used to calculate volume and mass requirements.

Contextual Awareness: Responding to the Design Brief
Examination of the data showed that all the students use CAD to make a 3D digital form of the site and its context. The data also suggests that this would be the only time that students would use CAD in the conceptual design phase.

Creativity: Driving Form / Function
The compiled data revealed that students both agree and disagree that CAD offers a different or a greater range of ideas to be explored rather than traditional methods. The negative response indicated that’s its only a tool used to present their ideas rather than drive them. The positive response indicated that by exploring unknown areas of the software students could generate new ideas and design concepts. The data indicated that CAD is used to drive the function of their designs during the conceptual design phase.

Transition to Schematic: Presenting the Concept
A traditional method of presentation is more effective in visually conveying an idea or concept. The data also indicated that CAD does aid in the transition to schematic due to its ability to speed up the design process.

Barriers in using CAD
Students faced multiple barriers / problems when using CAD –

• Students needed to consciously ‘dumb down’ their idea in order for CAD to work for them
• No higher education was provided on the more intricate parts of the programs
• Students had to teach themselves new CAD programs and packages in order to keep up with the standard set in the major design course
• Some students had to consciously design without using CAD to keep their direction as the form they were proposing didn’t seem achievable using CAD with their skills and the software available

Closing Remarks / Future Direction
The data collected in this section revealed –

• A mixed response as to whom CAD benefits the most. One student suggested it was the ‘crit panel’, another said it was more beneficial to the student based on CAD’s ability to output efficiently
• Students learned about CAD during their second year at the university; the process was learned ‘step by step’.
• Students only think of CAD as a tool for documentation rather than a tool for a conceptual generative process
• Students see academics and the curriculum being dictated by the programs that practices are using at the time, ‘the current approved by practices trend’
• That current CAD packages and tools within students architectural education need to adapt and be updated as technology advances over time
• That student’s have taken ownership of learning different methods of CAD themselves
• The student’s aren’t using CAD to its full potential; only using a small percentage of the ecology of the software that is available to them
• If complex 3D modelling programs were made available they would use the tools to drive a complex and generative design process
• CAD was being used for documentation and 3D modelling and in 10 years conceptual design will be heading towards ‘more of a mixed media approach’ at the university

3.2. Group 2: Student Focus Group Interview
The data collected from the preliminary questions asked to the participants targeted the level of computer aided tools and software available to the students by the university and revealed a large range of software packages are available to the students. The data identified designated courses and electives that teach students CAD and that the school curriculum promoted the use of CAD from the early stage of conceptual design. Also to emerge was a view that there was a danger of getting too caught up in CAD during the conceptual design phase.

Pre-Design: Initial Interaction
Students tend to use CAD as their initial medium when beginning the conceptual design phase; however a combination of mediums is also used. The data identified a transition point where the students were able to express a new range of design intentions.

Contextual Awareness: Responding to the Design Brief
It is apparent from the collected data that students are using CAD to transpose the brief into a digital form and that student’s use collected site information to contribute to a shared 3D site file.

Creativity: Driving Form / Function
The current CAD tools and programs available to the students at the university do provide students with the ability to explore a different or greater range of ideas and concepts than traditional methods. CAD’s ‘iterative’ process was identified in the data as a major contributing factor to the success of CAD tools in the creative design process. The data identified that students use CAD in one form or another to drive the function of their designs.

Transition to Schematic: Presenting the Concept
Physical models are more effective during a presentation than a digital 3D model. The data also revealed that CAD does aid students in the transition from the conceptual phase to the schematic phase.

Barriers in using CAD
The compiled data indicated that students faced a few barriers in CAD’s application to the conceptual design phase. These barriers / problems included –
• Losing sight of the overall design direction and strategy
• Wasting time on aspects that require minimal technical resolution
• Applying simple ‘button push’ processes that result in banal design outcome

Closing Remarks / Future Direction
The data collected in this section revealed –

• CAD benefits the student, educator and the review panel, but more so the educator
• CAD was introduced in first year at university
• CAD software’s ability to produce multiple iterations of designs was the most use to students, promoted by educators
• Generally, CAD has a positive effect on both education and the industry. However one negative effect for education included the case where students who possess good computer skills can sometimes get away with poor design because of the seductive images they produce
• Students aren’t using CAD to its full potential
• Students would use CAD more if the resources were there to support its growing use
• CAD is a tool for 3D modelling and visualization, in 10 years time CAD is going to be very heavily focused on from year one.

4. COMPARATIVE ANALYSIS

The aim of this research was to understand the role and the effect of CAD software in architectural education, primarily within the conceptual design phase. From the extensive data collection, synthesis and comparison carried out by the researcher a conclusion was established comparing the response of both groups to the list of objectives that was developed to address the research question.

4.1. To understand the participants pre design methods / mediums of design
This data indicated that university Group 2 is using a larger and more diverse range of CAD packages than Group 1, revealing a significant difference in how students in Group 2 are much more likely to use digital methods and mediums to begin their design process. Each group has designated courses that teach CAD, however Group 2 appeared to have more that focused on specific packages such as code based software and parametric design. A difference can be noted in the two student’s group’s attitude towards CAD. Group 1 generally believes CAD is a restriction and a diversity of mediums was more appropriate in this phase. Group 2 generally believed that CAD is an advantage, however noted there was a danger in getting too caught up in CAD during this early phase.

As with the previous data comparison there was a similarity between students in both university groups, indicating that both groups used a mixed variety of mediums when beginning the conceptual design phase, using both mediums and tools in an integrated design approach. However students in Group 1 were more likely to just use traditional methods, using CAD only to calculate volume and mass requirements.

4.2. To understand CAD’s role in responding to a design brief and its application to contextual awareness
A comparison in this section revealed another similarity between the two university groups; both groups are encouraged to use CAD to transpose the brief into a digital visual form. This comparison revealed that this would be the only time that students from Group 1 would use CAD in the conceptual design.

4.3. To understand CAD’s role in generating forms and driving functional requirements in conceptual design
A comparison of these two data sets revealed an almost identical perception of CAD’s role in this section. However students from Group 1 suggested that by exploring unknown areas of the software they could potentially generate new ideas and design concepts, a similar sentiment was expressed by students from Group 2 who stated CAD’s ‘iterative’ process is a major contributing factor to the success of CAD tools in aiding the creative design process.

4.4. To understand CAD’s role and effect in presenting a concept during the transition to the schematic design phase
The comparison of data revealed interesting similarities between the two university groups. The data revealed that both student groups believed traditional methods, such as hand drawing and physical model making, were more effective than using CAD to present their concepts. Both groups also agreed however that CAD aids in the transition between the conceptual and schematic design phases.

4.5. To understand any barriers evident in CAD’s application to conceptual design / understanding current views towards CAD and its future role in architecture education
In regard to understanding current views towards CAD and its future role in education, differences and similarities were revealed during the comparison of the data collected during the closing questions of the interviews. The apparent similarities included –

• CAD’s effect on architectural education and the industry is a positive move, however the current CAD packages and tools within students architectural education need to adapt and be updated as technology advances over time
• Students are not using CAD to its full potential; they are only using a small percentage of the ecology of software that is available to them
• CAD’s current role in education is a tool for 3D modelling and visualization

The apparent differences include –

• Students in Group 2 suggested that in 10 years time CAD is going to be heavily focused on from year one in education; whereas Group 1 suggested that more of a mixed media approach would be adopted
• Students from Group 1 learned about CAD in their second year of university, whereas students from Group 2 learned about CAD in their first year

CONCLUSION

From the comparative analysis it can be concluded that CAD’s role and effect on conceptual design in architectural education is still very much divided between the teaching style and architectural ethos present in each university grouping. The collation and analysis of student responses for each university group has confirmed the expected perception of each university group; Group 1 oriented more towards a traditional approach to design using minimal
CAD; and Group 2 more CAD oriented in its design teaching method. However, there are many similarities and differences that reflect changing perspectives of CAD’s role in architectural education in both university groups. One of the most notable similarities is within the area of Pre Design. The data indicated that traditional methods and a mixed medium approach is ultimately the foundation of the conceptual design process, not the use of CAD at this stage. This was an interesting finding as even though CAD programs are taught to students and encouraged in Group 2 from an early year they are still more prone to using hand drawn methods and creating physical models, a conceptual design process almost identical to students in Group 1. Another notable similarity includes both groups perception of CAD as an effective tool for understanding contextual restraints and using CAD programs to create a 3D digital representation.

As the research questions were designed to stimulate a dialogue surrounding CAD’s role and effect on conceptual design in architectural education, the research revealed interesting insights into the future direction of architectural education. Both groups combined insight, although somewhat hypothesized, highlighted a desire for CAD programs to become further integrated into the structure of the architectural education program as both time and technology progresses. One key discussion within the interviews on the future direction of the degree and the profession revealed an aspiration to create a design and teaching environment that encourages students to ‘rip open’ and explore CAD software packages, pushing the packaged functions beyond their intended purposes.

In conclusion this research found that there is not a ‘singular’ role of CAD software in architectural education, rather a series of roles and functions of the software that are used at different stages of conceptual design and in conjunction with traditional hand drawn and modelling methods. The effect of CAD on architectural education is primarily seen as a positive and necessary move for education and the industry but more importantly (as identified by the overall perception of each university group) that computer-aided design is not seen as a replacement for traditional methods of design, rather integrated with an ecology of software that facilitates a diverse range of design intentions.

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