CAD as a 'Recording' or 'Designing' Tool: Evidence From User Behaviours

Aede Hatib Musta'amal, Dr Eddie Norman, and
Tony Hodgson, Loughborough University, England

Abstract

Previously published research has explored the implications of using CAD for the quality of design development, and the quality of design outcomes (Fraser & Hodgson, 2007; Hodgson & Fraser, 2006; Hodgson & Fraser, 2005; Kimbell et al, 2002). Prior study has also revealed, that users' perceptions affect how CAD is applied, and reflect the benefits received from such use (Robertson & Allen, 1991).

In order to link creativity to the use of CAD, a literature review concerning behaviours associated with creativity was conducted. This was discussed in a PowerPoint presentation presented at the 2007 Design and Technology Association International Research Conference. A framework of seven groups of creative behaviour were identified, particularly *'Novelty', 'Appropriateness', 'Motivation', 'Fluency', 'Flexibility', 'Sensitivity', and 'Insightfulness'*.

Evidence for these behaviours when using CAD was sought by a number of research methods such as interviews, protocol analysis, observations, and design diaries. This paper is reporting part of an initial study undertaken to research the implications of using CAD for creativity in designing. A small-scale case study exploration based on the masters projects by four postgraduate students from the Design and Technology Department at Loughborough University has been carried out.

The results from the current research showed that the use of CAD in designing was linked to design behaviours associated with creativity in the literature.

Key words

computer-aided Design (CAD), creative behaviour, observations, protocol analysis

Introduction

Since first developed, *Computer-aided Design (CAD)* has been going through a rapid technological evolution in terms of its capabilities and use in designing. Today, millions of people around the globe have easy access to and use CAD. Its wide use by designers has led to a range of views on the significant consequences it could bring to individual design ability and efficiency, and the quality of the output. For some, CAD is a useful drafting tool which could help designers to effectively communicate and present their design intent accurately (e.g. Charlesworth, 2007). But for others, it is more than just a great presentational tool, as CAD, is considered able to support designing which is also undertaken within the software (e.g. Hodgson & Fraser, 2005).
Prior studies by Robertson and Allen (1991, 1993) have explored users' perceptions on the role of CAD and the consequent way the users exploited the software. They grouped the perceptions into three categories:

a) *physical capital*: seeing CAD as an electronic/automated drafting tool.
b) supporting *human capital*: to enhance user potential in terms of designing skill and/or creativity.
c) enabling improvements in *social capital*: to improve communications of design information between engineers and/or designers. (*ibid*.:4)

Referring to the first two categories, the CAD users can be considered within two main groups; namely *users who considered CAD as a recording tool (recorder)*, and *users who considered CAD as a designing tool (designer)*. A *CAD recorder* can be defined as a CAD user who uses the software for presenting the final design ideas without actively involving it during the development of design ideas. While, a *CAD designer* can be defined as a CAD user who actively involves the software during designing and also in presenting the final ideas or design intent. Although, in reality CAD users might represent a spectrum between the two categories, these definitions provide a useful starting point for the research.

Researchers have made continuous efforts to explore the potential for CAD to make a greater contribution to the performance of designers (e.g. Bhavnani & Garret, 1993). Lawson (1999) has made arguments on whether CAD would affect individual creativity through experiential examples from a number of architects. He implied that CAD could support the designer in exploring design ideas and give freedom to visualise their creative imagination. Although, expressing concern about the quality of the design outcomes, he clearly agreed that CAD enabled designers to produce convincing and original designs. However, no clear distinction was made between the CAD recorder and designer in the case studies. Further, he noted concern about the lack of research that critically investigates the consequences of using CAD in designing and called for more substantial and appropriate research to be undertaken. These concerns not only related to design practice, but also to design education.

Subsequent to the *CAD/CAM in Schools Programme*, research in the UK has been conducted to explore its implications for the design curriculum and student attainment. Kimbell *et al*. (2002) carried out a study which aimed to compare the designing approaches of students who used CAD with those who were non-CAD users. The findings clearly indicated that it promoted student motivation in designing through the '*real imaging*' visualization features. Students were impressed by the accuracy and the high quality of presentation. Apart from this, the study has suggested that level of skill in using the software would influence students' confidence and effort to involve CAD in designing. However, there was no discussion of the two types of CAD users (*recorder and designer*).

In order to understand the importance of CAD users having adequate skills for them to be able to model their product via CAD, Hodgson and Allsop (2003) initiated a research project involving a group of first year undergraduate students from the Industrial Design and Technology programme, Loughborough University. The study aimed to identify how prior CAD knowledge at school might influence students' ability in developing more complicated CAD models using more complex software. They found that students who had sufficient skill at CAD were able to fully make use of it in the design development process and model more complicated products. These findings supported previous suggestions, that CAD skill is one of the factors that influence designers' perceptions of CAD usage. There was however, still no distinction between the two potential types of CAD user.

Further research has been conducted by Hodgson and Fraser (2005) to determine the *level of CAD capability* and *the nature of its implementation* in UK schools. Some crucial issues such as the possibilities for the use of CAD throughout designing, CAD usage capability, CAD's impact on workshop activity, and the primary use of CAD were explored. The data indicated that CAD was successfully applied for '*post-processes*' e.g. virtual and/or tangible output, which gave substantial indication of CAD's capacity as a recording tool. Still, this study was unable to definitely demonstrate that design development activities were taking place within CAD, despite users identifying the potential of CAD in a wider context.

Due to the inconclusive evidence of CAD's contributions in designing, additional research has been undertaken to explore this matter. Fraser and Hodgson (2006) in their research had implied the occurrence of designing within CAD, but with restricted evidence, due to the poor design development recording strategy employed by participants. In a recent study, Fraser and Hodgson (2007) have continuously emphasized the potential of CAD's capacity as a designing tool, but there is still limited evidence of its application in this way. As a 'stepping stone' towards such evidence, this research explored the occurrence of creative behaviours when using CAD.

A literature review was undertaken to gain understanding of creativity (e.g. Amabile, 1999; De Bono, 1999; Ward *et al*. 1999; Dewulf, 1999; Gilchrist, 1972). Whilst there is a vast amount of published information on creativity, little of this concerns its relationship with CAD in designing. A number of creativity characteristics were recognised, and a structured framework for creative behaviour established. It comprised seven categories which are novelty, appropriateness, motivation, fluency, flexibility, sensitivity, and insightfulness. In order to clarify the meaning of these categories, three descriptors were assigned to each of them to facilitate the observation of creative behaviours during the use of CAD (shown in Table 1).

Samples

Initially, four postgraduate students in the Design and Technology Department at Loughborough University, volunteered to participate in this study. However, only three were available for data collection activities and subsequently completed the participation.

Procedure

A series of qualitative approaches comprising interviews, protocol analysis, observations, and design diaries were carried out for data collection. Interviews were carried out before the design project commenced to give an initial overview of participants' perceptions about the roles of CAD in their projects.

Methods

Creative behaviours	Descriptors	Meaning
Novelty	uncommon	Ability to seek unusual idea(s) to solution
	unexpected	Ability to come up with surprising idea(s)
	original	Ability to come up with unique idea(s)
Appropriateness	useful	Ability to produce practical design idea(s) or solution(s)
	sensible	Ability to have good judgement in making decisions for practical design
	functional	Ability to propose idea(s) or solution(s) that capable of being operational
Motivation	enthusiastic	Showing excitement or interest with the activity
	determined	Firmness in doing things to achieve satisfactory idea(s) or solution(s)
	risk-taking	Not afraid to try new ideas and willing to cope with the consequences
Fluency	spontaneity	Ability to come up with sudden idea(s) or solution(s) without logical planning
	open to new ideas	Receptive to new idea(s) and not sticking to an idea only
	fluency of ideas	Ability to generate idea(s) to fulfil certain requirements in some space of time
Flexibility	exploring possibilities	Allow a variety of approaches through which problems may be solved
	continuous reflection	Continuously evaluating and considering previous or present idea(s) or solution(s)
	associate remote ideas	Ability to combine disparate information into meaningful idea(s)
Sensitivity	understand problem	Ability to see the problem(s)
	display curiosity	Desire to ask or speculate about things
	seek perfection	The act of perfecting previous or present idea(s)
Insightfulness	organizing information	Ability to put together old and new information to gain new idea(s)
	intuitive decision	Ability to come up with a decision without support from logical reasoning
	influence by inspiration	Reaction which is stimulated by instinct or intuition

Table 1: Creative behaviours and their descriptors

During the progress of the design projects, observations, protocol analysis, and design diaries were completed. This allowed researchers to observe behaviours in the natural setting in which it occurred. The protocol analysis and observations were undertaken to provide real time data for analysis allowing the students' design processes to be observed, documented and analysed. The design sessions were also audio and video recorded. Further, predetermined design diaries were provided for the participants to record the use of CAD during their project's completion.
The data have been analysed through the methods shown in Table 2.

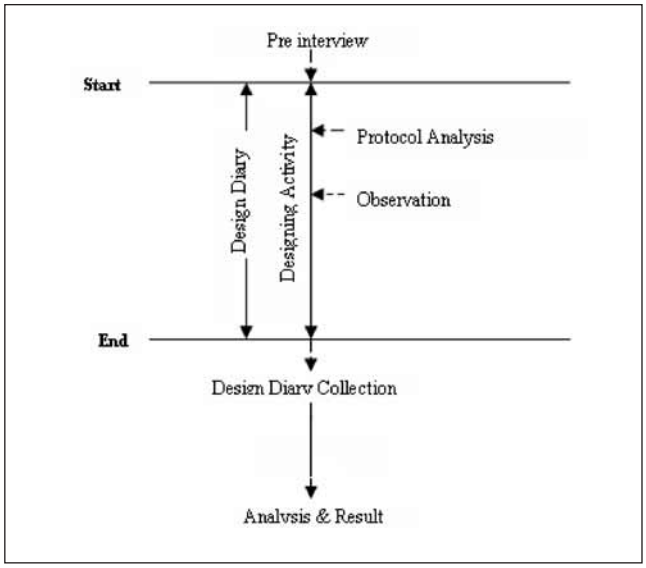


Figure 1: Research framework

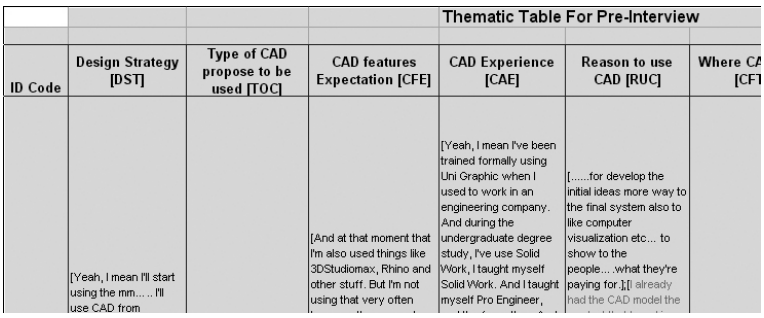
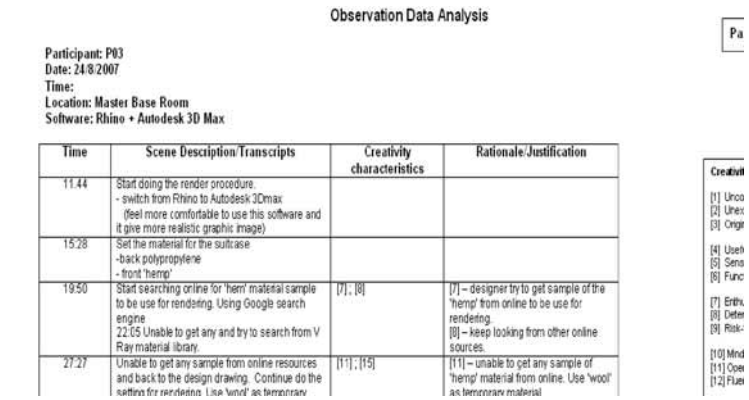
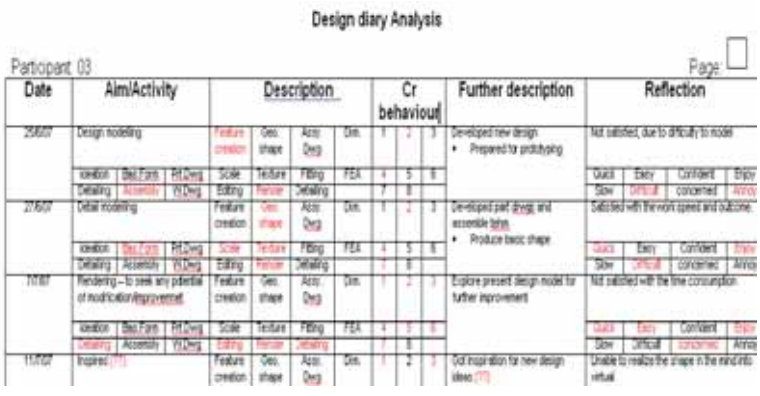
Data collection method	Analysis method	Sample
Data collection method for interviews results shown in Table 3		
Interviews	Transcribed, and grouped repeated ideas into coding themes shown opposite (Britton, 1996)	 Thematic Table For Pre-Interview ID Code | Design Strategy [DST] | Type of CAD propose to be used [TOC] | CAD features Expectation [CFE] | CAD Experience [CAE] | Reason to use CAD [RUC] | Where CA [CF [Yeah, I mean I'll start using the mm..... I'll use CAD from [And at that moment that I'm also used things like 3DStudiomax, Rhino and other stuff. But I'm not using that very often [Yeah, I mean I've been trained formally using Uni Graphic when I used to work in an engineering company. And during the undergraduate degree study, I've use Solid Work, I taught myself Solid Work. And I taught myself Pro Engineer, [.....for develop the initial ideas more way to the final system also to like computer visualization etc... to show to the people... what they're paying for.];[I already had the CAD model the
Data collection methods for creative behaviour occurrences shown in Table 4		
Protocol Analysis	Video clips were analysed and presented in PowerPoint format.	 Design task (2) Time print: 0 m 26 s ~ 0 m 39 s Activity: E Duration: 15 s Creativity chars.: Sensible; understand prob P04: 'I need to consider space here is long enough.... is big enough to keep yo Episode functions: [thinking aloud]---[speculative]
Observations	CAD design activities were observed and video recorded. Video data were analysed to complement the direct observations analysis. (e.g: Paterson et al, 2003; Powell and Steele, 1996)	 Observation Data Analysis Participant: P03 Date: 24/8/2007 Time: Location: Master Base Room Software: Rhino + Autodesk 3D Max Time | Scene Description/Transcripts | Creativity characteristics | Rationale/Justification 11:44 | Start doing the render procedure. - switch from Rhino to Autodesk 3Dmax (feel more comfortable to use this software and it give more realistic graphic image) 15:28 | Set the material for the suitcase -back polypropylene - front 'hemp' 19:50 | Start searching online for 'hem' material sample to be use for rendering. Using Google search engine | [7]; [8] | [7] – designer try to get sample of the 'hemp' from online to be use for rendering. [8] – keep looking from other online sources. 27:27 | Unable to get any sample from online resources and back to the design drawing. Continue do the | [11]; [15] | [11] – unable to get any sample of 'hemp' material from online. Use 'wool'
Design Diaries	Data were analysed by identifying the frequency for each creative behaviour responded by the participant.	 Design diary Analysis Participant 03 Page Date | Aim/Activity | Description | Cr behaviour | Further description | Reflection Design modeling Detail modeling Rendering – to seek any potential of modification/improvement Inspired [11]

Table 2: Creative Data Analysis Methods

Results and Discussions

It was crucial for the study that the types of user which were suggested from the literature could be distinguished. So in the preliminary interviews, participants were also asked the way they were going to involve CAD in their design projects. Some of the responses from the transcriptions are shown in Table 3. It was clear that the four participants were grouped into two types of user categories who perceived CAD as a *recording tool* and *designing tool*. This was based on the feedback that clearly presented their view on how they believed CAD would be involved in the projects. Following these judgments, the participants were observed and the data were analysed to gain insight into how the implications of users' perception on CAD might affect their creativity.

ID Code	Where CAD fits [WFT]	CAD user types
P01	'.....I mostly use CAD for just to get renders..... just to get photo realistic images..... the main purpose.'	Recording tool
P02	'After we've got the final..'	Recording tool
P03	'I think I will introduce computer [CAD} even like in the beginning of my designing [start from the beginning]..... '	Designing tool
P04	'And, basically, I'm using CAD from the start to finish.'	Designing tool

Table 3: Types of CAD user identified

From Table 4, it is shown that higher frequencies of creative behaviours were distinguished from P03 and P04 compared to P02. The data in Table 4 shows that 63 creative behaviour occurrences were observed for P02, 99 for P03 and 100 for P04. These figures indicate that the users who anticipated using CAD throughout designing displayed more creative behaviours than those who simply regarded it as a final design modelling tool. This supports prior research by Robertson and Allen (1991;1993).

Interestingly, the results also indicated that CAD is a tool that provides a conducive environment for creativity by supporting creative behaviours for users who had not anticipated using CAD throughout the designing whilst engaged with the software. This was shown by the creative behaviours recognized from P02 who believed CAD would only be used for presenting the final ideas through its realistic imaging capability. These findings suggest that CAD encourages creative behaviours in users whatever perception they previously had about CAD use. However, seeing CAD as a vital tool for designing would considerably increase the potential of creative behaviours being encouraged.

Creative behaviour	Descriptors	P02	P03	P04
Novelty	uncommon	0	0	0
	unexpected	0	0	0
	original	0	0	0
Appropriateness	useful	0	0	0
	sensible	10	11	16
	functional	0	1	0
Motivation	enthusiastic	2	2	1
	determined	7	9	8
	risk-taking	7	12	11
Fluency	spontaneity	0	0	0
	open to new ideas	0	4	2
	fluency of ideas	3	0	2
Flexibility	exploring possibilities	6	12	7
	continuous reflection	15	13	18
	associate remote ideas	1	3	1
Sensitivity	understand problem	0	0	3
	display curiosity	0	4	2
	seek perfection	8	23	23
Insightfulness	organizing information	4	3	5
	intuitive decision	0	2	1
	influence by inspiration	0	0	0
	Total	63	99	100

Table 4: Creative behaviour occurrences between participants (Recorder vs Designer)

Amongst the descriptors of the seven creative behaviours, those such as open to new ideas, *display curiosity*, and *intuitive decisions* were displayed by P03 and P04, but not P02. The reason might be that the straightforward activity of modelling final design ideas did not facilitate the user in becoming involved with further decision making activity and/or exploring possibilities for alternative design solutions or ideas. However, it was different for P03 and P04 participants, where the use of CAD in design development had encouraged them to explore a wider range of possibilities.

The results also showed that a number of creative behaviours descriptors were not observed for both types of users i.e. *uncommon, unexpected, original, useful, spontaneity*, and *influence by inspiration*. The failure to identify these types of behaviours suggests that the established research instrument needs refinement, in particular, the definitions of observed behaviours. For example, to identify any sign of novelty occurrences, the focus of observation must not only consider the emergence of innovative aspects, but must also consider the evolutionary aspects in designing. This is suggested by Tovey (1989:27) who quoted as:

> Not all product design has to be radically original. The design process for some manufactured products is concerned with creativity in respect of the appearance of the product, but little major change otherwise.

Innovative is referring to a major transformation in a new product design creation which is obviously unique in terms of its form, and/or purpose. Whilst, evolutionary, is 'concerned with the development of existing products, with the new

design evolving out of the current product' (Tovey, 1989:30). These are essentially similar to the definitions of an archetype and evolutionary design proposal by Thistlewood (1990). This would suggest that, creativity, in design should not only be measured by its newness compared to the existing artefacts, but also, in the context of its 'surprising' factor as a result of the modification and/or elaboration of the existing products.

It should also be noted that the data analysis was not based on design outcome, which may be one of the reasons why the novelty criteria could not be distinguished. This is, however, to be the subject of further analysis.

Conclusions

This research has demonstrated that all the participants have displayed creative behaviours whilst using CAD. The findings also emphasised that anticipating using CAD throughout designing made the likelihood of creative behaviours being displayed during design development work greater. In the case of these users particularly significant creative behaviours were identified within their CAD activity.

What remains to be established therefore, is whether or not creative behaviours link to creativity? This will be the subject of further research in establishing the role that CAD could play in contributing to creativity in designing.

Acknowledgement

The authors gratefully acknowledge the support of the University Technology Malaysia in funding this research.

References

Amabile, TM (1999). *The Social Psychology of Creativity*. Springer-Verlag,New York.

Bhavnani, S.K and Garret, J.H (1993). Leading indicators of CAD Experience in Flemming, U and Van Wyk, S. CAAD Futures '93. Elsevier Science Publisher BV, 313-334.

Britton, A (ed) (1996). Advice about Empirical Research. A Middlesex University provided by Andrew Roberts. Accessed via: http://mdx.ac.uk/WWW/STUDY/RESEARCH.htm [13 June 2007]

Charlesworth, C (2007). Student Use of Virtual and Physical Modeling in Design Development-An Experiment in 3D Design Education. *The Design Journal*. Vol. 10(1), 35-45.

De Bono, E (1994). *Parallel Thinking*. Penguin Group: London

Dewulf, S and Bailie, C (1999). *How To Foster Creativity*. Deaprtment for Education and Employment: UK

Gilchrist, M (1972). The Psychology of Creativity. Melbourne Press: Hong Kong.

Hodgson T and Fraser A (2006) 'The Application of Computer Aided Design and Manufacture in School-based Design '. In E W L Norman, D Spendlove and G Owen-Jackson (Eds) *Designing the future, D&T Association International Research Conference 2006*, The Design & Technology Association: Wellesbourne, UK, 59-68

Hodgson T and Fraser A (2005) 'The Impact of Computer Aided Design and Manufacture (CAD/CAM) on School-based Design Work'. In E W L Norman, D Spendlove and P Grover (Eds) *Inspire and Educate, D&T Association International Research Conference 2005*, The Design & Technology Association: Wellesbourne, UK, 95-106

Hodgson T and Allsop C (2003) 'Beyond Pro DESKTOP Computer Aided Design (CAD): The Transfer of CAD-based Design Modeling Skills From Schools to Higher Education'. In E W L Norman and D Spendlove (Eds) Design Matters, D&T Association International Research Conference 2003, The Design & Technology Association: Wellesbourne, UK, 45-49

Kimbell, R, Lawler, T, Stables, K and Balchin, T (2002) 'Pro/DESKTOP in Schools: A pilot research study', J*ournal of Design and Technology Education,* Volume 7(1), 29-34

Lawson, B (1999). 'Fake' and 'real' Creativity using Computer Aided Design: Some Lessons from Herman Hertzberger. *Creativity and Cognition*. ACM: Loughborough, UK, 174-179

Paterson, B.L, Bottorf, J.L and Hewat, R (2003). Blending Observational Methods: Possibilities, Strategies, and Challenges. *International Journal of Qualitative Methods*, 2(1). Article 3. Accessed via: http://www.ualberta.ca/iiqm/backissues/2_1/html/patersonetal.html [13 September 2007]

Powell, E.T and Steele, S (1996). *Collecting Evaluation Data: Direct Observation*. Program Development and Evaluation of Wisconsin University. Cooperative Extension Publications: USA. Accessed via: http://learningstore.uwex.edu/pdf/G3658-5.pdf [2 April 2008].

Robertson, D and Allen, T.J (1991). CAD System Use and Engineering Performance in Mechanical Design. WP# 3251-91. Sloan School of Management. Massachusetts Institute of Technology. Accessed via http://hdl.handle.net/1721.1/2338 [23 December 2007]

Robertson, D and Allen, T.J (1993). CAD System Use and Engineering Performance. Transactions on Engineering Management. *IEEE* Vol.40(3). August 1993, 274-282

Accessed via http://ieeexplore.ieee.org/iel1/17/6027/00233189.pdf [2 April 2008].

Thistlewood, D (1990). The Essential Disciplines of Design Education in Thistlewood, D (Ed). *Issues in Design Education*. Longman: New York, London.

Tovey, M (1989). Drawing and CAD in Industrial Design. *Design Studies*, Vol. 10 (1), January 1989, Butterworth & Co (Publishers) Ltd, 24-39.

Ward, T.B et al (1999). *Creativity and the Mind: Discovering the Genius Within*. Plenum Press: New York, London.