LINKS BETWEEN CAD AND CREATIVITY: REALITY OR MYTH?

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ABSTRACT
A new perspective on how CAD might influence creativity in designing has been explored in this paper, based on an initial research investigation with postgraduate design students. The aim of the study was to distinguish whether creative behaviours were promoted through the use of CAD in designing. From the literature review, a number of creativity characteristics were distinguished and grouped into seven categories which were novelty, appropriateness, motivation, fluency, flexibility, sensitivity, and insightfulness. Research methods such as interviews, protocol analysis, design diaries, and observations have been employed to seek the links between CAD and creative behaviours in design activity. This paper presents and discusses the findings from the application of these methods in a number of case studies. From the research findings, significant relationships between the use of CAD and creative behaviours were established. Evidence from, in particular, protocol analysis will be presented showing these links. Further research will analyse a larger sample and explore the link between creative behaviours and creative outcomes.

Keywords: Computer-aided Design (CAD), creativity, creative behaviours

1 INTRODUCTION

Computer Aided Design (CAD) is a well-established technique that is now commonly used to facilitate designing. Consequently, it has also been introduced in design education worldwide. For example, the CAD in Schools programme was introduced in the UK 1999. Research has been conducted subsequent to this initiative to explore its implications for designing. A pilot study conducted by Kimbell et al [1], found that students displayed their enthusiasm for using CAD in designing as it helped them to 'present works professionally', 'visualise the ideas/objects', and 'work accurately'. These findings supported prior research by Robertson and Allen [2] which indicated that CAD would facilitate the designer in analyzing and communicating design work efficiently. However, in a further research study Hodgson and Allsop [3] found that skill was an essential factor in enabling CAD to be used effectively and with confidence for design development and modelling tasks. A later study by Hodgson and Fraser [4] showed that CAD was successfully supporting 'post processes' in design development and was a useful presentational tool. The virtual reality features in CAD provided designers with an efficient environment to communicate their design thinking with adequate aesthetic quality and design details [5].

Robertson and Allen's study also investigated the links between the types of CAD usage perceptions and users' engineering performance [2] and Bhavnani and Garret [6]

studied the effects of different levels of CAD users' experience (e.g. novice, regular, and expert) on their behaviour in using CAD and the quality of outcomes. These and further studies [eg 7, 8, 9, 10] have been seeking to understand the affects of the use of CAD on the designer's ability and performance whether in the industrial or educational sector. However, as reported by Lawson [11], there has been a lack of research exploring the links between the use of CAD and creativity. A recently reported study by Charlesworth [12] stated that CAD could not facilitate the development of new concepts as other design tools, such as physical modelling, did. It was claimed that CAD, had less significance as a designing tool, and suggested that it was only appropriate as a finishing tool to finalise design proposals. The research reported here explores the link between CAD and creativity through the investigation of behaviours reported in prior research to be linked to creativity, and, in turn, the relationship of such 'creative behaviours' to the use of CAD.

2 CREATIVE BEHAVIOURS

Researchers agree that creativity is a complex and 'slippery concept' for which definitions are elusive [13, 14]. Rather than have one universal definition, the concept of creativity is described by a variety of definitions [15]. A literature review of the publications concerning creativity written by leading researchers has been conducted [eg 16, 17, 18, 19, 20, 21]. In order to establish a structured framework for the research, the characteristics of creative behaviour identified by such researchers were distinguished as indicated in Table 1. The characteristics were then grouped into seven categories of creative behaviour, novelty, appropriateness, motivation, fluency, flexibility, sensitivity, and insightfulness.

In order to clarify the meaning of these categories for the researcher and participants, three descriptors were assigned to each of these categories (also shown in Table 1). These descriptors were intended to facilitate the observation of creative behaviours during the use of CAD. Further explanations were often required by the participants and the additional phrases used are also shown.

3 METHODS

3.1 Samples

This initial study was conducted with a number of post-graduate students in the Design and Technology Department, Loughborough University. The students were given a brief presentation about this research and how they could be involved as participants. Following the presentation, four students volunteered, although one only completed the preliminary interview. The study was based on their masters design projects.

Table 1 Participants' types of CAD used and skill competencies

Participant	P01	P02	P03	P04
Type of CAD (intended to use or used)	Rhino and ProEngineer	ProEngineer	Rhino	AutoDESK Inventor
Competency	• Formal training – via undergraduate and post-graduate course	• Formal training – via on-job training different type software [IDEAS]	• Self-learning	• Formal training – via on-job training [UniGraphic] • Self-learning [SolidWork and ProE]

3.2 Procedure

A series of qualitative approaches comprising interviews, protocol analysis, observation, and design diaries were chosen. Interviews were carried out before the design project commenced to give an initial overview of the participants' perceptions about the potential roles of CAD in their projects. The interviews were recorded and later transcribed. An observation schedule was used to record the occurrence of creative behaviours and video was also used in some of these sessions to allow later analysis. Protocol analysis as recommended by Young [22] was also used

> *'to capture what the subject is actually doing; to provide a source of insights during the early phases of investigation of a behaviour'*

Summaries were prepared of the designing sessions for which protocols were recorded using PowerPoint. In order to give a more complete record of the use of CAD, participants were asked to keep a design diary for their project in a predetermined format as discussed by Pedgley [23] and Crosbie [24].

Table 2 Creativity characteristics and creative behaviours categories

Creative behaviour categories	Literature references	Creativity behaviour descriptors assigned	
Novelty	Originality [e.g. 19, 20, 21] etc.	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	Appropriate for its purpose [19] Practicle or sensible [20] etc.	Useful	Ability to produce practical design ideas or solution.
		Sensible	Ability to have good judgement in making decision
		Functional	Ability to propose ideas or solution that capable to operate.
Motivation	Risk-taking [e.g. 21] Self confident [21] Enthusiatic [21] Provocative [18] Preference for complexity [e.g. 16, 21] Complexity of thinking [19] etc.	Enthusiastic	Showing excitement or interest with the activity
		Determined	Firmness in doing things to achieve satisfactory ideas or solutions
		Risk-taking	Not afraid to try new ideas and willing to cope with the consequences
Fluency	Fluency of ideas [e.g. 19] Receptive to new ideas [21] etc.	Spontaneity	Ability to come up with sudden ideas or solutions without logical planned
		Open to new ideas	Receptive to new ideas and not only stick only to an idea.
		Fluency of ideas	Ability to generate ideas to fulfil certain requirements in some degree of time
Flexibility	Flexibility of ideas [20] Flexibility of thinking [e.g. 19] Elaboration [e.g. 20] Plays with ideas [21] etc.	Exploring possibilities	Allow the varieties approach which problems may be solved
		Continuous reflection	continuously evaluate and considering previous or present ideas or solutions
		Associate remote ideas	Ability to combine disparate information to meaningful idea(s)
Sensitivity	Sensitivity [e.g. 16] Sensitivity to problem [e.g. 19] etc.	Understand problem	Ability to see the problem
		Display curiosity	Desire to ask or speculate things
		Seek perfection	The act of perfecting previous or present ideas
insightfulness	Insightfulness [20] Intuitive [e.g. 21] etc.	Organizing information	Ability to put together old and new information to gain new idea(s)
		Intuitive decision	Ability to come with a decision without supported by valid or logical reasoning
		Influence by inspiration	Reaction which stimulate by instinct or intuition.

4 RESULTS AND DISCUSSION

As shown in Table 3, 247 creative behaviours occurrences were identified from the study. Seventeen behaviours were recorded as occurring at least once. From the protocol analysis, 122 occurrences were recorded, whilst video observation resulted in 50, design diaries in 46 and direct observation in 29.

Table 3 Frequency of creative behaviours occurrences from the study

Creative behaviours categories	Creative behaviours descriptors	Protocol Analysis	Video Observation	Direct Observation	Design diaries	Total	% Percentage
Novelty	uncommon					0	0
	unexpected					0	0
	original					0	0
Appropriateness	useful				4	4	2
	sensible	23	2	2		27	11
	functional	1			7	8	3
Motivation	enthusiastic	1	3	3	3	9	4
	determined	3	7	6	6	22	9
	risk-taking	15	4	3	2	24	10
Fluency	spontaneity					0	0
	open to new ideas	2	3	1	2	8	3
	fluency of ideas	5			3	8	3
Flexibility	exploring possibilities	14	5	3	1	23	9
	continuous reflection	23	10	3		36	15
	associate remote ideas			1	1	2	1
Sensitivity	understand problem	3			3	6	2
	display curiosity	4	1	1	3	9	4
	seek perfection	18	13	5	5	41	17
Insightfulness	organizing information	10		1	2	13	5
	intuitive decision		2			2	1
	influence by inspiration				4	4	2
	Total	122	50	29	46	247	100%

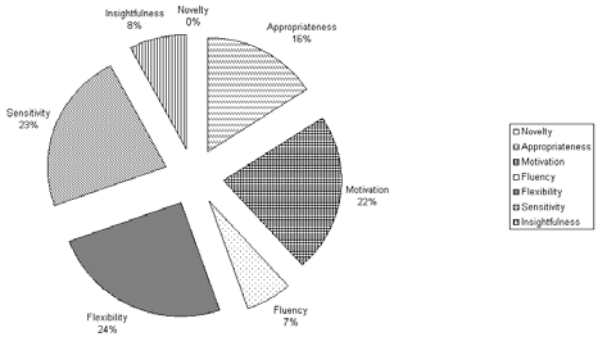

Figure 1 Percentage of creative behaviour occurrences from clustered data obtained

Further analysis showed that the percentage of creative behaviour occurrences varied from 1% to 17%. The most frequent behaviours were 'seek perfection' (17%), 'continuous reflection' (15%), 'sensible' (11%), 'risk taking' (10%), 'exploring possibilities' (9%), and 'determined' (9%). Others recorded at between 1% to 5% were 'fluency of ideas', 'display curiosity', 'open to new ideas', 'understand problem', 'determined', enthusiastic', and 'functional'. Figure 1 shows the data obtained clustered under their creative behaviour categories. The chart indicates that six out of the seven creative behaviour categories had been recorded within the data. The most occurrences were 'flexibility' (24%), 'sensitivity' (23%), 'motivation' (22%), and 'appropriateness' (16%) Less frequent were 'insightfulness' (8%), and 'fluency' (7%). No occurrences were recorded for 'novelty' or its associated creativity characteristics 'uncommon', 'unexpected', and 'original'.

The results show that a number of creative behaviours were consistently detected during the design sessions, and hence indicate creativity's potential relationship to CAD. The most frequently occurring creative behaviours were 'continuous reflection' and 'to seek perfection' . This suggests that CAD might facilitate the designer in the periodic assessment of design ideas and in making continuous efforts to improve them. This finding also indicates that CAD might have a more significant role in supporting

designers' development of creative ideas than previous research studies have suggested (eg Charlesworth's analysis that CAD is essentially a presentation tool [12])
The failure to identify novelty or its associated creative behaviour characteristics suggests that the research instrument design does not allow this category to be recognized. This needs further analysis, but is perhaps unsurprising given that these attributes tend towards external rather than internal perspectives.

5 CONCLUSIONS

Creativity is seen as a key aspect of human responses to all aspects of sustainability, whether economic, social or environmental. Designing has a key role to play in the creating of preferred futures, and it is vital that the tools used for designing are supportive of creative behaviours. This research suggests that even in its current forms, CAD has a role to play in this arena.
The seven categories of creative behaviours derived from the literature provided a framework for observing and recording their occurrences when CAD was used in designing. To facilitate the process of observing the occurrences, it was found to be necessary to assign creative behaviours descriptors to each of these categories. The research instrument allowed six of the seven categories to be observed during the use of CAD. The results allow the recognition of the role that CAD could play in relation to creative behaviours, and their link to creative outcomes will be the subject of further research (Figure 2). The creative aspects of the outcomes will be defined by the various design stakeholders.

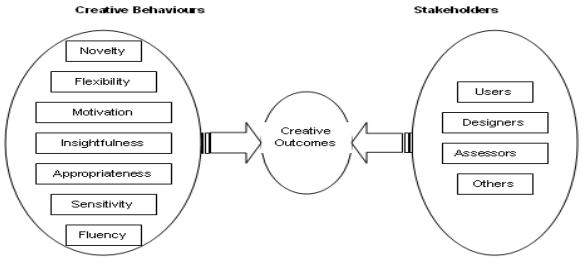

Figure 2 Linking creative behaviours and creative outcomes

REFERENCES

[1] Kimbell, R, Lawler, T, Stables, K and Balchin, T .Pro/DESKTOP in Schools: A pilot research study, *Journal of Design and Technology Education*, 2002 Volume *7(1)*, 29-34.

[2] Robertson, D and Allen, T.J .*CAD System Use and Engineering Performance in Mechanical Design*,[PDF] Massachusetts Institute of Technology. Available: http://hdl.handle.net/1721.1/2338 [23 December 2007], (1991).

[3] Hodgson A.R. and Allsop C . Beyond Pro DESKTOP Computer Aided Design (CAD): The Transfer of CAD-based Design Modelling Skills From Schools to Higher Education. In E W L Norman and D Spendlove, eds., *Design Matters, DATA International Research Conference*, pp.45-49 (The Design & Technology Association, Wellesbourne, UK, 2003).

[4] Hodgson A.R and Fraser A .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, DATA International Research Conference*, pp.95-106, (The Design & Technology Association, Wellesbourne, UK, 2005).

[5] Fraser A and Hodgson A.R .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, DATA International Research Conference*, pp.59-68. (The Design & Technology Association, Wellesbourne, UK, 2006)

[6] Bhavnani, S.K and Garret, J.H. Leading Indicators of CAD Experience in Flemming, U and Van Wyk, S, eds. CAAD Futures '93, *Elsevier Science Publisher BV*, 1993, 313-334.
[7] Fraser A and Hodgson A.R . Computer Aided Design: Implications for pupil attainment and assessment. In E W L Norman and D Spendlove, eds., *Linking learning, DATA International Research Conference*, pp.21-26 (The Design & Technology Association, Wellesbourne, UK, 2007).
[8] Asperl, A. How to Teach CAD. *Computer-Aided Design Applications*, 2005, 2 (1-4), 459-468.
[9] Spendlove, D and Hopper, M. Creativity and Technology and ICT: Imagining Possibilities in a Digital Age. *Data International Research Conference 2004:Creativity and Innovation*, pp.173-178, (The Design & Technology Association, Wellesbourne, UK, 2004)
[10] Connolly, P.E. Introducing Students to CAD Selection and Control Technology Issues. *GraphiCon'2001* (Nizhny Novgorod, 10-15 September, 2001)
[11] Lawson, B . 'Fake' and 'Real' Creativity using Computer Aided Design: Some Lessons from Herman Hertzberger. (*ACM :Creativity and Cognition*, Loughborough, U.K., 1999)
[12] Charlesworth, C . 'Student use of virtual and physical modeling in design development-An experiment in 3D design education', *The Design Journal*, 2007. Volume 10(1), 35 – 45.
[13] Spendlove, D. Creativity in Education: A Review. *Design and Technology Education: An International Journal*, 2005. 10 (2), 9-18.
[14] National Advisory Committee on Creative and Cultural Education-NACCCE. *All Our Futures: Creativity, Culture & Education.* (Department for Education and Employment, United Kingdom, 1999)
[15] Dewulf, S and Baillie, C.*How to Foster Creativity.* (Department for Education and Employment, United Kingdom, 1999)
[16] Amabile, TM . *The Social Psychology of Creativity.* (Springer-Verlag, New York, 1999)
[17] Ward, T.B *et al*. *Creativity and the Mind: Discovering the Genius Within.* (Plenum Press, New York, London, 1999)
[18] De Bono, E . *Parallel Thinking.* (Penguin Group, London, 1994)
[19] Gilchrist, M. *The Psychology of creativity.* (Melbourne Press, Hongkong, 1972)
[20] Finke, R A *et al*. *Creativity Cognition:Theory, Research and Applications.* (MIT Press, Cambridge Massachussetts London, 1992)
[21] Davis, G A. Barriers to Creativity and Creativity Attitudes in Runco, M A eds. *Encyclopedia of Creativity Volume 1*. 583-589 (Academic Press, San Diego, 1999)
[22] Young, K A. Direct from the source: the value of 'think-aloud' data in understanding learning. *Journal of Educational Enquiry*, 2005, 6 (1).
[23] Pedgley, O.F . *Industrial Designers' Attention to Materials and Manufacturing Processes: Analysis at Macroscopic and Microscopic level*. (Loughborough University. PhD Thesis, 1999)
[24] Crosbie, T. Using Activity Diaries: Some Methodological Lessons. *Journal of Research Practice*, 2 (1), Article D1. 1-13. (ICAAP, 2006)

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