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DESIGN PROBLEM-SOLVING: UNDERSTANDING THE SIGNIFICANCE OF ITERATIVE-BEHAVIOUR IN DESIGN

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Abstract

Different concepts and definitions associate iterative-behaviour with repetition. This study consider iterative-behaviour simply means as the act that involve repetition of activities to improve the evolving design. The research further investigate the significance of designer iterative behaviour in design using sketching as the media for design interaction. The retrospective protocol analysis of the video data have identified and measure designer iterative behaviour in design, through a sketching and scoring sessions by five (5) final year undergraduate students and five (5) design tutors, all from the Department of Architecture, University of Technology Malaysia. The design and score were qualitatively and quantitatively compared using close group discussion and the Pearson correlation coefficient analysis. The result shows that in design problem-solving, designer iterative-behaviours were not statistically significant in determining the quality of design.

Keyword: Iterative-behaviour, modification, revisit, fixation, representation

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INTRODUCTION

Iterative-behaviour simply means involving repetition of activities to improve an evolving design (Eppinger, Nukala & Whitney, 1997). Different concepts and definitions associate iterative-behaviour with repetition. Among research specifically conducted to measure iterated-behaviour uses straight observation, interviews, questionnaires, and protocol analysis with records of verbal and actions of real design activity (Stauffer & Ullman, 1991; Ericsson & Simon, 1980) To date, there has been little research specifically addressing issues of designer iterative-behaviour in design (Jin & Chusilp, 2006). Literature indicated repetitive actions such as physical actions, sign language, and eye movement, and sketching activities such as regroup, interpret, reorganize, generate, revise, refine and consolidate are all form of iterative-behaviour developing a design idea (Robbins, 1994; Gero, Tversky & Purcell, 2001; Suwa & Tversky, 1997; Schön, 1983; Goldschmidt & Smolkov, 2006; Safoutin, 2003). However, studies on the relationship of iterative-behaviour and sketch quality was slightly under researched. To this end, this study had successfully observed, identified and analysed some of the above classification of iterative-behaviour in design problem-solving that uses sketching as the design tool (Furlinger & Moore, 2008; Aguero et al., 2010).

THEORETICAL FRAMEWORK

In recent times information and communication have become key features in any technological advance. The use of sketch as a medium for communication that has begun in early civilization and has continued up to the present digital era for design ideation. This study adopted a method use to study designer behaviour by Adams and Atman (1999) using fresh and senior students in their engineering design coursework. The focus of their work was to identify designers' behaviours, such as the monitor, search, verify, plan, redefine and capture, and further related to design competency. The research method used was verbal protocol. Alternatively, this study used sketching and pin-up design assessment as design media and scoring tool. Coding categories were equally used to describe and measure the specified required behaviour. Although the result of their study suggest designer behaviour is a significant component of design activity, whereas this study suggests otherwise. Their result indicates measures of designer activities correlate positively with design success, and senior students tend to have more efficient behaviour than freshman students (Adams & Atman, 1999).

The architects are trained professionals charged with the responsibilities of solving design problems and managing the building processes. The behaviour of these professionals could provide insight into their problem-solving processes; therefore lacking in this knowledge constitutes a significant research gap in the study of Architectural design process. Iterative-behaviour is the act of repetitive behaviour, usually with the aim of achieving the desired goal, yet the occurrence

of iterative-behaviour in architectural design is under-researched. In addition, since sketch is a common visual thinking tool for design, the study of designer behaviour with regards to it potentially forms an important issue of research in the architectural design process. Findings and results of this kind of study can assist stakeholders in design domains to improve on existing manual and traditional methods of design problem solving. The main objectives of the study are to identify and investigate the role of designer iterative-behaviour in sketching using final year undergraduate architecture students and design tutors.

ITERATIVE-BEHAVIOR

According to Wynn, Claudia and John (2007), iterative-behaviour has five (5) attributes namely repetition, revisit, rework, modification and fixation. Repetition means the repetition of a process such as do it again, reworks, copy, delineation and revisit activities until you are satisfied with the outcome of your design. Copy activity means the act of duplication or reproduction direct or indirect transfer of drawings from the same sheet or between two sheets. Another aspect of repetition considered is delineation as the process of outlining or defining an object for further clarification by tracing, shading or colouring. According to Wynn, Claudia and John (2007), modification is the refinement of primary characteristics of secondary characteristics by enhancing and integrating of shapes, lines or texture together with maintaining the originality of the design. Also, by combining and amalgamating different parameters of various shapes to converge as well-defined design (Wynn, Claudia & John, 2007).

Visual or Haptic visitation using eye movement or haptic hand contact during sketching are other forms of iterative-behaviour found in this study. Visual visitation refers to designers' act of visit and revisits with eye movements between drawing sheets at a distinctive time interval during the sketching session, while Haptic visitation means designers transformation moves between drawing sheets using physical hand movement during sketching. Also Haptic and Visual visitation are also found to transfer or communicate information ideas or to draw during design. Further research can prove the need to develop a computerized designer haptic sketching tool for effective sketching activity. Figure 1 illustrates visual and haptic visitations in the sketching session. According to Bilda, Gero, & Purcell (2006), designers' undergo some premature difficult caused by cognitive and behavioural activities such as brainstorming and handling tools during sketching. A moment where innovation is blocked (Figure 2). The fixedness occurs as a result of identifying and finding solutions to the problem using knowledge, skills, experience, measure, construct, observe, tasks and information or handling sketch working tools such as pencil, pen, and drawing sheet. Designers' communicate their ideas using methods such as visual information transfer either manually or computerized. According to Fish and Scrivener (1990) designers communicate abstract and concrete ideas using

imagery and sketches (Abstract), schematic drawings and 3D modelling (Concrete). This study used the same concept to categorized designers embodiment design as Concretization while Abstraction represents the method of preliminary designs presentation. This study used the 5 classifications of iterative-behaviour illustrated by Wynn, Claudia and John (2007) and in Table 1 as the variables that will represent iterative-behaviour in the research.

Figure 1 Designer Visual and Haptic Visitations during Sketching Activity

Figure 2 Designer Cognitive Fixation in Design

METHODOLOGY

Among methods of studying design activities are protocol studies, observation, interviews, content analysis, close group discussion and linkography. Eastman conducted the first protocol study in 1968 in which experienced architectural designers were asked to redesign the interior of a residential bathroom (Akin & Lin, 1995).

Protocol studies is classified into content oriented and process oriented studies (Gero, Tversky & Purcell, 2001) where the content-oriented approach is centred on the study of the drawings produced, such as sketch, CAD drawings, and models while, the process-oriented approach is the study of the process of production such as behaviours, verbal use, and gestures. Most recently an empirical protocol analysis was used to compare two design working environments, which were manual pencil and paper and the monitor, keyboard, mouse working environments, using FBS, Chi-square Test, and Paired-T test (Tang, Lee & Gero, 2010).

This study select protocol study as research methodology because of the ability to study procedures based on behaviour, verbalization, and gestures found in architecture, industrial design, mechanical engineering, electronic engineering, and software design conducted in an observed experiment involving a drawing or sketching process (Cross & Anita, 1996).

The aim of this research is to identify and investigate the significance of designer iterative-behaviour in design problem-solving. The research method and design include stages of experimental design, subject recruitment, conducting experiments, transcribing protocols, coding schemes, quantitative and qualitative comparisons using close group discussions with a supervisor and members of the research group, literature review and non-probabilistic experiment that established findings and possible options for future research.

EXPERIMENTAL DESIGN

The experimental design consists of planning, positioning, and distribution of experimental components such as designers, instruments with appropriate distribution of methods, processes, time, position of the instrument, space allocation and other facilities required for the study. The design consists of the designers positioning, design task and arrangement of supporting instruments. The designers are five highest grade score final year students of architecture selected based on their sketching ability, design grade and willingness to participate in the exercise. The selected subjects worked independently for a period between 45 to 60 minutes.

The design problem requires the design of an internet café for the international student of UTM. The café should have a range of shopping and commercial shops, along with some public, cultural and social space within the same site. It will also have some courts. There shall be adequate parking facilities and landscaping to provide the student with a sense of identity. Pedestrian paths and sidewalks shall ensure safety for the student from vehicular movement. The proposed design shall aim to evolve a more humane internet café through sustainable strategy, appropriate construction and technology, innovative planning, creative architecture, and sustainable environmental design. These shall be the main criteria for the evaluation of the project.

Experimental procedure akin to this research experiment was conducted using two high-level video cameras in the corners of the room20. One of the cameras points to the designer behaviour while the other to the sketching activity (Dorst & Cross, 2001). This study also used three video cameras, one digital photo camera, film editing computer system, stopwatch, bell, voice recorder, loudspeakers, drawing sheets and instruments, table and chair.

These instruments are technically arranged in an Audio/Visual Lab as illustrated in Figure 3.

Figure 3 Experimental Set-up

DESIGN ASSESSMENT

In a similar context, a research study conducted an experiment that uses design tutors assessments as a method of obtaining the overall 'quality of a design using five independent, skilled design teachers from the TU Delft Faculty of Industrial Design Engineering, all of whom are also practicing designers to assess the designs (Dorst & Cross, 2001). Below is the procedures of the design quality measurement set-up:

First, the assignment was read, and some of the relevant information were shown to the judges. The judges could ask questions for further clarification. Slides of all the concepts were shown in random order for 15 seconds, accompanied by a one-sentence summary to explain the way each of them works.

The scoring categories together with the design concepts are presented to the judges for scoring. The scoring categories are creativity, aesthetics, technical aspects and ergonomics, and business aspects. In the last run-through, the judges were asked to give total judgments of the concepts. Thus, the 'total' judgments is not a mean of the other scores, but a separate, 'overall impression' score (Dorst & Cross, 2001).

In this research, the assessment was done by experienced architectural design academicians from the architecture department at the Faculty of the Built Environment, Universiti Teknologi Malaysia. The drawings produced by the students was collected immediately after every experimental session and immediately presented to the assessors for scoring.

The scoring process was the same as the normal "pin-up" studio design assessment. Four different criteria were used to judge a design where each criterion have a maximum of 25% marks which in sum gives a total of 100% marks. The first criterion is designer ideation (Aesthetics order) which is the role of achieving a sense of unity or synthesis through the characteristics of shapes,

patterns, or detailed that constitute the design (Laseau, 2001). The second criterion is designer skills (Proficiency in communication) which represent the designer ability to communicate explicitly design ideas (Laseau, 2001). The third criterion is the progression (transformation) in design, which is the transformation of concept and detailed design (Laseau, 2001). The final criterion is the clarity of the information contained in the drawing (Laseau, 2001).

RESEARCH DATA

The process of data collection is classified into phases of different protocols starting with an introductory warm-up exercise before proceeding with both sessions (design and scores). The first category of data is the drawing while the second category is the information derived from video record based on the five variables that represent iterative-behaviour, i.e. repetition, modification, revisit, representation, and fixation. Then the third and final category which is the result of the design quality measurements carried out by the design tutors (Data on Design Quality Measurements).

Table 1 Proposed Coding Categories for the Study of Iterative Behaviour

ACTIVITIES	CODE	ACTION	DESCRIPTION
Repetition	C1 D1	Copy Delineation	The act of duplicating and defining objects in sketching
Modification	E1 N1	Enhancement Integration	Adding of lines, colour, texture, magnitude as well as connecting shapes in sketching
Revisit	V1 H1	Visual Haptic	Designer eye and hand contacts during sketching activity
Fixation	C2 B1	Cognitive Behavioural	Designer fixedness during caused by Brainstorming or physical actions
Representation	C3 A1	Concretization Abstraction	Detailed and conceptual design

The authors further divided the five variables into ten sub-variables of copy, delineation, enhancement, integration, visual, haptic, cognition, behavioural, concretization and abstraction. These ten sub-variables are the designer behaviour that represents iterative-behaviour in the design session. The second category is the score that is produced by the four judges. The scoring variables include ideation, clarity, skills, and progression which collectively give the actual measurement of the sketch. Each variable is assigned with 25% weight, and the sum of the four variables makes the actual measure of the design. The approach used in extract the data from the data involves the use of various tables and codes for data categorization and collection.

ANALYSIS AND RESULT

Processing and summing designers' iterative-behaviour and judges score has established the figures that has been used for qualitative and quantitative data analysis. The two different analysing factors are judges' score and iterative-behaviour. Table 2 illustrate the sum of individual designer iterative-behaviour and score.

Table 2 Data on Designers Iterative-Behaviour and Score

Designers	Iterative-behaviour	Score
D1	166	74
D2	204	79
D3	122	79
D4	161	62
D5	242	69

Based on the result of the observed designer iterative-behaviour as presented in Table 3, Figure 4 indicated that the relationship between the sum of iterative-behaviour and score (column 2 and 3 in table 2) was negative and weak. Moreover, the influence of the measured iterative-behaviour seems to be very low or even close to zero when compared with the score implying that iterative-behaviour has a negative and weak relationship with the score.

Correlations

		iteration	score
iteration	Pearson Correlation	1	-.196
	Sig. (2-tailed)		.752
	N	5	5
score	Pearson Correlation	-.196	1
	Sig. (2-tailed)	.752	
	N	5	5

Figure 4 Correlation score between Iterative-Behaviour and Design quality (Score**)**

Table 3 Research Data for Iterative-Behaviour

Subjects	ITERATIVE-BEHAVIOR									Sum
	D1	E1	N1	V1	H1	C2	B1	C3	A1	
D1	44	6	6	21	21	0	0	38	9	166
D2	59	4	4	33	33	0	0	48	2	204
D3	18	3	3	30	30	0	0	10	9	122
D4	43	5	5	36	34	0	0	16	1	161
D5	48	5	5	53	49	0	0	32	4	242

However, the findings have shown some positive relationship between skills and score together with ideation and progression. There are nearly no correlations between Iterative-Behaviour and score but some findings between other scoring criteria have a strong and positive relationship with iterative-behaviours. The result further expressed that getting higher scores in architectural design sketch is not related to designer iterative-behaviours as presented in Table 4.

Table 4 The Correlation between Iterative-Behaviour and Scores

	Correlation coefficient
Iterative-Behaviour and Score	-0.196

CONCLUSION

This study examines the role of iterative-behaviour in architectural design sketching where the empirical comparison is used to compare iterative-behaviour and sketching through protocol analysis and Pearson correlation coefficient analysis. The results show that the relationship between iterative-behaviour and score was negative and weak. Moreover, the influence of iterative-behaviour seems to be very low or even close to zero when compared with the score implying that iterative-behaviour has a negative and weak relationship with the score of architectural design sketch. However, the findings have shown some positive relationship between skills and score together with ideation and progression. The results of Pearson correlation (Table 3 and Figure 4) show that there was no significant relationship between iterative-behaviour and a total score of architectural sketching processes. In other words, too much of iterative-behaviour does not have either positive or negative impact on the outcome of the overall score of an architectural sketch. Maybe the reason for the negative and weak correlation result could be due to the conventional sketching method used in this research. Maybe a computerized sketching tool could proof a strong and positive relationship between iterative-behaviour and score.

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