Environmental Factors Influencing Sketching Behaviour among Mechanical Engineering Undergraduates

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Abstract

In the development and communication of an engineering design sketching is an important aspect. It is almost impossible to explain or modified a design without the ability to draw simple freehand sketches. Sketches are used by engineers to communicate engineering ideas, problem solving and innovation. Sketching is sometimes considered as a generic skill, and Mechanical Engineering undergraduates, being naturally mechanistic; their sketching ability is believed to be easily affected by environmental factors. This study attempts to identify the environmental factors that will influence sketching performance of Mechanical Engineering undergraduates. A survey was conducted on a sample of 140 Mechanical Engineering undergraduates and the data was analyzed statistically to determine the degree of influence of group dynamic, communication, audio visual and ergonomic design on sketching performance. Based on mean values, the results indicate that all respondents 'slightly agree' to 'agree' that their sketching performance will be easily affected by environmental factors. These factors are weakly correlated (Pearson's value between 0.25-0.59).The mean between the Malay and the Chinese Mechanical Engineering undergraduates of other races are significantly different. This finding provides insights for better design improvement and better interpretation of observable design activity to understand the sketching behavior and environment needed during design process.

Keywords: Sketching, Sketching Behavior, Design, Environmental factors

1. Introduction

In University Technology of Malaysia, various design courses are offered to the Mechanical Engineering undergraduates. The purpose to offer the design courses allow them to polish their creativity, critical thinking, rationality and innovation in problem solving, increase performance, ability to optimize resources, have better control of system and material, ability to brainstorm ideas, and apply aesthetics to design. Sketching is a quick and easy way to express ideas graphically. It is a natural psychomotor process of ideation in which design ideas are generated in one's mind and expressed through freehand sketches for others to see. (College of Engineering, University of Texas @ Austin, 2000) Engineering sketching is at the heart of the ideation loop of imagining, sketching and seeing. (College of Engineering, University of Texas @ Austin, 2000) Sketching behaviour involves human's mental thinking and memory to reflex the physical movement. The study of sketching-behavior is a means to gain insight in mental imagery; many of the sketching in engineering design are done for the purpose of recording and transmitting the appearance of an object (Anderson and Helstrup, 1993). This process is the result of the efforts of representing or recording a phenomenon which already exists or as an idea or concept in the mind until it is committed to a sketch..

2. Sketching Role in Mechanical Engineering Design

Specific design ideas are developed through geometrical size and shape in the form of sketching. It is the beginning of a more concentrated effort to fix the final geometric parameters and constraints that will ultimately define the design. Sketching as a thinking methodology in developing and recording initial idea and reflective analysis of concept detail; design concept is hard to convey with word, sketching act as a visual method to

communicate with other quickly and clearly. The ability to sketch to make an imagined object real is of prime importance.

2.1. The Importance of Sketches for Engineering Design

Sketching is an important component in early design. Extensive research has been done to determine the importance of drawing formal drafting and informal sketching. Almost all designs begin by sketching ideas out before moving to the computer for two reasons which is to express their ideas quickly and naturally and give a rough visual representation of how system will look. Walderon (1988) shows that mechanical designs are perceived on a variety of levels of sketch abstraction, ranging from simple geometrical entities to functional components.

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Ullman et al (1990) state several sketches are required in the course of the design process; ranging from informal sketches to formal drafting. Sketching is not just an artefact of the design process, in fact; it is proven to be essential at all stages of the design process. In the early stages of design, rough sketches are typically drawn on paper or on a white-board. This stage of the drawing can further be broken down into two types, which are graphic representations such as drawings of mechanical parts, and support notation such as textual notes and dimensions. Jenkins and Martin (1993) also indicate that rough sketching is important in terms of flexibility and speed.

Fang (1998) concludes that drawing and sketching have six primary uses which are to achieve the geometric and topologic form of a design, to communicate ideas among designers, to act as an analysis tool, to stimulate the design, to serve as a completion checker, and to act as an extension of the designer's short term memory. An additional important aspect of sketches is that because they are rough, one is less reluctant to discard them and try a different approach to the design.(H.Lipson and M.Shiptalni, 2000).

Based on Temple, S. (1994), the function of sketch is likely to be made for one of three reasons and from one of three sources:

- To communicate the physical nature of an entity conceived in the imagination;
- To visually recall the physical nature of objects or environments from memory;
- To make a quick visual representation of entities or environments exposed to the naked eye.

The ability to sketch objects and communicate ideas to look real is very important. In engineering, this utility can often help in explaining mechanisms like cams and gears.

Sketching can reflect design thinking. It is an activity affected by many factors, including drawing skill and visualization ability; and in some cases might even be viewed as behaviour consequence rather than a key element of design thinking. Because sketching is, in part, a reflection of the cognitive activities of designer, it is instructive to refer to research in mental imagery ability to develop a framework for understanding sketching. According to Maria C. Yang and Jorge G. Gham, (2007) "mental imagery is defined as the recall of an image stored in memory, and drawings are conceptions of these mental images. An engineering student is normally assessed on their mathematical and verbal ability and less by their visualization skills. A good understanding of the role of sketching will help them to provide insights for better design and better interpretation of observable design in their quest to understand the design activities and cognitive processes that occur during the design process.

2.2 Sketching Behaviour

Sketching behavior is a science of understanding the behavior and so called "classical conditioning" which led to the rise of operant conditioning. Behaviorism insisted on working only with what can be seen or manipulated and in the early view of the field, nothing was inferred as to the nature of the entity that produced the behavior. (Watson, 1998)

During simulation and development of design creativity sketching behaviour could be considered as a key factor. Sketching behaviour is an essential part of revising and refining ideas, generating concepts and facilitating problem solving before coming to the production stage (Chang Frawn Lee, 2002 in Phua 2010).

Sketches, as a concrete trace of the thought process, make the designer's thoughts visible and self-explanatory. In mechanical engineers' line of work, they need to combine their range of technical knowledge in accordance to the requirements, rules of thumb, ecological commitments and etc. Most researchers concentrate their research on sketching activities; because sketching is, in part, a reflection of the cognitive activities of the designer. It is instructive to refer to research in mental imagery ability for understanding sketching skill.(Maria C.Yang and Jorge G.Cham, 2007).

2.3 Sketching Behaviour and Environmental Factors

Sketching behavior is influenced by one of the five major factors, which is, the environment. Environment or surrounding factor is an interdisciplinary field focused on the interplay between humans and surroundings. Environment is defined as the surrounding atmosphere or condition for existence that may directly affect behavior (Paul. A Bell, 2001 in Phua 2010). In real life, behavior also occurs in the context of an environment. Environmental psychology deals with behavior in relation to the physical environment.(V. George Mathew, 2001) Environmental psychology is a science that studies how human behavior is influenced by the environment and the environment in this context comprises social, natural, constructed, learning and information settings.(Wise GEEK, 2003-2012). It has been hypothesized that environment influences behavior at several levels and immediate behaviour is a function of the settings in which it occurs, for example, the arrangement of furniture in a room influences the way in which people in the room interact. (V. George Mathew, 2001). Character and behaviour of an individual can be distinguished through the influence of the surrounding during sketching. Sketching will provide an experience and feeling for a person to explore their options. A person's character is mainly influenced by the great impact demonstrated in their everyday life environment and they will react uniquely when encountered with a specific situation or experience. These responses fall into three categories and all of which are influenced by factors within the environment: Sociological determinant, psychological determinant and physiological determinant (Edward T. Hall, 1998).

Sociological determinants relate to the social needs and problems, and factors that pertain to these sociological responses including group dynamics and communication. Group dynamics (the interpersonal relationships among members of small group) are a result of the personality and cultural backgrounds of the

individuals involved their task and the nature of the physical setting. (US Army Corps of Engineers, 1997). According to Johnson & Johnson (2003) group dynamics as a conceptual framework, provide heuristic approach for understanding how effective groups both work and advance our knowledge of the impact of those process on students. Studies of communication reveal that, in conversation, people prefer to sit across from one another rather than side by side and if the distance between conversing people becomes too great however, they will usually choose to sit side by side rather than across from one another. (US Army Corps of Engineers, 1997). The scale of a room and its size relative also influences conversational distance. As room scale diminishes, people tend to sit closer together. (US Army Corps of Engineers, 1997). Likewise, increased noise levels and distractions drive people to sit closer together (Edward T. Hall, 1998).

Psychological determinants in the planning of an environment relate to the psychological needs and concerns of the occupants. Visual privacy, acoustic privacy and aesthetic factors are key determinants to be considered to addresses the ability to limit other's view of oneself and can be achieved through the use of furnishings, partitions or walls. (US Army Corps of Engineers, 1997). In private space, people will often orient their desk in order to visually control the doorway and achieve a visually private space on one side of the desk

Physiological determinants relate to physical needs of human. Factors to be considered during the planning phase that deal with physiological responses include functionality, and ergonomics (Edward T. Hall, 1998). Functional efficiency relates to the degree to which physiological needs are supported in the space plan, which are physical in nature, relate to human body requirements while interior environments will respond to basic human functional needs such as vision, hearing, stability and mobility to achieve both comfort and efficiency because all physiological needs will affect how a person perceives and reacts to an environment. (US Army Corps of Engineers, 1997).

Ergonomic design recognizes that the environment significantly and impacts human behavior. Each aspects of interior design including space, furnishings, and environmental variables such as temperature, sound, humidity and ventilation needs to be carefully assessed in terms of its compatibility with the purpose for which it is intended such as to conform to the human body. Ergonomics combines anthropometries (human body measurement data), physiology, and psychology in response to the needs of the user in the environment. (US Army Corps of Engineers, 1997). An effective design should maximize freedom of behavior, mobility and flexibility while some of the other considerations are possible use and misuse of space, and contrasting needs of privacy and socialization. (V. George Mathew, 2001).

3. Research Methodology

The brief review in the preceding paragraphs points to the key environmental factors that influence sketching behaviours among Mechanical Engineering undergraduates and as follows; group dynamics, communication, visual and acoustic privacy and ergonomic design. These factors have been considered as the constructs during the development of the questionnaire used as the research instrument.

Group dynamics looks at the level of cooperation and interaction between colleagues during the process of sketching. Communication is more focus to the working relationship between colleagues. Visual and acoustic privacy relates students comfort with related facilities. Finally, the effect on students sketching is investigated by focusing on ergonomic design workspace.

Questions are built around the constructs and Likert scales were used to record respondents' opinions. The quality of the instrument has been checked and corrected based on Cronbach test. Responses from 140 Mechanical Engineering undergraduates at University Technology of Malaysia were collected and analysed using Statistical Package for Social Science (SPSS). Demographic, descriptive, variance, and correlation analysis were performed to gauge the degree of importance of each factor to one another and also their degree of interdependence. The differences between undergraduates of different demographic groups were also checked.

4. Results

This section will present the results in terms of the analysis performed.

4.1 Demographic Result

Table 4.1: Frequency Distribution and Percentage of respondents by Gender

Gender	Frequency, (n)	Percentage, (%)
Male	108	77.1
Female	32	22.9
Total	140	100.0

Table 4.2: Frequency Distribution and Percentage of respondents by Race

Race	Frequency, (n)	Percentage, (%)
Malay	116	82.9
Chinese	21	15.0
India	1	.7
Other	2	1.4
Total	140	100.0

Table 4.3: Frequency Distribution and Percentage of respondents by programs of studies

Programs of studies Mechanical Engineering	Frequency, (n)	Percentage, (%)
Marine	44	31.4
Automotive	43	30.7
Material	34	24.3
Industry	19	13.6
Total	140	100.0

4.2 Result of Descriptive Analysis for Mean, Standard Deviation

Table 4.4: Mean and standard deviation of group dynamic, communication, visual and acoustic privacy and ergonomic design

No	**Variables**	**Mean**	**Standard deviation**
1.	Group dynamic	3.7405	0.5246
2.	Communication	3.2721	0.4482
3.	Visual and Acoustic privacy	3.4937	0.7025
4.	Ergonomic design	3.9723	0.5263

4.3 Results for Analysis of Variance

4.3.1. Normality test results

Table 4.5: Table of normality test result

No	Variables	Significant
1.	Group dynamic	0.181
2.	Communication	0.041
3.	Acoustic and visual privacy	0.000
4.	Ergonomic design	0.000

4.3.2. Chi Square test results

Table 4.6: Table of Chi square result

No	Variables	Significant
1.	Group dynamic	0.000
2.	Communication	0.000
3.	Acoustic and visual privacy	0.000
4.	Ergonomic design	0.000

4.3.3. Correlation

Table 4.7: Table of Correlation

	Group dynamic	Communication	Visual and Acoustic Privacy	Ergonomic design
Group dynamic (Pearson Correlation) Significant	1	0.590	0.247	0.331
Communication (Pearson Correlation) Significant	0.590	1	0.295	0.322
Visual and acoustic dynamic (Pearson Correlation) Significant	0.247	0.295	1	0.273
Ergonomic design (Pearson Correlation) Significant	0.331	0.332	0.273	1

5. Discussion

The study of environmental factors influencing sketching behavior is important to identify the type of environments and their effect to Mechanical Engineering Undergraduates to produce a quality sketch and might be a useful source to improve the sketching environment for engineering students. Without a good sketch, they cannot develop the ideas into reality. Out of 140 respondents, there were 108 male students and 32 female Mechanical Engineering Undergraduates.

Malay males represent 77% of the respondents, and therefore it is safe to deduce that Malay male Mechanical Undergraduates at University Technology Malaysia are not stable enough as their sketching behavior conceived when environmental factors persist during sketching class. Malay males will feel disturbed when interrupted (mean= 3.74), they are not ready to listen to others (mean= 3.86) and they are not open to giving ideas on their friends' sketches (mean= 3.90). However they support the idea of working in a group (mean= 4.23). It proposes that Mechanical Engineering Undergraduates only slightly agree on the proposition that they are adaptive to environmental factors when sketching. Their sketching behavior is easily affected by environmental factors. Based on the correlation results, the three standard classifications of relationship and strength between the four construct had been defined as. "strong" relationship, "moderate" relationship and "weak" relationship. Most of the construct have moderate and weak relationships. The constructs used are not strongly related and do not support each other. The other reason for this situation might be that the respondents did not understand the construct such as visual and acoustic privacy. This is supported by the fact that visual and acoustic privacy construct have a weak relationship with the three other constructs. Based on the result, lecturers who teach sketching should focus more on maintaining group work and have a class session in the studio to allow Mechanical Engineering Undergraduates' to adapt better to their sketching environment.

6. Conclusion

This study is focused on UTM's Mechanical Engineering undergraduates, corresponding to the future planning of the Faculty of Mechanical Engineering to improve Mechanical Engineering courses with consideration to the design subject as a cap stone and corner stone subject. This research enclosed the implementation for the research outcome of environmental factors influencing sketching behavior among Mechanical Engineering undergraduates in order to improve the quality of sketches and understand the importance of sketching:

a) Provide a design studio for Mechanical undergraduates with a high tech laboratory and studio.

b) Encourage engineering students to work together in a team to generate a high quality of design and sketching.

c) Support students in any sketching task.

d) Mechanical Engineering Undergraduates should be exposed with more authentic hands-on design tasks.

e) Mechanical Engineering Undergraduates should improve their design thinking and task.

All respondents find it easy to adapt to the environmental factors when significant value is > 0.05, then that group is affected and influenced by all the factors and as confirmed by chi square value, the correlation between the entire construct is strong and moderate. However, for Malay respondents, a majority of them are non dynamic, (M= 3.74), they are also not communicative too, (M= 3.27) and as confirmed by chi square value, the correlation between group dynamic and communication is strong, (r^2=0.59). Significant value for chi square is > 0.05, and then this group is not dynamic. So, they are not adaptive to the requirement of group dynamics and communication. However, Malay male Mechanical Undergraduates are not affected by visual and acoustic privacy, (M= 3.49) and ergonomic design, (M= 3.97), It is affirmed by chi square value is > 0.05, and the correlation between visual and acoustic privacy and ergonomic design is weak, (r^2= 0.273).

Finally, for Chinese students and students of other races, effects of environmental factors to their sketching behavior are yet to be confirmed because the sample is too small and cannot be defined. The objective of this research was achieved; to identify the environmental factors influencing sketching behavior among Mechanical Undergraduates. The patterns of the results are as expected and support the hypothesis that Mechanical Engineering Undergraduates are not easily affected by environmental factors. The improvement of sketching behavior is very important. The influence of the environmental factors on sketching behavior can be referred back to the elements and factors of the physical environment and sociological needs such as size of room and studio, furniture style, furniture arrangement, lighting, external noise, general cleanliness, and social interaction. These must be considered to get the satisfaction, motivation and encouragement for Mechanical Engineering Undergraduates to produce a good sketch and improve their sketching skills to ensure that they can communicate and transform their ideas into a high quality sketch. In turn, this might help them improve their skill to convey ideas and communicates with their design projects. Therefore, it is strongly encouraged that this line of research is continued. For the further study and continuation, there are some other improvements that can be done for this field of research by extending this research based on the recommendations stated below:

1. Set a wider target group of respondents, either in UTM or outside.
2. A well structured of research methodology must be utilized i.e. qualitative method.
3. Attain respondents of well distributed ethnic variety. Avoid having a majority of a single race.
4. Get more dependent factors tested other than the four factors mentioned in the analysis.

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