Visualization Skills among Engineering Student: Pilot Study

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Abstract

Visualization skills are very important in engineering field and they are positively correlated with achievement in engineering disciplines. With the enrolment of the first-year students in engineering field, varying degrees of visualization skills development came from different backgrounds and experiences. A number of 357 engineering students from six faculties ranging from the first year to fourth year students of Universiti Teknologi Malaysia (UTM), Skudai participated in this study. This quantitative study applies descriptive and inferential analytical methods, whereby a biographical data sheet and short version of visualization standard tests as the main instruments. The finding for this pilot study revealed that the engineering students of UTM possess moderately high visualization skills. Hence, the appropriate approach should be done in order to implement the right techniques for teaching engineering drawing in enhancing student's visualization skills.

Introduction

Visualization is one way of thinking where the image is produced or memorize back in memory. It is an essential factor in learning engineering drawing subjects such as drawing graphics (Kopp, 1999). Most students have problems when studying the topics in engineering drawing that requires high visualization skills (NSF, 2006). When students fail to master these abilities, they will also have difficulties in mastering the concepts that are based on the visualization ability. Therefore, all engineering students are introduced an engineering drawing subject in which the objective is to provide the students with basic knowledge and skills of engineering. Basically, the main goal of engineering drawing subject is to improve the student's skills in practicing the use of standard geometry, geometry equipments and abilities to develop the visual image (Mohd Safarin, 2009).

The students must be well prepared with the basic concepts of engineering drawing that complements to understand the complexity of learning in other engineering subjects. However, to master engineering drawing basics concept, the students must first master the visualization skills. Some studies show that students usually faced difficulty in solving problems in engineering drawing because of poor in visualization skills.

According to Bertoline & Wiebe (2002), engineering drawing subject consists of the fundamental of visualization ability where this subject deals with the construction of 2D and 3D geometry and creating multi-view and pictorial representations. In Malaysia, engineering drawing was taught at all technical and vocational schools. Only a few selected daily secondary schools provide engineering drawing subject to students. According to Widad & Lee (2004), students always faced problems in engineering drawing because they have difficulty in visualizing the given images. In developing understanding, students use their mental scheme to visualize and develop the view or certain images. Previous studies (Abe and Yoshida, 1999; Adanez and Velasco, 2004; Alias et al., 2002; Basham, 2007; Contero et al., 2005; Crown, 2001; Godfrey, 1999; Kinsey et al., 2006; Mathur, 2001; Nussbaumer, 1998; Sorby et al., 2005, Sorby, 2007) showed that visualization is important in engineering drawing because, in the technical work, communication through graphic is compulsory and engineering drawing is the basic of capability of communication technique in graphic method. Contero et al. (2005) suggested that engineering students need to improve their visualization skills because it is necessary in explanation, information devices besides using them to explain the concepts, ideas and processes as well as to attract attention and information delivery.

Background of Study

Visualization Skills

The approach of the conventional method in a learning process causes students faced difficulties to memorize and understand. When the students did the self-studied, their cognitive level will increase. The heavy load of information in working memory will caused the failure of information for being register in the long term memory during conducting that activity (Tabbers et al., 2004; Chandler, 1998; Klein, 1996). Even though, there are practical has been practiced for various subject, but not all the content of the syllabus can be practiced practically when it involved large, dangerous and costly equipment (Bullough, 1974). With that, it is particularly beneficial to have a dynamically cognitive device to overcome the problem such as the multimedia animation appearances and the uses of courseware and teaching aids which more practical and suitable for the topic.

In developing knowledge, the students use their mental schema to visualize or develop a pictures or images. Visualization is a way of thinking in which images are produced to recall the memory. Among the definitions given, it includes the ability to manipulate the mental images and the ability to interpret visual information in the brain (Wiley, 1990). Besides that, Contero et al. (2005) suggested that engineering students need to consistently improve their skills as

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visual visualization plays a significant role in education as an explanation, tool, and information. It is also used to explain concepts, ideas and processes, and to stimulate interest and provide information. There are many other visual functions such as improving the performance of memory, causing emotional response and enriching the reading as well as the demonstration. This statement is supported by a study conducted by Ramanujan Dimension Group (2001) which stated that the use of visuals can be applied to convey different information in education.

Gender Relations with Visualization Skills

There is an evidence to suggest that the visualization skills of female lag significantly behind those of their male counterparts. Theories for the cause of these differences include the assertions that visualization ability related to a male sex hormone (Hier & Crowley, 1982) or that environmental factor is the main reasons for male-female differences in visualization skill levels (Fennema & Sherman, 1977).

Debate on the issue for gender differences in visualization abilities has been started since year 1980 when Stanley and Benhow printed one science review. In this report, they found that the male student is better than female student in mathematical problem solving ability. This article also proves that the boys were exceedingly ability to solve problems involving space.

Furthermore, the factors which influenced the development of visualization ability occur in a few psychology studies such as sex, age and experience (Miller, 1996). Besides that, Vandenberg and Kuse (1978) and Hamilton (1992) found that male showed greater ability than females in spatial mental rotation task.

Two studies published in memory and cognition, to determine the gender gap through Mental Rotation Test achievement (MRT). Based on this test, students were asked to look at an object of 3-dimension. Then, they are given four answers (two rotation is the original object) to identify two appropriate alternative with the original object. These studies used the ratio of performance to conclude that gender differences for mental rotation skills are significantly reduced when the effect of performance factors such as length of time and strategy to guess the answers eliminated.

The first study focused only on the MRT, while the second study provides an analysis of fifteen skills assessment while the study area, proved that there are gender differences only in tasks that require mental rotation. In addition, several studies in visualization abilities conducted and the researcher found that there are differences between the gender differences where the male students who enter the technology field have higher visualization ability compared to male students in Social Sciences.

Besides that, female students in the field of technology have the visualization ability higher than female students in Social science but lower than male students in the Social Sciences (Nordvik, 1998). However, Feingold (1993) and McGee (1979) found that there is no significant difference in the visualization ability between male and female students.

Levine et al. (1999) stated on average, male beat female in visualization ability at the fourth stage. This is because; male tend to look for a technique or method by using space and direction or orientation strategy while female prefer to use sign and route directions (Lawton, 1994 and Geary, 1998). This study is consistent with the findings from Koenig et al. (1990) found that women's advantage is in relation to absolute space (location of the object) while the men's advantage is in the space coordinated relations (distance and direction). Based on visualization tests, gender differences in strategy used has not been adopted widely, but at least one form that male more commonly used holistic strategies than female, and female more commonly used analytic and mixed strategies than male in two different visualization tests (J Gluck and S. Fitting, 2003).

The holistic strategy relies on visualizing the whole object, and the analytic strategy uses a structured, stepwise approach. The holistic strategy has found to be most effective in timed tests. Linn & Peterson (1985) therefore, concluded that "spatial strategy selection" is a factor in gender differences in mental rotation tasks. However, Hsi et al. (1997) determined that spatial strategies can be acquired through training.

Therefore, the objective of this study is to determine the level and gender differences in visualization skills among students who are pursuing their studies in engineering at UTM Skudai. This is necessary to determine the level of student's visualization ability and gender differences. The educators need to take positive steps to ensure that the method of teaching and learning can assist in increasing the student's visual abilities.

Study Methodology

This visualization skills study was conducted at Universiti Teknologi Malaysia, Skudai Campus. The students from Bachelor of Engineering were the respondents for this study. In order to identify the student's level in visualization skills, this study applied six standard visualization tests on the visualization skills and their components towards the students of engineering courses. This study carried out the quantitatively methodology with the studies are being descriptive statistics and inferential statistics.

The obtained data was collected and analyzed by using the Statistical Packages for Social Science (SPSS) version 13.0. The descriptive statistics is to obtain a mean value, frequency and percentage. According to Azizi Yahya et al. (2005), the used of descriptive analysis is to explain or provide an overview of the information or data obtained for the population or

sample. Meanwhile, inference analysis used to describe the relationship between achievement tests and gender difference of engineering students who have earned. Inference statistics used in this study is to test the correlation at the alpha 0.05 levels and one-way ANOVA analysis.

Research Instrument

The instrument used for this study was adopted from the Spatial Visualization Ability Test (SVAT), Mental Cutting Test (MCT), Differential Aptitude Test: Space Relations (DAT:SR), Purdue Spatial Visualization Test for Rotation (PSVT:R), Purdue Spatial Visualization Test for Development (PSVT:D), Minnesota Paper Form Board Test (MPFBT) and Transformation 3D to 2D Test (T3D2D).

The standard MCT consists of 25 problems (Tsutsumi, 2004). This test aims to test the students' visualization skills on cutting effect of three-dimensional objects through the identification of the section view that will result in a cutting plane. In each tests, students are given a perspective drawing of the solid test, which is to cut with the hypothetical cutting plane. Students need to choose one correct cross section from five alternatives. The display surface of the cut is the right answer, whereas the rest serves as a distractor. In this test, the form of cutting three-dimensional objects is different, and it has been cut into various positions.

PSVT test consists of three sections of the test trials which are overlay, rotation and viewing. The overlay test in PSVT is to test the student's ability to identify the shape that will resulting overlay diagram of three-dimensional object given. While, the rotation test of PSVT contains 30 items to test one's ability to identify a three-dimensional object that screened. Each item in this test began with the screened objects and the procedure followed by the screening the same object, but its in state after rotated at a certain direction and angle of rotation.

The test of DAT: SR contains 50 items and adapted to measure the visualization ability that will resulting from the crease of the layout of an object. Each of the questions started with illustration of the net proceeds of an object in the right lane and followed by a paper of four illustrations of three-dimensional objects as an options. One illustration of the object three-dimensional is the most accurately described the appearance of the object layout should be selected after the fold.

MPFBT test which developed by Likert Quasha in 1941 (Contero et al., 2005) contained 64 tests. MPFBT test used to test students' ability to combine 2-dimensional objects mentally.

T3D2D test which developed by Mohd Safarin in 2007 contained 30 questions and tested the students' ability on levels transform of 3-dimensional objects to 2-dimensional shape mentally. The ability to produce multi-view drawings of the pictorial views of an object known as web skills involved six elements that related to the visualization capabilities such as (a) describe the orthographic drawing of the orientation view, (b) selecting views correct, (c) describes the look and the shielded, (d) distinguish area adjacent to a different object height or depth, (e) distinguish an area adjacent to a slope or oblique, and (f) distinguish adjacent a surface of a cylinder (Bertoline et al., 2005).

This research also used SVAT test set (Maizam, 2002) which to determine the students' spatial visualization ability. This instrument was chosen because the scores obtained via this instrument can differentiate students' of high spatial visualization ability (from low spatial visualization ability. This test contained 29 questions. Respondents need to answer the question by choosing one of the four answer choices given.

Questions in the questionnaire for this study are to test the reliability and validity. In this study, Mental Cutting Test (MCT), Differential Aptitude Test: Space Relations (DAT: SR), Purdue Spatial Visualization Test for Rotation (PSVT:R), Purdue Spatial Visualization Test for Development (PSVT:D), Spatial Visualization Ability Test (SVAT), Minnesota Paper Form Board Test (MPFBT) and Transformation 3D to 2D Test (T3D2D), used it as a standard achievement tests. Thus, the reliability and validity of the test will determined and obtained to ensure that the instrument are consistently and measure what supposed to be measured.

Table 1: Alpha Value for Research Instrument

Research Instrument	Alpha value
MPFBT	0.801
PSVT:R	0.802
PSVT: D	0.804
DAT:SR	0.805
MCT	0.803
T3D2D	0.807
SVAT	0.804

Meanwhile, the content validity of instruments determined through the verification carried out by the expertise in this discipline areas of study. Items are reviewed in terms of content, namely the relationship between the research question and the scope of the study.

Discussion

The Level of Visualization Skills of Students by Year of Study

Table 2 shows the scores on visualization test based on year of study. As results, the level of students' visualization skills tested in seven aspect which are mental cutting, mental rotation, development, transformation 3D to 2D, combining 2D object mentally and folding skills. Researchers have divided four scale to measure level of visualization skills which are high, medium high, medium low and

low. The findings showed visualization skills of engineering students at UTM are to be at moderately high. This is based on the achievement of the proficiency testing of each aspect of visualization test involved in this study. Meanwhile, based on the student's academic year, the analysis found that the students' visualization skills are in their fourth year is high. Meanwhile, visualization skills of the third year student, second year and first year student are to be at moderately high.

Table 2: Average Score of Visualization Skills Test by Year of Study

Year of Study	Average Score of Visualization Skills Test (%)							
	MPFBT	DATSR	SVAT	T3D2D	PSVTR	MCT	PSVTD	Average Score (%)
1	74.3	72.2	69.2	66.8	64.0	54.8	59.9	**65.9**
2	78.5	74.3	73.3	68.7	69.7	58.7	63.0	**69.5**
3	82.7	82.2	82.8	70.5	76.8	69.0	72.1	**76.6**
4	85.4	85.4	83.6	77.6	79.2	71.3	74.6	**79.6**
Average Score (%)	**80.1**	**78.2**	**77.1**	**70.9**	**72.3**	**63.2**	**67.2**	**72.9**

These results are paralleled with a study that was conducted by Mohd Safarin and Muhammad Sukri (2007) which was related to the visualization ability of engineering students at High School. The results showed an average of students studying engineering in this study only had a satisfactory level of mastery in one of the six tests. These abilities are the skills which combined the forms of 2-dimensional objects found in the MPFBT test. Analysis of this study proved that more than half of the students are at the moderate level and are lacking in the aspect of transformation, development, folding and rotating it mentally. Besides that, studies conducted by Rebecca (2000) showed that students with higher levels of visualization skills may be influenced by students' previous experience especially during their earlier exposure in subjects such as geometry or engineering drawings. In addition, according to a study done by Oyanka and Kinsey (2007), various engineering disciplines apply visualization skills in teaching and learning, such as CAD software, to enhance the visualization skills of the students.

Visualization Skills According To Gender

Table 3 shows that the average test scores of visualization across the both gender. The figure shows that the male students are more overcome than the female students in DAT:SR test, PSVT:R test, MCT test, SVAT test, T3D2D test and PSVT:D test. Meanwhile, the female students only overcome more than the male students in MPFBT test. Findings from the previous studies also showed the possibilities of the relationship between visualization ability and gender representation capabilities. Levine et al. (1999) stated that on average, men are more than women in the ability space.

Table 3: The Score of Visualization Skills Test across Gender

Gender	Visualization Skills Test (%)						
	MPFBT	DAT:SR	PSVT:R	MCT	SVAT	T3D2D	PSVT:D
Male	80.0	78.8	73.4	64.1	51.7	66.8	68.2
Female	80.2	77.7	71.3	62.4	48.3	59.7	66.3

Bain and Rice (2006-2007) founded that there are still existed gender differences in technology use. This consistently with the research by Hogan in 2006 where he suggested that the persistence of higher level of technophobia may not be confined to the United State. Besides that, research frequently showed that gender factor as the strong predictor in term of technological self- efficacy. This is because female is more likely to consider self- perception of computer skills is lower than males (Bain & Rice, 2006-2007; Busch, 1995; Hargittai & Shafer, 2006; Hogan, 2006; Temple & Lips, 1989). Not only that, female student also frequently reported less confidence in computer software with the use of visualization related material (Terlecki & Newcombe, 2005).

The study also found that some components of the visualization capabilities have not dominated by the engineering students at UTM Skudai. Therefore, the appropriate efforts should be made to rectify the weaknesses in visualization test components identified thus increased their visualization skills of engineering students at UTM Skudai. In conclusion, this study showed that there are some elements of visualization skills are still not dominated by handful of engineering students at UTM Skudai. More attention should be given to the development of these visualization spatial skills in all engineering programs offered at this campus.

CONCLUSION

Appropriate approach for teaching is needed to help engineering student in enhancing their visualization skills. Thus, various parties must help the students to improve their visualization skills with the effective teaching and learning environment. The overview of this study will help the Ministry of Education, researchers, educators and students on the impact of new teaching methods in teaching engineering drawing for the visualization skills for engineering students.

Therefore, department of engineering curriculum revealed the key elements of engineering drawing subjects that may be less emphasized or aware of the development of visualization skills for engineering students. In addition, the new paradigm of computer technology in the field of engineering, particularly for the engineering drawing subject has shown through this study. Element of visualization skills should be given attention in the curriculum explicitly stating

the goal of producing students who skilled visualize the engineering drawing subject.

As a conclusion, the researchers believed that a combination of the existing methods and new approaches such as computer integrated and virtual environment application can be an alternative in the visualization skills of the students in studying the engineering drawing subjects as well as to improve the existing teaching methods. Finding effective ways to use technology in order to enhance teaching and learning is a challenge for the educators, academics, policy makers also the researcher, they need to work together to solve the existing problems (Gates, 2002). The profit for introducing new technologies into the creation of didactic material that is suitable for university and technical education must be found and implemented. There are many other possibilities to create a computational model, especially in places that are suitable for the description of a row over for the level of development.

References

Abe, H., & Yoshida, K. (1999). Measurement of Visualization Ability of Architectural Space. *Journal for Geometry and Graphics, 3*(2), 193-200.

Azizi Yahaya., Asmah Suboh., Zurihanmi Zakariya., & Fawziah Yahya (2005). *Aplikasi Kognitif Dalam Pendidikan.* Edisi pertama.Bentong, Pahang: PTS Professional.

Bain, C.D., & Rice, M.L. (2006-2007). The influence of gender on attitudes, perception, and use of technology. *Journal of Research on Technology in Education, 39*(2), 119-132.

Bertoline, G. R., & Wiebe, E. N. (2002). *Technical Graphics Communication* (3rd ed.). New York McGraw-Hill.

Bullough, R. V. (1974). *Creating Instructional Materials.* New York: Macmillan Publishing Company.

Contero, M., Naya, F., Company, P., Saorin, J. L., & Conesa, J. (2005). Improving Visualization Skills in Engineering Education. *IEEE Computer Graphics in Education, 25*(5), 24-31.

Feingold, A. (1993). *Cognitive gender differences: A developmental perspective.* Sex Roles, *29*, 91–112.

Fennema, E., & Sherman, J. (1977). Sex-related differences in mathematics achievement, spatial visualization and affective factors. *American Educational Research Journal, 14*, 51-71.

Gates B. (2002). *A Vision for Lifelong Learning-Year 2020*-introduction by Bill Gates, Vision 2020: Transforming Education and Training through Advanced Technologies. Retrieved February 16, 2010 from http://www.technology.gov/report/TechPolicy/2020Vision.pdf

Geary, D. (1998). Male, female: *The evolution of human sex differences*.Washington, D.C: American Psychological Association.

Hamilton, J. (1992). *Virtual reality: How a computer-generated world could change the world.* Businessweek. (3286), 96-105.

of Modality and Cueing." British Journal of Educational Psychology. Leicester: Mar 2004. 74 (1), 71-82.

Terlecki, M., & Newcombe, N. (2005). *How important is the digital divide? The relation of computer and videogame usage to gender differences in metal rotation ability*. Sex Roles 53, 433-441.

Tsutsumi, E. (2004). A Mental Cutting Test using Drawings of Intersection. *Journal for Geometry and Graphics, 8*(1), 117-126.

Hier, D. B. & Crowley Jr., W. F. (1982). Spatial ability in androgen-deficient men. *New England Journal of Medicine, 306*(20), 1202-1205.

Hsi, S., Linn, M., & Bell, J. (1997*).* The role of spatial reasoning in engineering and the design of spatial instruction. *Journal of Engineering Education, 86*(2), 151-158.

J. Gluck & S. Fitting. (2003). Spatial Strategy Selection*. Interesting Incremental information.* International Journal of Testing.

Koenig, W. D. (1990). *Spatial Autocorrelation of Ecological Phenomena*. Trends in Ecology and Evolution *14,* 22-26.

Kopp, G. A. (1999). *Engineering Graphics in the New Millennium: Integrating the Strengths of Sketching and CAD.* 29th ASEE/IEEE Frontiers in Education Conference, San Juan, Puerto Rico.

Lawton, C. A. (1994). *Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety*. Sex Roles, *30*, 765–779.

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). *Early sex differences in spatial skill*. Developmental Psychology, *35*, 940–949.

Linn, M. C., & Petersen, A. C. (1985). *Emergence and characterization of sex differences in spatial ability: a meta-analysis.* Child Development, *56*, 1479–1498.

Maizam Alias (2002). "*Instructions on Spatial Skills and Spatial Visualization Ability in Engineering Students."* International Education Journal, 3 (1), 1-12.

McGee, M. G. (1979). *Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences*. Psychological Bulletin, 86, 889–918.

Miller, C. A. (1996). *Historical review of applied and theoretical spatial visualization publications in engineering graphics*. Engineering Design Graphics Journal.60(3):12–33.

Mohd Safarin Nordin. (2009). *Kemahiran Visualisasi: Kemahiran Kognitif Tahap Tinggi Dalam Pendidikan Teknik Dan Vokasional.* Paper presented at the Seminar Kebangsaan Pendidikan Teknik Dan Vokasional 2006, Senai, Johor.

Mohd Safarin Nordin,. & Muhammad Sukri Saud. (2007). *Kajian Awal Terhadap Kebolehan Ruang Pelajar-pelajar Pengajian Kejuruteraan Di Sekolah-sekolah Menengah Teknik.* Paper presented at the 1st International Malaysian Educational Technology Convention, Senai, Johor Bahru.

Nordvik, N. (1998). *Gender Differences in Spatial Abilities and Spatial Activity Among Univeristy Students in an Engineering Educational System*. Sex Roles *38*(Jan). 1009-1023.

NSF. (2006). Tools, *Multimedia Tutors Developed to Teach Visualization Skills*: The National Science Foundation.

Onyanka, R., & Kinsey, B. (2007). *The Effect of Engineering Major on Spatial Ability Improvements Over the Course of Undergraduate Studies.* 37th ASEE/IEEE Frontiers in Education Conference.

Ramanujan Dimension Group . (2001). Teknologi Visual dalam Pendidikan. Retrieved July 9, 2009 from http://www.geocities.com/kump_dimensi/ilmiah.htm

Rebecca Lynn Rodrigue Robichaux .(2000). *The Spatial Visualization of Undergraduates Majoring in Particular Fields of Study and The Relationship of This Ability to Individual Background Characterictics.* A Dissertation Submitted to the Garduate Faculty of Auburn University. Auburn, Alabama.

Tabbers, H.K., Martens, R.L., & Van Merrienboer, J. J. G. (2004). "Multimedia Instruction and Cognitive Load Theory: Effects

Vandenberg, S. G., & Kuse, A. R. (1978*). Mental rotations, a grouptest of three-dimensional spatial visualization.* Perceptual & Motor Skills, 47, 599-604.

Widad Othman., & Lee, M. F. (2004). "Pembelajaran Lukisan Kejuruteraan Berteraskan Visualisasi: Keupayaan Pelajar Menyelesaikan Masalah." Universiti Teknologi Malaysia.

Wiley, S. E. (1990). Computer graphics and the development of visual perception in engineering graphics curricula. *The Engineering Design Graphics Journal, 54*(2), 39-43.