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Message from the Chair

Dennis K. Lieu
University of California at Berkeley

I remember when the movie *Jurassic Park* was first released many years ago. Besides the realistic physical and digital dinosaur models, one of the most memorable scenes was that of a child searching for information on a computer with a graphical user interface (albeit old by today's standards) where information was stored and organized in the form of simulated 3-dimensional objects in a 3-dimesional space. The implication was that information stored in this manner would be so easy and intuitive to manipulate that a child could do it. Geometry is all around us. We can see it, touch it, and change it. Because we experience it every day, we usually find it easy to visualize, simulate, and understand. In the engineering world, the design and production of physical parts has always required the control of geometry. Our work in visual communication must continue to foster not only a deeper understanding of geometry, but also a deeper understanding of the cognitive processes that will make the communication of geometry faster and more accurate. While many people think of geometry as a static condition, it can actually be made dynamic by combining it with other forms of information, and it is this unique quality of geometry that needs to be further explored developed. In the simplest example, a time component can be added to make a three-dimensional presentation into one that is four-dimensional. Time can be unidirectional, and it is for streaming video, or it can be interactive and controllable, and it is in a virtual reality environment. In either case, the amount of information that can be transferred, as compared to a static model, is tremendous. In addition to physical objects, other types of information can be conveyed in the form of geometry. In the past, this presentation has also been static. For example, certain types of data can be presented in the form of bar or pie charts, which essentially take large amounts of information and present them in the form of physical objects. In more recent manifestations, the presentation of data, as well as the search for data, in geometric form can be made dynamic. The transient velocity, density, and pressure distributions of gases in three dimensions, for example, can be shown dynamically with streamlines and colors in finite element models. The search for applications of geometric visualization beyond that of physical objects is still a developing art that presents unique research challenges. I encourage you to search for such applications, and develop them, because they represent opportunities to apply what we know about the understanding and control of geometry to other engineering areas. To be successful in this venture, we must seek and embrace those who are knowledgeable in these new areas, and expand the scope and membership of this Division to include them.

Dennis K. Lieu

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Message from the Editor

Robert A. Chin
East Carolina University

The abstract is one of the most important elements of an *Engineering Design Graphics Journal (EDGJ)* article or Engineering Design Graphics Division (EDGD) Mid-Year Conference paper. Guidance for preparing abstracts appears in the most current edition of the *Publication Manual of the American Psychological Association* (APA Manual), the style manual adopted by the EDGD for its publications. And because the *EDGJ* is indexed by the Education Resources Information Center (ERIC), their guidance, which can be found at http://eric.ed.gov/?abstract, should also be taken into consideration.

While there are some differences between the two pieces of guidance, there are more similarities than not. As an example, the APA Manual suggests a word limit of between 150-250 words, but also refers authors to the specific journal when preparing an abstract. ERIC suggests between 150-500 words. Both however, say the abstract should be limited to a single paragraph. When in doubt, the APA Manual should take precedence.

So what’s the big deal? Adding to the body of knowledge is the goal of research, the scientific method of inquiry, and other creative activities. The pursuit of new knowledge, however, is dependent upon the dissemination and archiving of research findings and the results of creative activities, and ready access to that new knowledge. Ready access, or the ability to retrieve new knowledge, cannot be overemphasized; timely access and ease of access are essential to sustaining the process of creating new knowledge and improving human undertakings. A well prepared abstract allows one to quickly survey the content of the article and to quickly retrieve it from an indexing database such as ERIC.

While it is not a primary source, https://owl.english.purdue.edu/owl/resource/560/01/ suggests the following when preparing an APA abstract: (1) the research topic, research questions, participants, methods, results, data analysis, and conclusions and (2) possible implications of the research and future work connected with the findings. While Purdue University’s Online Writing Lab (OWL) is a source, authors should always refer to the APA Manual.

Key to preparing an effective abstract is ensuring it is dense with information and that key words, which are used to retrieve the article or paper, are embedded in the abstract.

EDGD Calendar of Events

Future ASEE Engineering Design Graphics Division Mid-Year Conferences

69th Mid-Year Conference - October 12-14, 2014, Illinois State University
Site Chair - Kevin Devine.

70th Mid-Year Conference - January 24-26, 2016, Embry-Riddle Aeronautical University
Site Co-Chairs - Heidi Steinhauer and Lulu Sun.

Future ASEE Annual Conferences

Year	Dates	Location	Program Chair
2015	June 14 - 17	Seattle, Washington	Ron Paré
2016	June 26 - 29	New Orleans, Louisiana	
2017	June 25 - 28	Columbus, Ohio	
2018	June 24 - 27	Salt Lake City, Utah	
2019	June 16 - 19	Tampa, Florida	
2020	June 21 - 24	Montréal, Québec, Canada	

If you're interested in serving as the Division's program chair for any of the future ASEE annual conferences, please make your interest known.

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Spatial Visualization Ability and Impact of Drafting Models: A Quasi Experimental Study

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Abstract

A quasi experimental study was done to determine significant positive effects among three different types of visual models and to identify whether any individual type or combination contributed towards a positive increase of spatial visualization ability for students in engineering technology courses. In particular, the study compared the use of different visual models - a 3D printed solid object, a 3D computer generated drawing and a 2D drawing.

Introduction

It is recognized that the ability to visualize is an important tool required of engineers in order to function effectively (Deno, 1995; Miller, 1990; Pleck, 1991; Sorby & Baartmans, 2000). More specific, visualization of problems is critical for success in engineering education (Sorby & Baartmans, 2000), and for that reason spatial abilities have been used as a predictor of success in several engineering and technology disciplines (Strong & Smith, 2001).

However, these abilities are not determined genetically, but rather a result of a long learning process. It has been shown by several studies that some type of intervention, whether a short course or a semester long course, can improve spatial abilities in students who score low on tests in this area (Hsi, Linn, & Bell, 1997; Martín-Dorta, Saorín, & Contero, 2008; Sorby, 2001). For this study, the following was the primary research question. Is there a difference between the impact of model type (2D drawing, 3D computer generated drawing, 3D printed object) on spatial visualization ability? The following hypotheses will be analyzed to attempt to find a solution to the research question. The hypotheses that guided this study were:

H_0: There will be no difference in spatial visualization ability between the impact of model type (2D drawing, 3D computer generated drawing, 3D printed object).

H_A: There will be significant difference in spatial visualization ability between the impact of model type (2D drawing, 3D computer generated drawing, 3D printed object).

Review of Literature

According to Piagetian theory, an individual acquires spatial visualization ability through three distinct stages of development (Bishop, 1978). During the first stage, children

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acquire topological spatial visualization skills with the ability to discern an object's topological relationship with other objects. During the second stage of development, projective representation is acquired and children can conceive what an object will look like from a different perspective. At the third stage of spatial visualization development, the individual learns to combine projective abilities with the concept of measurement.

Due to the reduced amount of instructional time given for engineering graphics content in many engineering and technology programs, faculty have expressed concern that students' ability to visualize 3D parts from 2D drawings is not being developed as well as in the past (Branoff, T. J. & M. Dobelis, 2013; Branoff, 2007; Clark & Scales, 2000; Meyers, 2000). To measure an individual's spatial ability, a plethora of standardized tests are available.

The most commonly used tests include:

a) The Purdue Spatial Visualization Test: Rotations (PSVT:R), devised to test a person's ability at the second stage of development (Sorby, 2005).

b) The Mental Rotation Test (MRT) a test designed to assess a person's ability to visualize rotated solids (Sorby, 2005).

c) The Differential Aptitude Test: Space Relations (DAT:SR) consists of 50 items and with a role to test spatial ability (Monahan, Harke and Shelley, 2008).

d) The Mental Cutting Test (MCT) that requires individuals to create a split view of an object; therefore, forcing to visualize and choose the correct cross-section among five alternatives (Tsunumi, 2004).

Several studies have been conducted to examine the usefulness of an engineering graphics literacy test (Branoff & Dobelis, 2012a, 2012b, 2012c; T. J. Branoff & M. Dobelis, 2013) and some of them have proven to be great predictors of an individual's ability to visualize (Kelly, Clark, & Branoff, 2013).Some of the factors that have been identified by various graphics education researchers are spatial visualization, spatial relations, spatial orientation, spatial cognition, spatial intelligence, spatial ability, and visualization (Hartman & Bertoline, 2005; Martin- Dorta, Saorin, & Contero, 2008; Miller & Bertoline, 1991; Sorby, 1999a).

According to Bodner and Guay (1997) two factors emerged from spatial ability research: spatial orientation, which involves not being puzzled by changes in visual inputs, and spatial visualization, which involves the ability to manage visual input components (Kelly, 2012). Eliot and Smith (1983) showed factors, such as spatial relations, in the context of mental rotation of objects, spatial orientation as the understanding of how an object would appear from a different perspective, and visualization from a surface development context (Kelly, 2012) According to Juhel (1991) the focus is on three factors: spatial orientation, which determines how an object will appear from a different position; spatial visualization, which involves the mental transformation of an object; and speeded rotation, which is the mental rotation of objects (Kelly, 2012).

In recent years, 3D spatial abilities have received much attention. Several studies have involved different interfaces to attempt to manipulate a person's understanding of 3D space (Carriker, 2009).Cockburn (2004) asked whether or not a person would have a better spatial memory if they were given a 3D representation of the object's location. For the specific study, the user is not allowed to move; it is only a simple comparison of perspective effects in the displays (Carriker, 2009). Cockburn (2004) also added visual cues that gave the illusion of a 3D object, including shadows, lighting and size, to see if individuals could recall the 3D objects better than their 2D counterparts. He found that there were no significant differences between the averages of the 2D and 3D conditions.

Authors, Tan, Gergle, Scupelli, & Pausch (2004) performed a study that was designed to examine the effects of physical display size on an individual’s cognitive strategy and performance on an interactive 3D navigation task (Carriker, 2009). Comparable to the prior study by Cockburn, Tan et al. attempted to analyze 3D spatial ability using different displays. However, they also addressed whether that performance is directly affected by the task being interactive or not. Tan et al. (2004) attempted to examine not only the implications of the display, but the effect on the subject when allowed different means of interaction with the 3D world.

In addition, several researchers have suggested that spatial ability can be enhanced and taught by some instructional designs (Alias, Black, & Gray, 2002; Kwon, 2003; Lajoie, 2003; Potter & Merwe, 2001; Woolf, Romoser, Bergeron, & Fisher, 2003). Many works demonstrated that instructions using computer-based 3D visualizations can provide learners with adequate spatial experiences for developing their spatial ability (Kwon, 2003; Woolf et al., 2003). However, few empirical studies have established the causal relationships in greater depth (Wang, Chang & Li, 2006).Moreover; few studies have explored the effects of two-dimensional (2D) versus three dimensional (3D) media representations on the influence of the spatial ability of undergraduate students (Wang, Chang & Li, 2006).

Based on this research, it is clear that changing the software or hardware has a high correlation to a student's understanding of 3D space. This encourages future research to find the most efficient tools to improve 3D spatial visualization ability for all students.

Methodology

A quasi-experimental study was selected as a means to perform the comparative analysis of spatial visualization ability during the fall semester of 2013. The study was conducted in an engineering graphics course, MET 120 (Computer Aided Drafting), offered at Old Dominion University as a part of the Engineering Technology program. The participants from the study are shown in Table 1. From the 54 students, 12 were

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females and 18 were African American and using a convenience sample there was a near equal distribution of the participants between the three groups.

Table 1. Research Design Methodology

Group 1	n1=20	MCT	Sketch from 2D drawing
Group 2	n2=16	MCT	Sketch from 3D image
Group 3	n3=18	MCT	Sketch from 3D object

The engineering graphics course emphasized “hands on” practice using 2-D and 3D AutoCAD software in the computer lab, along with the various methods of editing, manipulation, visualization and presentation of technical drawings. In addition, the course included the basic principles of engineering drawing/hand sketching, dimensions and tolerance principles.

The students attending the course during the fall semester of 2013 were divided in to three groups according to the section of the course that they chose to participate the semester prior to the study. The three groups (*n1*=20, *n2*= 16 and *n3*=18 with an overall population of *N* = 54) were presented with a visual representation of an object (drafting model) and were asked to create a sectional view. The first group (*n1*) received a 2D drawing of the cone (see Figure.1), the second group (*n2*) received a 3D PC generated image of the cone (see Figure. 2) and the third group (*n3*) received a 3D printed cone using a 3D rapid prototyping machine (see Figure. 3).

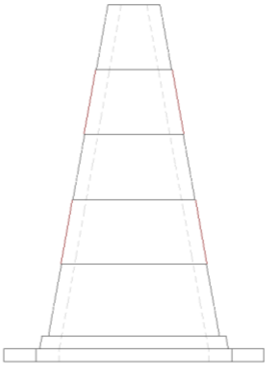

Figure1. 2D Drawing

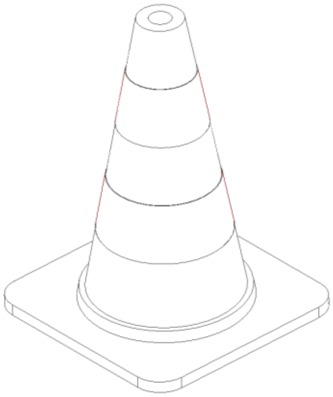

Figure 2. 3D Computer Generated Drawing

Figure 3. 3D Printed Object Using Additive Technology

In addition, all groups were asked to complete the MCT instrument 2 days prior to the completion of the sectional view drawing to identify level of visual ability and show

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equality between the three groups. According to Nemeth and Hoffman (2006) the MCT has been widely used in all age groups. The “standard MCT” consists of 25 problems. The Mental Cutting Test (hereafter MCT), a sub-set of the CEEB Special Aptitude Test in Spatial Relations has been used by Suzuki et al.to measure spatial abilities in relation to graphics curricula (Tsunumi, 2004).

In each problem, subjects are given a perspective drawing of a test solid, which is to be cut with a hypothetical cutting plane. Subjects are then asked to choose one correct cross section from among 5 alternatives. There are two categories of problems in the test (Tsutsumi, 2004). Those of the first category are called `pattern recognition problems', in which the correct answer is determined by identifying only the pattern of the section. The other are called `quantity problems' or `dimension specification problems', in which the correct answer is determined by identifying not only the correct pattern but also the quantity in the section, e.g., the length of the edges or the angles between the edges (Tsutsumi, 2004).

Upon completion of the MCT the instructor of the course placed the 2D drawing, 3D computer generated image and 3D printed object in a central location in the classroom (the three groups were positioned in to three different rooms) and asked the students to create a sectional view of the cone. The engineering drawing that was used in this research was a sectional view of a cone which had different levels of different materials. These levels had different colors. Sectional views are very useful engineering graphics tool, especially for parts that have complex interior geometry. Sections are used to clarify the interior construction of a part that cannot be clearly described by hidden lines in exterior views (Plantenberg 2013). By taking an imaginary cut through the object and removing a portion, the inside features could be seen more clearly. Students had to mentally discard the unwanted portion of the part and draw the remaining part. The rubric used included the following parts: 1) use of section view labels; 2) use of correct hatching style for cut materials; 3) accurate indication of cutting plane; 4) appropriate use of cutting plane lines; and 5) appropriate drawing of omitted hidden features. Maximum score for the drawing was 6 points.

Data Analysis

Analysis of MCT Scores

The first method of data collection involved the completion of the MCT instrument prior to the treatment to show equality of spatial ability between the three different groups. The researchers graded the MCT instrument as described in the guidelines of the MCT creators. A standard paper-pencil MCT was conducted, in which the subjects were instructed to draw intersecting lines on the surface of a test solid with a green pencil before selecting alternatives. The maximum score that can be received on the MCT is 25 and as it can be seen in Table 2, n1 had a mean of 21.47, n2 had a mean of 19.76 and n3 had a mean of 21.37. There was no significant difference between the three groups as far as spatial ability as measured by the MCT instrument.

Table 2. MCT Descriptive Results

					95% Confidence Interval for Mean	
	N	Mean	SC	Std Error	Lower Bound	Upper Bound
2D	16	21.471	8.02	3.213	13.629	17.513
3D PC	20	19.766	6.121	2.096	14.169	19.164
3D Solid	18	21.314	6.945	2.390	18.049	21.379
Total	54	21.85	6.87	2.56	16.28	19.352

Analysis of Drawing

The second method of data collection involved the creation of a sectional view drawing. As shown in Table 3, the group that used the 2D drawing as visual aid (n =16) had a mean observation score of 4.06. The groups that used the 3D computer generated visual (n = 20) and the 3D printed solid cone (n = 18) had higher scores of 5.87 and 5.12 respectively. A one-way ANOVA was run to compare the mean scores for significant differences among the three groups. The result of the ANOVA test, as shown in Table 4, was significant, F(2, 52) = 14.54, $p < 0.01$. The data was dissected further through the use of a post hoc Tukey’s honest significant difference (HSD) test. As it can be seen in Table 5, the post hoc analysis shows a statistically significant difference between the 3D Solid vs. 3D PC ($p < 0.001$, $d = 2.08$) and the 3D Solid vs. 2D ($p = 0.008$, $d = 1.54$), with 3D Solid vs. 2D being significantly lower in both cases.

Table 3. Sectional View Drawing Descriptive Results

					95% Confidence Interval for Mean	
	N	Mean	SC	Std Error	Lower Bound	Upper Bound
2D	16	4.061	.2672	.0724	3.917	4.235
3D PC	20	5.876	1.287	.3075	5.209	6.424
3D Solid	18	5.122	.8492	.2547	4.594	5.790
Total	54	5.036	1.163	.1859	4.691	5.301

Table 4. Sectional View Drawing ANOVA Results

Quiz	SS	df	MS	F	p
Between Groups	13.531	2	11.765	14.536	< 0.001*
Within Groups	22.376	50	.809		
Total	55.907	52			

* Denotes statistical significance

Table 5. Sectional View Drawing Tukey HSD Results

Visual Aids (1 vs. 2)	Mean Diff. (1-2)	Std. Error	*p*
3D Solid vs. 3D PC	-1.80	0.334	< 0.001*
3D Solid vs. 2D	-1.07	0.340	0.008*
3D PC vs. 2D	0.724	0.334	0.090

* Denotes statistical significance

Discussion

This study was done to determine significant positive effects among three different types of visual models and to identify whether any individual type or combination contributed towards a positive increase of spatial visualization ability for students in engineering technology courses. In particular, the study compared the use of different visual models- a 3D printed solid object, a 3D computer generated drawing and a 2D drawing. It was found that the 3D printed solid model and 3D computer generated image both provided statistically significant higher scores than the 2D drawing. While not statistically significant, the students who received treatment via the 3D printed solid model outperformed their peers who received treatment from the other two models in the drawing. This could indicate that students were better able to comprehend visual data given from 3D solid models, over 3D computer generated models or 2D drawings.

It should be noted that the majority of visual models used in the past and today are 2D drawings, asking the students to recreate different views. Using 3D solid models as visualizations aids for engineering graphics courses has great potential. With the current status of additive technologies instructors have the ability to design and built almost any model in a very short time frame. However, potential issues include: a) availability of 3D printers at all institutions and b) it appears that more research is needed utilizing populations with different background. This small quasi experimental study provided results contrary to the commonly used method of 2D visual modeling. Instead, a 3D solid model seems to give the students a better understanding of the task being taught.

Future Plans

Future plans include, but are not limited to:

- Repeating the study to verify the results by using additional types of models.
- Repeating the study using a different population such as technology education, science or mathematics students.
- Repeating the study by adding additional visual cues during the display of 3D objects, including shadows, lighting and size.
- Repeating the study by comparing males vs females as it has been suggested that males tend to do better on spatial ability tasks than females (Carriker, 2009).

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