A Comparison between 2D & 3D Computer-Aided Drafting in Displaying the Features of a Product

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Abstract: This paper conducts a visual comprehension in pictorial drawing for designs by using three-dimension computer aided drafting (3D CAD) and 2D graphical representation. It designed a spatial ability test to evaluate the understanding or misunderstanding about all the presentation of objects which are classified into five categories of surfaces with three levels of difficulty depended upon the numbers of sectional planes. This test is designed through sixty objects what are individually offered with one 3D graphic and two accompanying orthographic views. After the spatial ability test was performed, the effectiveness (or accuracy) and perceptibility of each presentation method is evaluated by conducting experiments, and analyzed through statistic techniques of ANOVA and Chi-square. Finally the conclusion illustrates that applying 3D CAD shows better performance than applying 2D graphics in understanding the appearances and features of object. Consequently, it is considerably useful for applying 3D CAD in the design process. Designing various products with different complicated surfaces, we could take advantage of 3D CAD to accomplish better communication. In addition, it can reduce the possibility of misunderstandings and save up a significant amount of time for exposition.

Key words: 3D CAD, Animation, Double-curved surface, Oblique surface.

1. Introduction

In the process of design, graphics is a very important medium to express your thought and creativity. The art of drawing is important not only as a tool for communication with others, it really helps designers see and comprehend the forms they work with. [5] Cecil Jensen & Jay Helsel regard a drawing as a graphic representation of a real thing, and it is a language for its picture to transfer thoughts and ideas. In general, we usually utilize the pictorial projections which are isometric, oblique, and perspective projection to describe a product in equipment, preservation drawings and design sketched. Pictorial drawings of objects are occasionally used, but multi-view drawings are still the main drawings employed in mechanical drafting for fully describing an object. Orthographic projection is one form of observing an object from different views, which are front, side, and top views, and systematically putting them on the drawing paper to transit the essential information to the reader [1, 8].

The purpose of this paper is to distinguish the differences between 2D & 3D Computer-Aided Drafting in displaying the features of a product. In order to realize viewers' comprehension about products in different degree, the orthographic projection could be a method to examine it. According to the classification of surfaces of objects, there are five types including Normal surface, Inclined surface, Oblique surface, Cylinder and Double-Curve surface [6]. This paper is designed in two spatial ability tests to explore the effect of these representations whether 2D pictorial drawings with the views of four directions or removing parts from the whole product and 3D graphics with animation are the same.

At the middle of 1960s, computer aided drafting (CAD) technology was first introduced as an instrument for the creation of drawings without the using traditional drafting devices. The drawings were made and displayed by operating the graphics elements on the computer screen instead of drawing them by hand [2]. In recent years, 3D CAD has been widely utilized in design and discipline. It has had a profound meaning on the three-dimensional design professions. Processes, such as rendering, prototyping, or animating, can be now finished by an individual designer without the assistance of other professional experts [9]. Using the 3D CAD enables grasp of time and space in construction of model. According to the features of 3D CAD, changing the dimension and shape can be finished at the same time by the function of parametric design. It is a prominent contribution to use the 3D CAD tools for shorting time to market and reducing costs of product about development & research [7]. By means of using 3D CAD technology, product development has been translated from 2D to 3D, from physical to digital model in the last few decades. Design, modeling, simulation and tooling belong to part of a totally digital development process [4, 10].

2. Method

2.1 Participants

There are two groups of participants committed to the empirical studies. One is thirty students of the Department of Crafts and Design from Taiwan University of Art (6 males and 24 females), and the other is seventy students of the Department of mechanical Engineering from Hwa Hsia Institute of Technology (69 males and 1 female). To achieve the capability of orthogonal projection in this spatial ability test, the participants have to finish one semester of course in basic graphic, and pass the final examination.

2.2 Styles of Display

Four types of display are presented in this spatial ability test. In two 2D drawings, one is exhibited with four views in different directions such as south-eastern and north-western corners and so on (see Fig 1,abbr. 2DR), and the other is described by cutting the object step by step (see Fig 2, abbr. 2DT). In two 3D rendering graphics, both of them are showed by animation to emphasis the whole shape of objects. One is expressed by gradually removing the separated parts from the whole object (see Fig 3, abbr. 3DT), and the other is expressed by rotating the object around the three axes, furthermore, slowly turning it to orthogonal plane towards observers (see Fig 4, abbr. 3DR). This test is designed through sixty objects what are individually offered with one 3D graphic and two accompanying orthographic views. Testers need to choose the third correct one from four similar views. In order to avoid the harmful effects caused by other factors to the goal of this study, all the representations of objects in the test are drawn by Computer -Aided Drafting and ignored in lighting and textures.

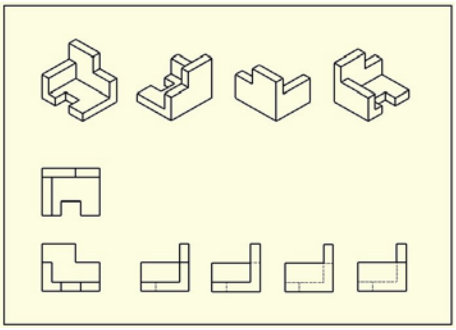


Figure.1 2D graphics expressed by four directions (2DR)

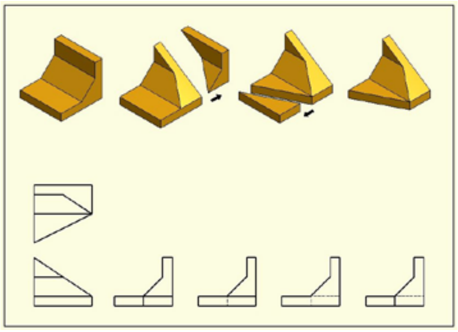


Figure.2 2D graphics removed from object (2DT)

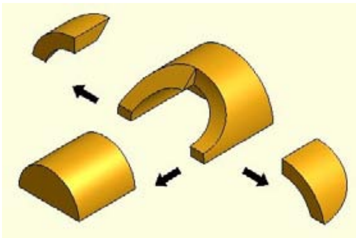


Figure.3 3D graphics removed with animation (3DT)

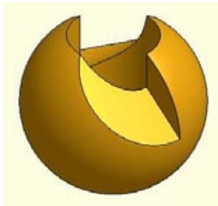


Figure.4 3D graphic rotated with animation (3DR)

2.3 Contents of the test

The spatial ability test has two versions of materials. In order to explore the comprehension of complicated shape about real products, it is provided by two empirical studies from the geometric construction of objects to real products orderly. The test of the first empirical study consists of sixty items divided into five categories of surfaces with three levels of difficulty depended upon the numbers of sectional planes. These five surfaces are respectively normal surfaces (see Fig 5), inclined surfaces (see Fig 6), oblique surfaces (see Fig 7), cylinders (see Fig 8) and double-curved surfaces (see Fig 9). Each kind of surface all has three sets of items which are categorized by the numbers of removed planes of objects. The test of the second empirical study contains five products which are daily commodities comprising five features of surfaces respectively (see Fig 10).All the 2D&3D graphics are drawn by the Package of Autodesk Inventor Professional at Version 2008.

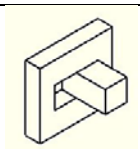
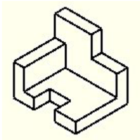
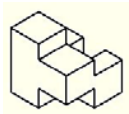
displays / surfaces		2D Rotated	2D Transfer	3D Transfer	3D Rotated
Normal Surfaces	easy				
	medium				
	difficult				

Figure.5 normal surfaces in three levels of difficulty

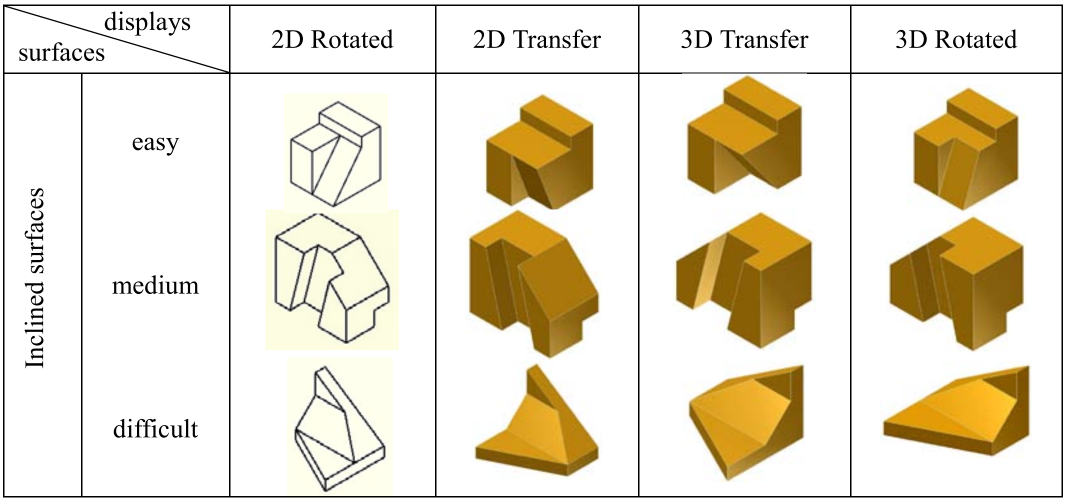


Figure.6 inclined surfaces in three levels of difficulty

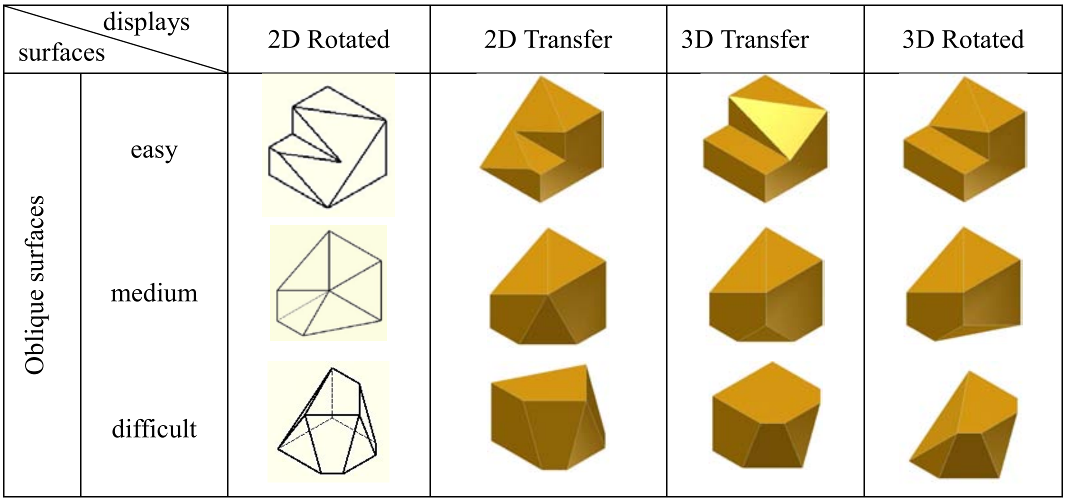


Figure.7 oblique surfaces in three levels of difficulty

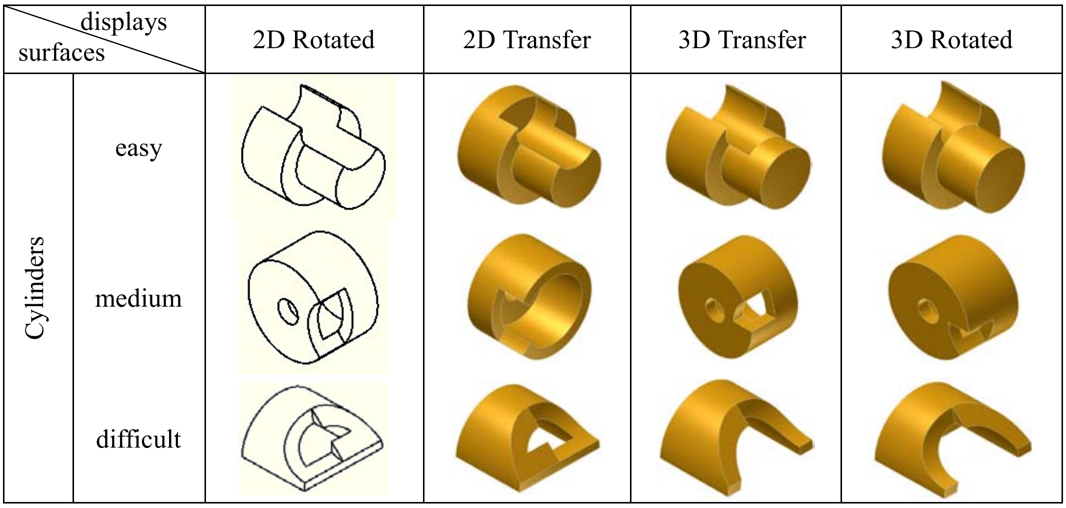


Figure.8 cylinders in three levels of difficulty

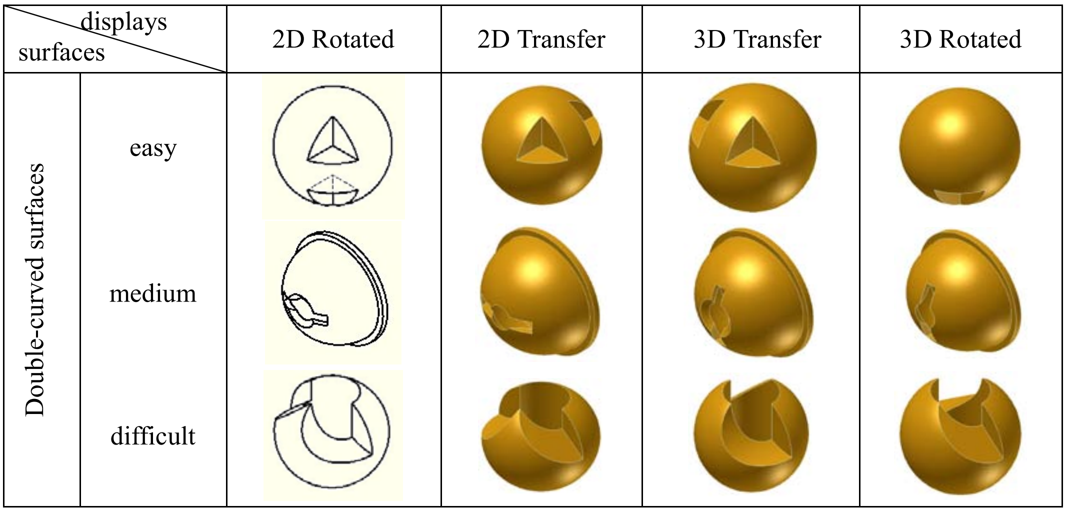


Figure.9 double-curved surfaces in three levels of difficulty

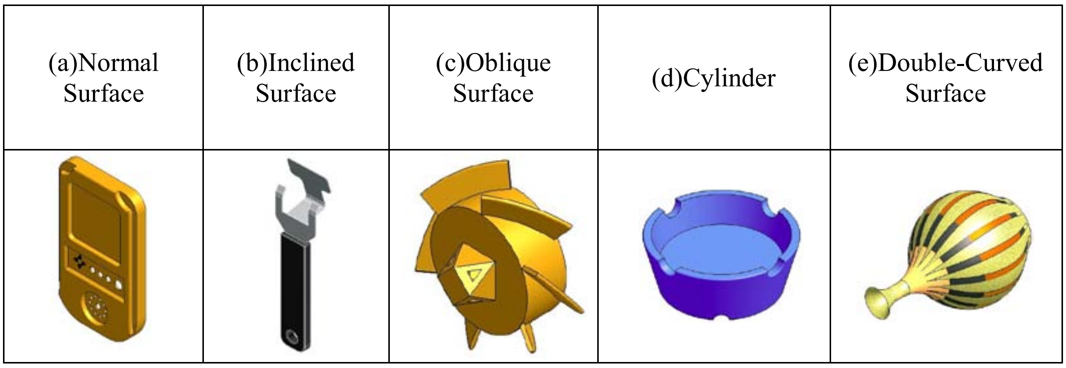


Figure.10 five products for daily commodity

2.3.1 Validity of test

The analysis of validity is composed of two parts. One is Content validity, and the other is Criteria validity. Content validity was evaluated from experts' opinions. The expert group consisted of 8 members including scholars of art education and teachers of graphic courses. These experts were asked to "if the questions are representative of the area of interest" [3]. Criteria validity was evaluated through a correlation coefficient to examine whether there was a significant correlation between the scores of the graphic course of the 30 students from Taiwan University of Art and the scores of this spatial ability test. As a result, there was a significant positive correlation (Pearson Correlation is 0.418*) existed.

2.3.2 Reliability of test

A Retest of Reliability was used to examine the stability of the spatial ability test. First, we selected 30 students from Hwa Hsia Institute of Technology to attend this test. After one month, they were retested again and evaluated through a correlation coefficient to examine whether there was a significant correlation in the scores of two tests. As a result, there was a significant positive correlation (Pearson Correlation is 0.833**) existed.

2.4 Procedure of empirical studies

With the purpose of corresponding to the sequence of learning process, two steps of test were taken placed in this study sequentially. In the first step of test, we chose 60 objects which are in the simple geometric shapes. In order to avoid the effects of learning during the process of test, objects with different surfaces were random set in order. On the average, it took about 1 min for testers to select the correct answer about each object and approximately 60 min for the all items. Furthermore, the second test was followed after a week. In that experiment, four groups were from 100 participants the same members as in the first step of test. Every group (25 participants) were randomly arranged to answer one of the four displays in the five products within 10 min.

3 Results and Discussions

3-1 Result

An analysis of variance (ANOVA) was performed here to investigate whether there were significant differences existed within the understanding of the features for 60 objects constructed with five types of surfaces by the four types of display in the first spatial ability test. Table 1 shows that for each subscale in the scale of *Comparison between 2D & 3D Computer-Aided Drafting in Displaying the Features of a product*, there was significant within the respondents from the displays of (1) 2D Rotation, (2) 2D Transfer, (3) 3D Transfer with animation, and (4) 3D Rotation with animation. In general, the representations of 3DR &3DT with animation are superior to 2DR and 2DT in displaying the features of objects.

Table1. Descriptive Statistics & Analysis of Variance for comprehension about all five surfaces in the four types of display

Source/ Four Types of display	SS	df	MS	F	Scheffe' Comparison	Types of Display	M	SD	N
Participants	2881.328	99	29.104		3>1,3>2	(1)2DR	10.55	3.135	100
Types of Surfaces	35.788	3	11.929	5.459***	4>1,4>2	(2) 2DT	10.43	2.931	100
Error	648.963	297	2.185			(3) 3DT	11.01	3.347	100
						(4)3DR	11.14	2.458	100

P***<0.001

Table2. Descriptive Statistics of comprehension about four types of displays in the five surfaces respectively

Types of Surfaces	2DR			2DT			3DT			3DR		
	M	SD	N	M	SD	N	M	SD	N	M	SD	N
(1)Normal Surface	2.27	0.874	100	2.43	0.769	100	2.22	0.917	100	2.46	0.731	100
(2)Inclined Surface	2.31	0.825	100	2.26	0.991	100	2.24	0.933	100	2.26	0.733	100
(3)Oblique Surface	1.90	0.810	100	1.50	0.628	100	2.55	0.730	100	1.85	0.687	100
(4)Cylinder	2.51	0.772	100	2.22	0.746	100	1.78	0.938	100	2.41	0.767	100
(5)Double-Curved Surface	1.56	0.998	100	2.02	0.974	100	2.22	0.860	100	2.16	0.735	100

Furthermore, if we analyze the effectiveness of each style of display the five surfaces alternately, Table 2 and Table 3 show that the results are various in the different situation presented. There are four outcomes to be obtained as followed:

1. During the expression by using the display of 2DR, Cylinder (M=2.51) was the best demonstration and Double-Curved Surfaces (M=1.56) was the worst. 2. During the expression by using the display of 2DT, Normal Surface (M=2.43) was the best demonstration and Oblique Surface (M=1.5) was the worst. 3. During the

expression by using the display of 3DT, Oblique Surface (M=2.55) was the best demonstration and Cylinder (M=1.78) was the worst. 4. During the expression by using the display of 3DR, Normal Surface (M=2.46) and Cylinder (M=2.41) were the best demonstration and Oblique Surface (M=1.85) was the worst.

In order to evaluate the differences of demonstrating one of the four displays in various contours of objects, Table 4 and Table 5 indicate that all five surfaces of objects featured in four types of displays are perceived as more differential. However, there are five conditions to be described as bellow:

Table3. Analysis of Variance of comprehension about the four types of display in the five surfaces

Source/Types of display	SS	df	MS	F	Scheffe' Comparison
2DR					
Participants	194.55	99	1.965		4>1>3>5
Types of Surfaces	57.220	4	14.305	33.093***	4>2>3>5
Error	171.18	396	0.432		
2DT					
Participants	170.102	99	1.718		1>4>3
Types of Surfaces	51.432	4	0.432	29.302***	1>5
Error	173.768	396	0.439		2>5>3
3DT(animation)					
Participants	221.798	99	2.24		3>1
Types of Surfaces	30.128	4	7.532	18.564***	3>2
Error	160.672	396	0.406		3>5>4
3DR(animation)					
Participants	119.608	99	1.208		1>2>3
Types of Surfaces	23.548	4	5.887	16.094***	1>5
Error	144.85	396	0.366		4>5>3

p***<0.001

1. If the object has the structure of Normal Surfaces in shape, 2DT and 3DR were clearer to modify them than 3DT. 2. If the object has the structure of Inclined Surfaces in shape, there was no significant differences existed in the four displays. 3. If the object has the structure of Oblique Surfaces in shape, 3DT was the best modification to them in four displays. 4. If the object has the structure of Cylinders in shape, 2DT and 3DR were clearer to modify them than 3DT. 5. If the object has the structure` of Double-Curved Surfaces in shape, 3DT and 3DR were clearer to modify them than 2DR.

Table4. Descriptive Statistics of comprehension about the five surfaces in the four types of display respectively

Types of Display	Normal Surface			Inclined Surface			Oblique Surface			Cylinder			Double-Curved Surface		
	M	SD	N	M	SD	N	M	SD	N	M	SD	N	M	SD	N
(1)2DR	2.27	0.87	100	2.31	0.83	100	1.90	0.81	100	2.51	0.77	100	1.56	0.99	100
(2)2DT	2.43	0.77	100	2.26	0.99	100	1.50	0.63	100	2.22	0.75	100	2.02	0.97	100
(3)3DT	2.22	0.92	100	2.24	0.93	100	2.55	0.73	100	1.78	0.94	100	2.22	0.86	100
(4)3DR	2.46	0.73	100	2.26	0.73	100	1.85	0.69	100	2.41	0.77	100	2.16	0.74	100

Table5. Analysis of Variance of comprehension about the five surfaces in the four types of display

Source/Types of display	SS	df	MS	F	Scheffe' Comparison
Normal Surface					
Participants	145.89	99	1.474		2>3
Types of Surfaces	4.170	3	1.390	3.320*	4>3
Error	124.33	297	0.419		
Inclined Surface					
Participants	185.628	99	1.875		No Significant
Types of Surfaces	0.267	3	0.089	0.224	Difference
Error	118.483	297	0.399		
Oblique Surface					
Participants	101.000	99	1.020		3>1>2
Types of Surfaces	57.500	3	19.167	55.537***	3>4>2
Error	102.500	297	0.345		
Cylinder					
Participants	148.840	99	1.503		1>2>3
Types of Surfaces	31.340	3	10.447	28.038***	4>2>3
Error	110.660	297	0.373		
Double-Curved Surface					
Participants	177.460	99	1.793		3>2>1
Types of Surfaces	26.760	4	8.920	18.691***	4>1
Error	141.740	297	0.477		

P*<0.05, p* **<0.001

Before finishing the first spatial ability test, we asked participants to answer which type of display was the best representation during the process of test. Table 6 shows that the display of 3DR with animation (44%) was the most selected in four displays. Through the statistic analysis of Chi-square, there is an obvious finding that 3DR with animation was the optimal answer including (1) 2DR, (2) 2DT, (3)3DT and (5) others.

Table6. The test of goodness of fit about the priority to choose the types of display in the spatial ability test

Item / f &%	(1)2DR	(2)2DT	(3)3DT	(4)3DR	(5)Others	χ^2	df
f	16	15	17	44	8	38.5**	4
%	16.00	15.00	17.00	44.00	8.00		

For the purpose of evaluating the results of the first spatial test whether can be transferred to real products, the second spatial ability test was conducted by the same participants after ten days. Table 7 shows that 3DT and 3DR with animation to demonstrate the features of the five products used in daily commodity were perceived as more distinct than 2DR and 2DT. Because the testing items are only five pieces, several of analyses can not be completely done in details. Maybe it will be more considerably studied for more selected products in the next research.

Table7. Descriptive Statistics & Analysis of Variance for comprehension about the four types of displays in all surfaces of five products

Source/ Four Types of display	SS	df	MS	F	Scheffe' Comparison	Types of Display	M	SD	N
Between	16.190	3	5.397			(1) 2DR	2.72	1.646	25
Within groups	159.120	96	1.658	3.256*	3>1	(2) 2DT	3.36	.952	25
Total	175.310	99				(3) 3DT	3.76	1.451	25
						(4) 3DR	3.64	952	25

P*<0.05

3-2 Discussions

The goal of this research is to investigate the comparison between 2D and 3D Computer Aided Drafting in displaying the features of a product. The results indicate that the comprehension of the products in different degrees mainly rely on what kinds of surfaces the products are constructed and how they are displayed. Although we designed 60 items to distinguish the differences of understanding objects, there could be a little change in the same level of difficulty owing to selecting the expression of varied views. However, it is necessary and important for researchers to choose the right direction about the displays of the products. In general, the display that was intended to be represented by 3D with animation is indeed comprehended as more effective than the display that is intended to be represented by 2D. Even though 2D is not comprehended as more effective, it was comprehended as more effective than 3D in some conditions. In this study, Table4 shows that the Means of 2DR and 2DT for the cylinders were higher than 3DT, and Table5 shows that there was no significant differences occurred within four kinds of display. Therefore, it is obviously identified that right style of display corresponds to an adequate surface. By the way, the degree of difficulty about these surfaces is considerably important key.

Because of spending more time and costs on making 3D graphics with animation, it could be a better choice to use the 2D graphics to describe the products constructed by the simple planes like normal surface and inclined surface. On the contrary, it is should be applied by 3D graphics with animation to demonstrate the products mainly constructed of double-curved surfaces.

An additional finding is that Table 2 shows the Mean of 2DR in the representation of cylinder rated the highest in the four displays. It seems that the result was not corresponded to those as we analyzed before. Through we checked the process of test in details, the objects with cylinder in the spatial ability test were placed in the clear direction so that it was easy to select the correct answer to the orthogonal projection in 2D display. So it was the reason why 2D display had the best performance in the four displays about the representation of cylinder.

4. Conclusion

The purpose of the survey in this research is to understand the differences of visual effect which are combined with computer technology and graphic education between 2D and 3D computer aided drafting to feature the products during the process of design. In conclusion, the results and their implications derived from the research findings show that (a) Designers and art teachers should more use the 3D computer aided drafting to design products or teaching aids to enhance the advantages of revealing the features of products. (b) The effect of performance by 3D graphics with animation is more powerful than the effect of 2D graphics. (c) Products with simple form of surfaces including normal surfaces and oblique surfaces should be better used by 2D graphics to display. (d) Products with sophisticated forms of surfaces including double-curved surfaces should be represented to the best expression by 3D graphics with animation.

In this study, it is obviously understood that the displays of 3D graphics with animation always increase the comprehension to the product with double-curved surfaces. If we extend this comparison, we may find that the changing sequence of removing from the whole products in the 3D representation might build the different visual effects. If we want to improve the effect of displaying the features of products, promoting computer technology and implementation of devices have already been necessary. Anyway, by means of displaying 3DT with animation can increase the ability to know how products construct. The displays of 3DR with animation can directly supply the dynamic image to the designers. If necessary, they can immediately modify the shape of products. 3D computer aided drafting not only help designers to completely observe the fully shape of products what direction you want, but offer the assembly graphics slowly disassembled by animation step by step. In spite of offering and testing a considerable number of objects, only five products were discussed in this study. Therefore, to select more adequate products in more categories and further analyze them with 3D computer aided drafting including attributes like shape, function, and texture is definitely an important issue for future research.

5. Acknowledgements

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