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Relationship between the students' spatial visualisation abilities and their performance of deducing 2D-Orthographic drawing

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A B S T R A C T

Many researches indicated that students' spatial ability influences their academic performance in engineering drawing and design. Significantly, a major limitation of traditional instruction is the problem of presenting three-dimensional spatial information in a two-dimensional format. Yet, there is no evidence base of how spatial ability influence the Eng-drawing learners' practice performance. This paper investigated the effects of the spatial ability level on novice Eng-drawing learners' practice performance in terms of shorting the learning time and increasing the drawing accuracy or not. 32 students from architecture department at the Sirte university were assigned equally into two groups regarding to their SA scores (high vs. low) to undertake specific Eng-drawing learning tasks of deducing the orthographic projection from an isometric model. The time taken and drawing accuracy were recorded. The results indicated that SA significantly related to drawing accuracy, but had little effect on learning time.

1. Introduction

Spatial ability can be defined as the ability to generate, retain, retrieve and transform well-structured visual images[1]. One component of spatial ability is the ability to correctly visualise a three-dimensional object when it is represented in two-dimensional spac[2]. Sorby[3],categorised the spatial skills into two groups, namely spatial visualisation and spatial orientation, as shown in figure-1. **Spatial visualisation** is the ability to visualise the situation in which we move an object mentally, while **spatial orientation** is the ability to visualise the transformation of an object form with the movement of your point of sight. Spatial visualisation is further subdivided into two categories of mental rotation and mental transformation. The difference between these two categories is that with mental rotation, the entire object is transformed by turning it in space, whereas with mental transformation, only part of the object is transformed in some way, as explained by Hitoshi et al[4] .

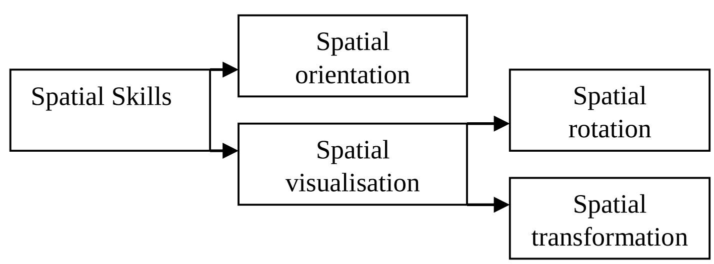

Figure 1. Spatial skills.

Many studies have indicated that spatial ability influences academic achievements in engineering related subjects such as structural design[5]. Spatial ability is a key factor in creative design performance in 2D and 3D design applications[6]. The significance of spatial visualisation abilities has also been noted by related researchers in a variety of teaching and learning domains. In general, spatial visualisation ability has been found to be essential for a student's success in particular engineering-related subjects such as computer visualisation activities, the practice of engineering drawing[78], engineering graphics[9], computer-aided design (CAD), 3D solid modelling, concrete experiences with geometrical objects[1011], traditional sketches using workbook paper and a pen or pencil[12]. Indeed, previous researchers discussed that adopting 3D virtual technology is positively related with students' spatial ability for applying 2D patterns into 3D garment fitting[1314]. It is therefore believed that spatial visualisation abilities affect a student's performance in 2D and 3D graphics environment and spatial skills are necessary for mastering several problems. However, there is little understanding of how spatial ability affect Eng-drawing learner's performance in practically terms of shorting the learning time and in improving the drawing accuracy.

2. Research aim

The aim of this research is to determine the effectiveness of the spatial visualisation ability level on novice Eng-drawing learner's practice performance (time and accuracy).

3. Research question and hypotheses

Q1. Does the student's spatial visualisation ability affect Eng-Drawing learners' performance?

The general null hypothesis (Ho) and its corresponding alternative hypothesis (Ha) for question (1) were formulated thus:

Ho1: There is no significant effect from the learner's spatial visualisation ability on Eng-Drawing learners' performance (in term of enhancing the drawing accuracy and shorting the learning time).

Ha1: Participants who have a high spatial visualisation ability will score higher in Eng-Drawing accuracy in less time than those who have low spatial visualisation ability.

4. Participants

A samples of 37 novice students from architecture courses participated in this study. Among these samples were males and females of different ages and levels of study. There ages ranged from 19 to 24. The sample were blocked by their spatial visualisation ability scores in two groups (low vs. high), this sample was divided almost equally into two groups to explore the significant differences between the (low vs. high) spatial visualisation ability on Eng-Drawing learning performance, therefore results of 5 participants were ignored to make both groups are equal in numbers of 16. The data file was programmed to be collected directly from participants via the on-line network. The personal details (students' name, course of study, level of study, ages and gender) as well as the results of the spatial visualisation ability tests were collected one week prior to the study.

5. Experimental design

The experimental work designed to test specific hypotheses: Examining the significance effects of spatial visualisation ability level on new Eng-Drawing learners' practice performance. The experimental study of Koroghlanian and Klein[15] suggests that in order to use the multimedia characteristics, such as sketches, graphics in the drawing learning process, the practice performance should be measured by the drawing accuracy and the time it takes to accomplish a specific drawing task. The experimental work involved the following three steps:

Step1. Determining the spatial visualisation ability level: The participant's spatial ability level was tested by using the spatial visualisation ability instrument (SVAI) that inspired by the work of Anon[17]. The different levels of spatial intelligence in Anon's method adopted and reproduced by embedding an automatic marking system shows in figure-2.

The spatial ability assessment instrument administered to the participants approximately one week prior to the study. Scores from all participants were ranked and a median split was used to classify participants as high or low spatial ability. For this study, 37 participants completed the image holding and the comparison and mental image of the objects tests (see figure-2) with a median score of 6.5 out of a total possible score of 10. The spatial visualisation ability instrument consists of 10 questions, categorised into two parts which relate to the corresponding factors of spatial visualisation skills. Part A is the spatial factor of Image holding and comparing – which is closely associated with Part B: the planar rotation, as the most basic of operations in the human spatial brain – namely the ability to imagine and manipulate an abstract object mentally. These two parts of the test assist in measuring and identifying an individual's spatial visualisation skills and the questions progress from an easy level to a very difficult one. Each question is given an illustrated test object and five other corresponding objects as the answer. The students are therefore expected to select the answer object that best resembles the test object. Figure 2 shows an example of this spatial visualisation ability instrument.

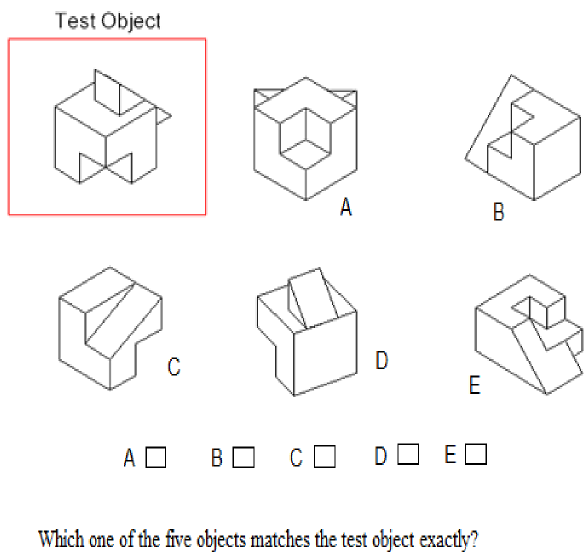

Figure 2. A sample of the Spatial Visualisation Assessment Instrument (Anon, 2002) [16].

Step2. Eng-Drawing tutorial: Because the participants in both groups had no idea about the basics of engineering sketching and drawing. Participants were required to follow a same tutorial guide of Eng-Drawing one week prior to the study. The purpose of this guide is to explain how to deduce the orthographic multiview from the isometric model. The tutorial was adapted from the design handbook[17], engineering drawing and sketching, as shown in figure-3.

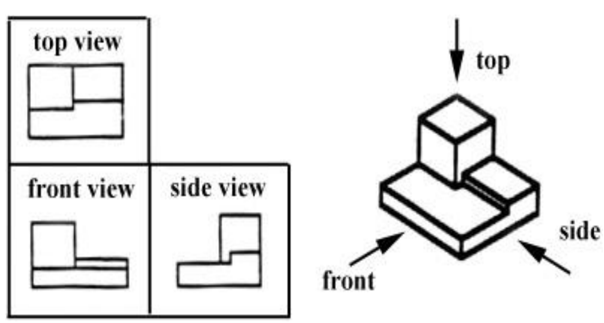

Figure 3. A multiview drawing and its explanation.

Step3. Eng-Drawing model: involved the selection and production of Eng-Drawing tasks presented in the form of printed materials of text and illustration The Eng-Drawing tasks were required from the participants to deducing the three projections (orthographic multiview) from the isometrics model shows in figure-4. The time it took to finish the Eng-Drawing tasks measured per minutes while the accuracy measured out of 12 points. The Eng-drawing model consisted of 12 points. Each point of accuracy measured by the correct drawing of the three orthographic projection parts in terms of the dimension and position in reference to the isometric model drawing as shown in figure-4.

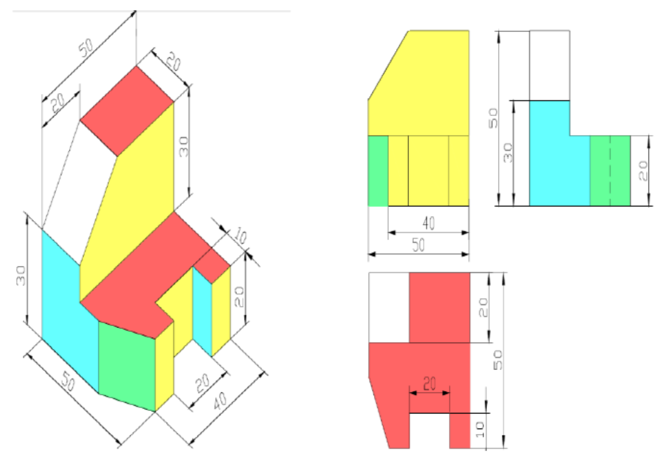

Figure 4. Isometric and three orthographic multiview views for the Eng-drawing model (Adapted from Antesar) [18].

6. Methods of interpreting the results

SPSS version 19 was selected for the data analysis. The experiment intended to examine the differences between the student's low versus the high spatial ability for Eng-drawing learning time and drawing accuracy. Therefore, the proper technique based on the comparison of the means scores of the two groups on a given variable (Independent Samples T Test). Oliver and Mahon [19] also indicated that the t-test is a common and powerful parametric test to compare the paired sample and to determine whether there are statistically significant differences between the two independent samples.

7. Result discussion of the learning time

Table 1 indicated that there were no differences in the learning time in mean in the two groups regarding the spatial visualisation ability level.

	Spatial ability	N	Mean	Std. Deviation	Std. Error Mean
Time min	L-SA	16	50.19	8.788	2.197
	H-SA	16	52.88	7.393	1.848

Table 2 demonstrated that there was no statistically significant main effect for the learner's spatial visualisation ability with the Eng-Drawing learning time with statistic significant of 0.05, where p= 0.357 > 0.05.

Table 2. Descriptive statistics (Time vs. SA).

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Time Per-min	Equal variances assumed	.475	.496	-.936-	30	.357	-2.688-	2.871	-8.551-	3.176
	Equal variances not assumed			-.936-	29.146	.357	-2.688-	2.871	-8.558-	3.183

From a comparison of figures 5 shows below for low-SA vs. high-SA and learning time, it appears that there were no significant differences in the learning time within the two groups for the high and low spatial visualisation ability levels.

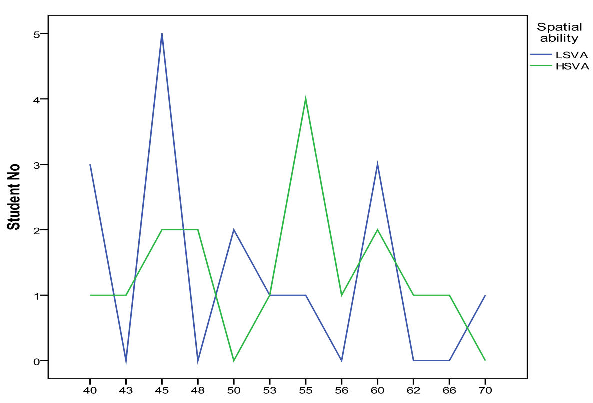

Figure 5. The relationship between high-SA vs. low-SVA and score of learning time.

8. Result discussion of the drawing accuracy

Table 3 indicates that the learners with a high SVA scored high in Eng-Drawing drawing accuracy with a mean score of 22.91 percent higher in comparison to the learners with a low spatial visualisation ability.

In further, table 4 indicates that there was a statistically significant main effect for the learner's spatial visualisation ability regarding to Eng-Drawing drawing accuracy, with statistic significant of 0.05, where p= 0.000 < 0.05.

Point of 12

Table 4. Descriptive statistics (Accuracy vs. SA).

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Point of 12	Equal variances assumed	.328	.571	-4.282-	30	.000	-2.063-	.482	-3.046-	-1.079-
	Equal variances not assumed			-4.282-	29.86	.000	-2.063-	.482	-3.046-	-1.079-

Figures 6 illustrate the significant mean differences in the drawing accuracy between the learners' of high and low spatial visualisation ability levels in comparison of the two groups.

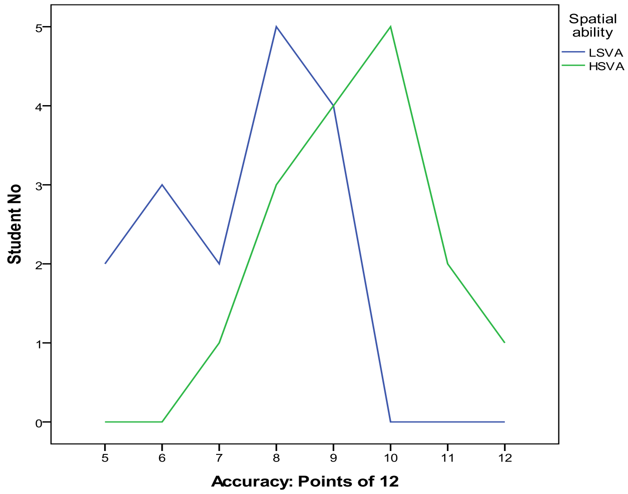

Figure 6. The relationship between high-SA vs. low-SA and score of drawing accuracy.

9. Conclusion

From the Independent Samples T-Test result (table 2), it can be confirmed that there was no statistically significant main effect for the spatial visualisation ability levels regarding the Eng-Drawing learning time, which supported the general null hypothesis (Ho) of this study, spicily (SVA level, does not affect the Eng-Drawing learning time).

However, by comparing the two groups for drawing accuracy (statistical description, table 4), it can be seen that there was a significant difference between the two groups in term of drawing accuracy (the significance was less than 0.05). Learners who have high-SVA level scored higher with drawing accuracy (22.91 percent) in comparison with those who have low-SVA level. It is therefore possible to say that there is a significant effectiveness of SVA level in term of drawing accuracy but does not affect the learning time spicily for the new Eng-Drawing learners. Indeed, learners who score higher in spatial visualisation ability could be more successful in learning of Eng-Drawing tasks than those who have a low-SA. In short, students' with high-SA will understanding the orthographic projection more strongly which will improve their ability to perform in Eng-Drawing courses, especially in the problem of presenting three-dimensional spatial information in a two-dimensional format. Therefore, since spatial ability is the most successful key in many field such as engineering drawing applications and design, engineering students are required to improve their spatial ability.

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