Development of Spatial Visualization Skills in 2D and 3D Offerings Measured via Different Tests

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Abstract

This manuscript reports on the development of spatial visualization skills on two different graphics courses at two different institutions. These two offerings are a hybrid approach (2D and 3D) and a solid modeling approach (3D only), both required courses in second year curricula. The comparison utilizes different visualization tests as indicators of spatial skills, i.e., PSVT:R, MCT, and MRT. The objective of this study is to further compare the two different offerings, given the fact that initial comparison indicated no significant difference in visualization skills between the two approaches when only the PSVT:R test was administered. Preliminary independent and combined results indicate some numerical differences in the scores, with limited statistical significance.

Introduction

The concept of spatial visualization has received significant attention from practitioners and researchers in the community. Spatial visualization skills have been often linked to mental capabilities that indicate likeliness or aptitude to perform certain tasks or professions. Similarly, there are numerous reports on exercises that focus on developing, evaluating, and improving visualization skills, both, for development of imagination and creativity, as well as development of competencies directly related to technical fields such as engineering graphics and design. These fields are linked to STEM education, and there are test such as the Purdue Spatial Visualization Test - Rotations PSVT:R (Guay, 1977), the Mental Cutting Test (MCT) (CEEB, 1939) and Vandenberg's Mental Rotation Test (MRT) (Shepard, 1971; Vandenberg, 1978). The underlying concept in these tests is the mental rotation of 3D objects. The PVST:R test has a series of problems with increased number of orthogonal rotations and resulting orientation of a given part is identified based on an given analogous rotation; in the MCT test the resulting solid representation is identified after a given 3D plane is used to cut a solid, and the MRT test requires the identification of two correct 3D views of a given block-chained solids. The PSVT:R test is perhaps one of the most commonly used test, and after its initial development in 1977 there have been reports about improvements and expansions of the test for spatial visualization and spatial orientation (Sorby, 1999; Branoff 2000; Yue, 2008; Ernst, 2015).

Methodology

This study is an extension of a previous report (Rodriguez, 2016) where the objective was to ascertain any difference in the spatial visualization skill of students that have a combined 2D-based (drafting) and 3D-based (solid modeling) instruction, and students with only 3D-based (solid modeling) instruction. In the original study, the data was based on PSVT:R scores for an specific semester. The study was completed at two institutions, in institution (A) there is a hybrid semester course where half of the course uses Autodesk's AutoCAD, and the other half of the semester is done utilizing Autodesk's Inventor. The other participating institution (B) offers a semester course which is based on instruction utilizing solid modeling packages, first Siemens' NX and then Dessault Systemes' CATIA. One reason of having two institutions is the independent offerings, implying that there are no students that might have taken other courses.

In this study all three aforementioned tests (i.e., PSVT:R, MCT, and MRT) were administered to the students. The decision on using these tests was with the intention to find out if some different specific skill was being developed in the students, or the previous conclusion was still the proper one. The tests were administered three times to both groups of students: at the beginning of the semester, midway through the semester, and at the end of the semester. The decision to include a midway evaluation was due to the fact that it is the moment when 2D instruction switches to 3D instruction at institution A, and it is the moment when institution B switches from the first 3D software (NX) to the second one (CATIA). Only two tests where administered to each student each time that testing was conducted, basically in order to avoid test fatigue, and expecting that the results will provide enough data for statistical analysis. Additionally, demographic information was collected from each participant, mainly gender, race, and program of study.

Results

The surveys were administered to the students during the Spring'15 semester, and their participation was completely optional. Some of the demographic information for both groups is provided in Table 1. In the first institution there was a total of 16 students participating (from a total of 17 registered), and at Institution B there was a group of 33 participants (from 35 students registered). The breakdown based on gender is similar at both institutions (10.5% at A, versus 13.9% at B), with higher percentages of under-represented and no traditional students at institution B.

The tests were administered during lecture time, at the end of the sessions, and there was a high level of participation (above 94% at both locations). Examples were presented and explained before the first time they did each test, and as clarification it was indicated that all figures represent solid objects (3D). The data was checked for normal distribution, and basic descriptive statistics for the compiled test scores at both institutions are provided in Table 2. From the table it can be stated that the scores have some difference between institutions. The table indicates as well that the average scores and standard deviations show variations at both institutions, with 50% of the scores showing increase as the semester progresses (with MRT results increasing at both institutions), and the other 50% having an increase/decrease at mid-semester but opposite trend at the end of the semester.

Table 1. Demographics for Each Institution Participating in the Study.

Demographic Information				
	Institution A (Graphics)		**Institution B** (Solid Modeling)	
	#	*%*	*#*	*%*
Number of Students	16		33	
Female Students	2	12.5	4	12.1
Male Students	14	87.5	29	87.8
Under-represented (gender, race)	2	12.5	7	21.2
Non-traditional (>25)	2	12.5	10	30.3

Table 2. Summary of Scores at Participating Institutions.

Evaluation Results						
	Institution A			**Institution B**		
	Pre-	*Mid-*	*Post-*	*Pre-*	*Mid-*	*Post-*
PSVT:R						
Average	23.297	21.685	24.240	22.206	23.246	22.385
Standard Deviation	4.570	4.520	4.809	4.845	4.000	2.696
MCT						
Average	18.082	19.263	18.200	19.252	19.371	20.660
Standard Deviation	3.883	3.807	4.198	3.840	3.100	1.932
MRT						
Average	28.017	30.502	35.200	28.112	28.464	32.735
Standard Deviation	5.913	6.220	5.923	6.206	5.65	3.561

With the purpose of finding out any statistically different scores between the two institutions, a 95% confidence t-test was performed to define the upper and lower limits for the confidence interval. The scores from Table 2 were normalized with a 100-points basis in order to have uniform results for comparisons. The normalized limits are represented in Table 3, with Figure 1 presenting the actual intervals sorted by pre-, mid-, and post- scores.

Table 3. Summary of Upper and Lower Limits for Confidence Interval.

Normalized UCI and LCI (5%)						
	Institution A			Institution B		
	Pre-	*Mid-*	*Post-*	*Pre-*	*Mid-*	*Post-*
PSVT:R						
Lower Confidence Interval	69.539	64.256	72.258	68.292	72.758	71.430
Upper Confidence Interval	85.773	80.312	89.342	79.746	82.213	77.804
MCT						
Lower Confidence Interval	64.051	68.936	63.851	71.564	73.088	79.900
Upper Confidence Interval	80.602	85.165	81.749	82.456	81.882	85.381
MRT						
Lower Confidence Interval	62.292	67.969	80.109	64.779	66.149	78.681
Upper Confidence Interval	77.901	84.543	95.891	75.783	76.171	84.995

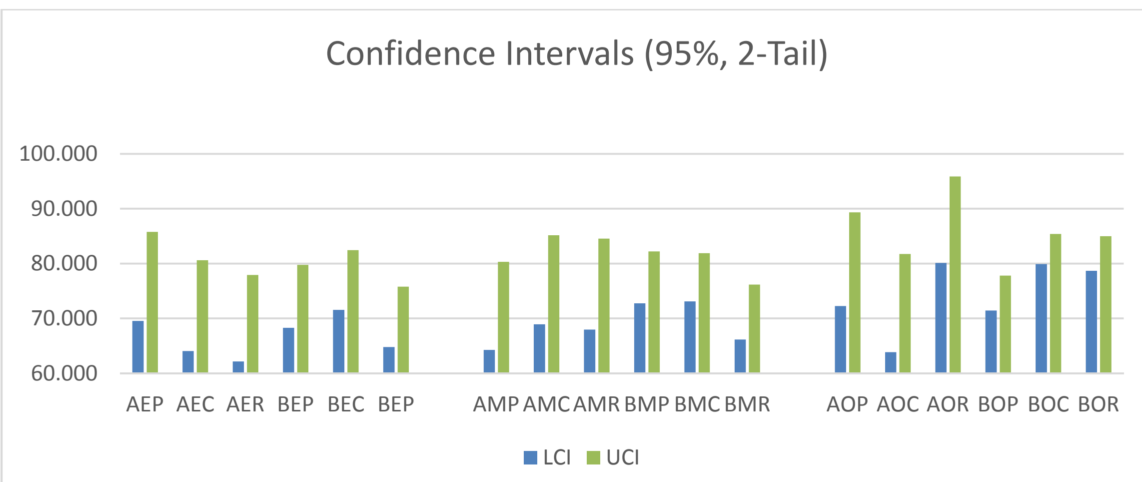

Figure 1. Confidence Interval Limits for All Scores.

Evaluation of the various confidence intervals for each institution indicate that there is no statistical difference between them at 95% confidence level. Even when trends can be observed at each institution, particularly in terms of standard deviations at institution B, they are not statistically different. In order to have significant differences between institutions the t-test needs to have at a minimum confidence level of 74% for MRT post-results, 56% for MRT mid-results, and 41% for PSVT:R pre-results, which are not acceptable levels.

Under the stated evaluation of no statistical difference, the scores are consolidated performing a weighted average for average scores and their standard deviations. The same 95% confidence is applied, and the results are shown in Figure 2. From these results it is possible to state that there is no significant difference between institutions, however there is difference between pre- and post- results (no difference between pre- and mid-results). This difference between pre- and post- is indicated as well in an ANOVA analysis, and it might be influenced by the higher scores obtained in the MRT tests.

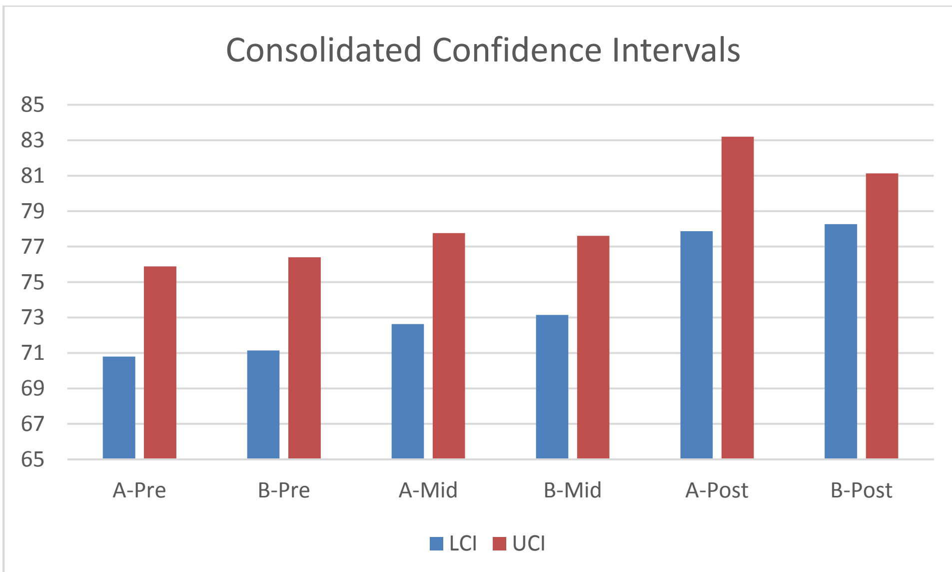

Figure 2. Confidence Interval Limits for All Scores at 95% Level.

Doing some comparison to results reported previously (only PSVT:R was administered), the general scores are consistent across all surveys. The difference in scores have a reduction of 1.95% at institution A and 3.33% at institution B, with similar trends in terms of larger improvement (i.e., reduction) in terms of the standard deviation at the post- results. Additionally, it is noted that once again question #30 is the one that has the lowest score, but now there are four question that had scores lower than 35%, as opposed to just the #30 in the previous report. For the MCT test it was question #18 the one with the lowest score, and for the MRT test it was question #10. Interesting to note that in the MRT test had the highest percentage (20%) of high scores (higher than 90%).

Conclusions

The results compiled for this round of tests indicate that there is no statistically significant difference in the spatial visualization scores obtained by students under two different course content. The use of additional visualization tests do show differences in the normalized scores, as indicated by their average scores and corresponding standard deviation, but there is no consistent trend among them. Such trends might be based on the individual skills and preferences by each student. Independent and consolidated scores have the same conclusions, with only consolidated post- scores being significantly different from the pre- and mid- scores at both institutions.

Even though there is no objective conclusion in terms of the benefit of one instructional approach over the other (2D *vs* 3D), this study has provided information on one outside pedagogical intervention (e.g. standardized testing), and the plan is to include internal intervention(s) (*e.g.*, course content and teaching approaches) that might improve the course offerings.

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