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Effect of Demographics on the Spatial Visualization Skills in 2D and 3D Course Offerings

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Abstract

This paper reports on the impact that demographic characteristics have in the development of spatial visualization skills on two different offerings of CAD-related courses at two different institutions. The ultimate objective of this information is to identify factors that might be influencing visualization skills development. The importance placed on visualization skills improvement is due to the fact that they have been related to expected performance by students in the technical fields. The data for this study has been collected for a span of one year at two different institutions, with one institution offering a hybrid course including 2D and 3D topics, and the other institution offering a course with only 3D topics. The collected data includes several parameters, and in this study the focus will be on gender, race, previous CAD experience, and age. The measurement of the visualization skills is based on on the administration of the PSVT:R test at three different times during the semester: at the start, in the middle, and at the end. Previous comparative studies have resulted in no statistically significant differences between the two course offerings. Results from this study indicate that CAD experience and age play a more direct role in positively affecting the visualization skills of students.

Introduction

The topic of visualization has received significant attention, for many years, from practitioners and researchers in fields such as education, psychology, and engineering. One of the issues that has, as well, increased the interest on the topic by people linked to technical fields is the conclusion that visualization skills have often been linked to mental capabilities that indicate likeliness or aptitude to perform certain tasks or professions. Consequently, there are numerous reports on techniques, methodologies, and 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.

In this field of graphics and design, which is more linked to STEM education, there are accepted test such as the Purdue Spatial Visualization Test - Rotations PSVT:R (Guay, 1977), the Mental Cutting Test (MCT) (Sorby, 1999) and the Shepard-Metzler Rotation (S-M) Test (Shepard, 1971) and its modification (Vandenberg, 1978). All of these tests have been used to measure the visualization skills in an individual at a given time, thus providing a reference for comparison. The underlying concept in these tests is the mental rotation of 3D given objects. PSVT:R is perhaps one of the most commonly used test, and after its initial development in 1977, there have been reports about improvements and expansion of tests for spatial visualization and spatial orientation. For PSVT:R in particular, there are reports based on trimetric representation (Branoff, 2000), the use of realistic 3D views (Yue, 2008), and the use of pictorials (Ernst, 2015).

Similarly, there are reports on techniques being utilized in order to develop spatial visualization skills, *e.g.*, the use of computer software [Shavalier, 2004], the use of 3D printed models [Katsioloudis, 2014], just as there are reports on the applicability and usefulness of various approaches (e.g., new and improved course content [Sorby, 2005], training for drafting [Samsudin, 2011]). These reports are a very small set of the work that has been conducted in the field, the complete set of works indicate the interest in having appropriate materials for improvement of spatial visualization skills, perhaps given the reports that such skills are a significant factor predicting success in technological programs [Sorby, 2005]. Visualization skills competency is nowadays being used for career advising, identification of potential success or need for additional academic preparation, and even as an admission factor.

Background

In most engineering and technology degrees students are required to have a course in technical graphics. There is variety of contents and approaches being used nowadays, with the most typical offering being a first-year course where students are offered spatial visualization topics using 2D concepts, such as orthogonal views and multi-views. In the past couple of decades it has been a trend to have first-year courses that cover similar visualization topics but in the context of 3D solid modeling. Nowadays, there is another trend were academic institutions have a hybrid course, where approximately half the course is in 2D concepts, and the second half covers 3D concepts. There is little information on the potential or actual benefit, in terms of visualization skills of the students, of any of the new offerings. There is clear evidence of the trend that has been occurring in terms of shifting to 3D concepts based on industry needs. Such industry needs have been defining and leading the development and implementation of solid modeling concepts in the CAD industry.

Two institutions with different approaches in their graphics offerings are, institution A (University of Wisconsin - Waukesha) there is now 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 institution is B (Western Michigan University) which offers a semester course based on instruction utilizing solid modeling packages, first Siemens' NX and then Dessault Systemes' CATIA. The offerings at both institutions are for students that have already decided on engineering or engineering technology programs, and both institutions are in a semester schedule. These two institutions have conducted comparative studies where the instrument selected to evaluate spatial visualization skills of the students was the Purdue test for rotations (PVST:R), given that it is an instrument that requires higher level of spatial visualization skills because of the use of inclined, oblique, and curved surfaces [Yue, 2004]. The test is a set of 30 questions where the number of mental manipulations increases as the test progresses. Table I summarizes the topics covered at each institution for the hybrid (A) and solid modeling (B) offerings.

The comparison of development of visualization skills in these two different offerings of graphics courses at two different institutions has been performed by the authors for the previous three semesters. The ascertainment of any differences in the spatial visualization skill of students that have 2D-based (drafting) or 3D-based (solid modeling) instruction was initially studied [Rodriguez, 2015]. The study pursued the assessment of any benefits on spatial visualization by students at each institution, and the results indicated that there was statistically significant difference between the two offerings. A second study was conducted where different tests for measurement of visualization skills (i.e., PSVT:R, MCT, and MRT) were administered to the students with the objective of finding any possible difference between the two offering modalities [Rodriguez, 2016]. Results indicated that all tests have similar trends, but there was no significant differences in visualization skills improvement for the two course offering modalities.

Table 1. Topics covered on each one of the offered courses.

Institution	
A - WI	**B - MI**
Orthographic Projections	S.M. Concepts
Auxiliary Views	Constructive Solid Geometry
Section Views	Constraints
Dimensioning	
	Orthographic Projections
S.M. Concepts	Auxiliary Views
Constructive Solid Geometry	Section Views
Constraints	Drafting
Assemblies	Dimensioning
GDT	Assembly

Methodology

This study looks at the possible effect that a demographic variable might have on the visualization skills of the students taking one of the offerings. Some of the data collected in the previous offerings of the course is the one being analyzed for this study, mainly data from the Purdue test for Fall and Spring semesters in the 2015-16 academic cycle. The reason for this decision is to increase the size of the dataset because that is the test that had been administered in all the previous semesters, and is still the one being administered now. The visualization test has been administered three times per semester at both institutions: 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).

In terms of the demographic data being collected, there is a set of 12 questions that is administered together with the first visualization test applied (see Appendix). The form is basically the same at both institutions, with some differences in terms of the standardized test used at the corresponding institution. From the complete list of demographic parameters, the following ones have been selected based on their relationship to their background: gender, race, age, and previous CAD experience. These are the factors used for the comparative analysis performed.

Results

The results are based on multiple ANOVA analyses in order to determine the validity of the hypothesis in each case that a given demographic parameter has direct relationship to a visualization test score. As it has been indicated in the past, the surveys were administered to the students and their participation was completely optional. The demographic information for both groups is provided in Table 2. In the first institution there was a total of 35 students participating, and at Institution B there was a total of 69 participants. The breakdown based on gender is similar at both institutions (11.4% at A versus 13.0% at B, female students), with higher percentages of under-represented and no traditional students at institution B.

Table 2. Demographics for each institution participating in the comparison.

Demographic Information				
	Institution A (UWW) (Graphics)		**Institution B (WMU)** (Solid Modeling)	
	#	%	#	%
Number of Students	35		69	
Female Students	4	11.4	9	13.0
Male Students	31	88.6	60	87.0
Under-represented (gender, race)	5	14.3	15	21.7
Non-traditional (>25)	5	14.3	22	31.9

Participation in the survey was without any incentive being offered, besides the explanation indicating that the results would be used for a possible redefinition of course content, and that their help would be greatly appreciated. The test was administered during lecture time, during the last 25 minutes of class and there was a high level of participation (i.e. few missing spots in the full dataset). Two examples were explained before the first time students took the test and, for clarification purposes, it was indicated that all figures in the test represent solid objects (3D).

The results of the ANOVA performed on the data are summarized in Table 3. The ANOVA test were done with a 95% confidence level. The results in the table indicate that there is no substantial correlation between the selected demographic parameters and the expected scores in the visualization test (i.e., most of the probabilities are above the threshold value of 0.05). There is some correlation for some factors but not consistently across all scores or between institutions, for example: at institution A there is a predictor only for the Post scores based on age and 2D CAD experience, and at institution B there is some statistically significant correlation between Race and only the Post- scores.

Table 3. Summary of Comparative Results – Probabilities of Correlation.

95% Confidence Level						
	Institution A			**Institution B**		
	Pre-	*Mid-*	*Post-*	*Pre-*	*Mid-*	*Post-*
Gender	0.209	0.555	0.254	0.142	0.975	0.776
Race/Nationality	0.545	0.434	0.386	0.109	0.784	0.008
Age	0.092	0.153	0.022	0.847	0.630	0.704
CAD Experience (2D)	0.117	0.228	0.032	0.460	0.475	0.383
CAD Experience (3D)	0.349	0.837	0.109	0.134	0.259	0.305

Some additional analyses were performed:

- A pairing (Tukey test) was performed in order to find out if there was any pairing or combination of demographic parameters that will serve as predictors. The results were similar to the ones obtained with the ANOVA tests.
- All demographic parameters collected were used in the statistical analysis. The result was that only one additional correlations was found. At institution A there were no additional possible predictors, and at institution B there was a $p = 0.015$ when the program (curriculum major selected, or expected) is linked with Pre- scores.

Conclusions

The results from this comparison indicate that even when there have been numerical differences in the scores for visualization skills among students, none of the demographic parameters applied in this study can be utilized as predictor. This conclusion is based on the statistical tests performed on the data collected at two different institutions with two different graphic course offerings.

It is interesting that all possible correlations for the parameters initially selected were found with the Post- scores. There are possible reasons to such fact, for example, it might be possible that the exposure to the test is skewing the results, or it might be that taking the course and being exposed to the material is helping in the development of their visualization skills. In the same manner, it is of interest to note that at institution A there is a correlation based on age and 2D experience and the Post-scores; further analysis of the data indicates the act that non-traditional, more mature students present in the offerings helped define such effect.

Data is being collected every semester and will be consolidated in order to increase the validity of the results and conclusions that have been formed up to this point. This situation is of interest because there might be small differences in the way the material is offered semester after semester, a natural situation. One additional analysis that will be studied with the full dataset is the possibility of combining demographic factors in the statistical analysis.

For now, it is encouraging, and certainly motivating, to know that the students have increased their test scores and that the spread of the scores usually decreases by the Post- results; the informal feedback from some students indicating that their mindset regarding their visualization skills is as well a positive information.

References

Ben-Chaim, D., Lappan, G., and Houang, R. T. (1988). The Effect of Instruction on Spatial Visualization Skills of Middle School Boys and Girls. American Educational Research Journal, 25(1), 51-71.

Conolly, P., Harris, L. V. A., and Sadowski, M. (2009). Measuring and Enhancing Spatial Visualization in Engineering Technology Students. Proceedings of ASEE Annual Conference and Exhibition, 14.868.1-9.

Guay, R. (1977). Purdue Spatial Visualization Test - Visualization of Rotations. W. Lafayette, IN. Purdue Research Foundation.

Branoff, T. J. (2000). Spatial Visualization Measurement: A Modification of the Purdue Spatial Visualization Test-Visualization of Rotations. Engineering Design Graphics Journal, 64(2), 14-22.

Ernst, J. V., Lane, D. & Clark, A. C., (2015). Pictorial Visual Rotation Ability of Engineering Design Graphics Students. Engineering Design Graphics Journal, 79 (1), 1-13.

Katsioloudis, P., Jovanovic, V., and Jones, M. (2014). A Comparative Analysis of Spatial Visualization Ability and Drafting Models for Industrial and technology Education Students. Journal of Technology Education, 26(1), 88-101.

Kinsey, B. L., Towle, E., and Onyancha, R. M. (2008). Improvement of Spatial Ability Using Innovative Tools: Alternative View Screen and Physical Model Rotator. Engineering Design Graphics Journal, 72(1), 1-8.

Maeda, Y. & Yoon, S. Y. (2013). A Meta-Analysis on Gender Differences in Mental Rotation Ability Measured by the Purdue Spatial Visualization Tests: Visualization of Rotations (PSVT: R). Educational Psychology Review, 25(1), 69-94.

Rodriguez, J & Rodriguez, L. G., (2015). Comparison of Spatial Visualization Skills in Courses with Either Graphics or Solid Modeling Content. . Proceedings of the 70th ASEE-EDGD Annual Conference.

Rodriguez, J & Rodriguez, L. G., (2016). Development of Spatial Visualization Skills in 2D and 3D Offerings Measured via Different Tests. Proceedings of the 71st ASEE-EDGD Annual Conference.

Samsudin, K., Rafi, A., and Hanif, A. S. (2011). Training in Mental Rotation and Spatial Visualization and Its Impact on Orthographic Drawing performance. Journal of Educational Technology & Society, 14(1), 179-186.

Shavalier, M. (2004). The Effect of CAD-Like Software on the Spatial Ability of Middle School Students. Journal of Educational Computing Research, vol. 31 no. 1, 37-49.

Shepard, R. & Metzler, J. (1971). Mental Rotation of Three-dimensional Objects. Science, 171, 701-703.

Sorby, S. A. (1999). Developing 3-D Spatial Visualization Skills. Engineering Design Graphics Journal, 63(1), 21-32.

Sorby, S. A. (2005). Assessment of a "New and Improved" Course for the Development of 3-D Spatial Skills. Engineering Design Graphics Journal, 69(3), 6-13.

Vandenberg, S. G. & Kuse, A. R. (1978). Mental Rotations, a group test of Three-dimensional Spatial Visualization. Perception and Motor Skills, 47, 559-604.

Wai, J., Lubinski, D. & Benbow, C. P. (2009). Spatial Ability for STEM Domains Aligning Over 50 Years of Cumulative Psychological Knowledge Solidifies Its Importance. Journal of Educational Psychology, 101, 817-835.

Yue, J. (2004). Spatial Visualization by Orthogonal Rotations. Proceedings of ASEE Annual Conference and Exposition, 9.1114.1-10.

Yue, J. (2008). Spatial Visualization by Realistic 3D Views. Engineering Design Graphics Journal, 72(1), 28-38.