Effect of Demographics on Improvement of Visualization Skills for Incoming First Year Students

J. Rodriguez
EDMMS Department
Western Michigan University

D. Bairaktarova
Department of Engineering Education
Virginia Tech

L. G. Rodriguez-Velazquez
Department of General Engineering
University of Wisconsin - Waukesha

Abstract

It has been established that the level of visualization skills of a student at the start of a technical program has a direct relationship with the likeliness that such student will have a successful endeavor in the program. As well, it has been established that there are differences in the performance in the program based on the gender of the student. In this report the effect of three demographic factors, i.e., gender, age, and race, is evaluated in the improvement of visualization skills of first-year students. The measurement used for evaluation of the visualization skills is a standardized test that was administered to students before and after their participation in a supplemental academic intervention.

Introduction

It was some decades ago when there was an initial link between spatial skills and good performance in technical endeavours, which was later documented for engineering careers (Sorby, 1999; Kozhevnikov and Thornton, 2006). Additionally, the effect of gender in most of those studies related to spatial skills has been documented (Sorby, 2005). Such reports have resulted in various actions at institutions of higher education that provide development and enhancement of spatial visualization skills in engineering and technology students. One such initiative is the EnVISION (Enhancing Visualization Skills-Improving Options aNd Success) project that was introduced in

2007 to test and enhance the spatial visualization skills of incoming engineering and technology students. Similar approaches are nowadays used in a variety of American universities (e.g., Michigan Technological University, Penn State University, University of Texas, and Virginia Tech). By helping students with low spatial visualization skills, particularly women as research shows that they are outperformed by their male peers on spatial related tasks (Voyer, 1995), the goal is to attract and retain students to STEM disciplines and to enhance their success (Veurink et al., 2009).

There is no definitive spatial visualization test, therefore variety of assessments, including the Purdue Spatial Visualization Test with Rotations - PSVT:R – (Guay, 1976), the Mental Cutting Test, the Revised Minnesota Paper Form Board Test, and the Differential Aptitude Test are used to screen FYE students for spatial ability (Maeda, et al., 2013). The PSVT:R is used in this study, and it consists of 30 questions with increasing degree of difficulty in terms of number and sequence of spatial rotations that need to be applied to a 3D object in order to end with a desired configuration.

While useful in identifying students, who would benefit from remedial spatial instruction, these tests are limited in their value to support remedial spatial instruction. Many standardized tests that are currently used to screen for spatial ability were developed with the goal of measuring skills that are likely to predict performance in skilled trades and crafts. Consequently, these tests use domain-general stimuli that bear little resemblance to authentic engineering tasks (Cohen & Bairaktarova, 2018).

OBJECTIVE

The objective in this study is to evaluate the effect of demographic factors on the improvement shown by students in terms of spatial visualization skills, which is measured by comparing pre-intervention and post-intervention test scores. Findings from this study can help in the development of pedagogical approaches with the aim of improving spatial skills. Of interest as well in the future is to compare the findings of this study with other reports, and eventually do some brainstorming to find reasons for their agreement or their disagreement, thus having a more robust pedagogical intervention.

METHODOLOGY

Data was collected from first-year engineering students in a large public university in the southeastern region. The well-accepted Purdue Spatial Visualization Test with Rotations (PSVT:R) was administered to the students at the start (pre-) and at the end (post-) of their first semester. All participants were enrolled in a one-credit Spatial Visualization course that provides preparation on fundamental spatial skills for an engineering curriculum. The course was designed for students with

low spatial skills as measured by PSVT: R. Students enrolled in the Spatial Visualization course scored 18 or below (60%) on the test administered during summer before their freshman year.

All participants received the same instruction through sixteen weeks-length of the semester, but they were split into three groups, each one having a different set of tools to work on assigned homework. The assigned homework (spatially-related problems) was similar for all three groups, with Group A having access to an augmented reality app, Group B using a spatial visualization app, and Group C utilizing free-hand sketching. All three groups received the same instruction in class through the whole semester. Students in all three groups moved through the course in three modules: i) sketching, ii) CAD, and iii) 3D object design and creation. Students were graded on completion of and time spent on the tasks.

ANALYSIS

The goal of this study is to evaluate the effect of demographic factors in the improvement of scores, as measured by the standardized test. The dataset utilized here only consists of valid cases, meaning students that have taken the pre- and the post- tests and received a score. A total of 185 pairs of scores were used in this study, with 89 female and 96 male students participating. The three demographic parameters are: gender, race and age. Race used five identifiers: Caucasian, African-American, Hispanic, Asian-American, other; while Age used three identifiers: below 18 years-old, 18 years-old, and over 18 years-old. The improvement measurement was basically the difference between each student scores. Table 1 provides basic descriptive statistics for the participants in the dataset, listing the overall list and the three subsets – corresponding percentages are provided.

Table 1. Descriptive statistics for dataset.

	Overall	**Group A**	**Group B**	**Group C**
Number of students	185	59 (31.9%)	66 (35.7%)	60 (32.4%)
Gender				
Female	89 (48.1%)	27 (45.8%)	30 (45.5%)	32 (53.3%)
Male	96 (51.9%)	32 (54.2%)	36 (54.5%)	28 (46.7%)
Race				
Caucasian	97 (52.4%)	29 (49.2%)	35 (53.0%)	33 (55.0%)
Non-Caucasian	88 (47.6%)	30 (50.8%)	31 (47.0%)	27 (45.0%)
Age				
Average	17.967	17.86	18.03	17.98
Standard Deviation	±0.545	±0.43	±0.34	±0.77

Two sets of analyses were applied, one using statistical analysis to test the hypothesis that there is a relationship between the demographic factors and the improvement in scores, and the other

using data analytics to identify the importance of any of the demographic factors in the score improvements. The statistical analysis was done using Minitab software, and the analytics approach was done with the use of the RapidMiner (2017) software package. The statistical analysis consisted of a series of ANOVA tests in order to test the formulated hypotheses, while the analytical test applied a decision-tree modeling for as many levels as needed.

RESULTS

The summary of results is presented in Table 2. When demographic factors are taken into account, the results indicate that pretty much they do not have a decisive influence. In several cases they do not appear at all as influential factor, and in other cases they appear at a very low probability/level, with neither gender or race being of importance for positive performance improvement.

For the statistical analysis, using a value of $p = 0.05$ to define the confidence of intervals to establish significance, it is observed that only one case: Race on Group A ($p = 0.038$) has a significant relationship; no other demographic factor has a direct relationship on the improvement of scores. Of interest is to point out that Hispanic subgroup has a significant negative relationship, i.e., decrease in scores.

For results based on data analytics it was found that demographic factors do not have a significant effect on score improvement. The information provided in the table are the level in the tree-branch approach applied where any of the demographic factors become a decisive factor. In this case it shows that only Gender is a factor at Level 4 on the Overall analysis (all three groups together) and for Group C, thus indicating that it is not a primary factor. Neither Age or Race are deciding factors in any of the evaluated cases.

Table 2. Effect of demographic factors and performance

	Overall	**Group A**	**Group B**	**Group C**
ANOVA (probability)				
Gender	0.694	0.370	0.452	0.472
Race	0.665	***0.038***	0.987	0.843
Age	0.350	0.239	0.849	0.760
Score Improvement (Level)				
Gender	***Level 4***	None	None	***Level 4***
Race	None	None	None	None
Age	None	None	None	None

These results indicate that none of the demographic factors can be considered significant. Further analysis will be done on different measurements of improvement, as reported in Rodriguez 2019, not just using the difference on raw score.

CONCLUSIONS

Effect of demographic factors on the improvement of spatial visualization skills were analyzed in this study. First-year engineering students were tested and three different pedagogical interventions were utilized. In summary, our findings suggest that demographic variables are not influential factors for performance, and for prediction.

These findings are of interest and further investigation is required. Mainly, they are not in agreement with similar findings, particularly for Gender, that have been reported. At the same time, the dataset used in this case corresponds only to one semester. There is an interesting number that corresponds to the percentage of female students in this group, which might indicate that the need of an additional instruction on spatial skills is of greater importance and need for the female population.

The identification of these effects, or lack of, on score improvement can help in defining the content needed in pedagogical interventions, and can provide a new perspective in the field of engineering education, and specifically in the development and enhancement of spatial skills of engineering students.

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