ASEE EDGD Midyear Conference

70th Midyear Technical Conference: Graphical Expressions of Engineering Design

Psychometric Properties of the PSVT:R Outcome Measure: A Preliminary Study of Introductory Engineering Design Graphics

Jeremy V. Ernst
Virginia Tech, jvernst@vt.edu

Thomas O. Williams
Virginia Tech, thwilli1@vt.edu

Aaron C. Clark
North Carolina State University at Raleigh, aaron_clark@ncsu.edu

Daniel P. Kelly
North Carolina State University at Raleigh, dpkelly@ncsu.edu

Psychometric Properties of the PSVT:R Outcome Measure: A Preliminary Study of Introductory Engineering Design Graphics

Jeremy V. Ernst
Integrative STEM Education
Virginia Tech

Thomas O. Williams
Special Education
Virginia Tech

Aaron C. Clark
Science, Technology, Engineering, and Mathematics Education
North Carolina State University

Daniel P. Kelly
Science, Technology, Engineering, and Mathematics Education
North Carolina State University

Abstract

The Purdue Spatial Visualization Tests: Visualization of Rotations (PVST:R)is among the most commonly used measurement instruments to assess spatial ability. This paper presents the preliminary findings of a factor analysis of the PSVT:R given to 335 introductory engineering design graphics students. Psychometric analysis of the student sample data indicated alternate loading patterns, divergent from a single factor solution.

Introduction

Calls for greater numbers of practitioners with skills in the fields of science, technology, engineering, and mathematics (STEM) are only increasing as global and societal demands for innovation in technology, medicine, transportation, communications, and other markets continue to advance. Spatial visualization skills represent a key component in a variety of STEM fields and of crucial importance in technical professions such as engineering (Sorby, 1999; Torpey, 2013). STEM credentialed professionals tend to demonstrate notable levels of spatial ability as students with skills significantly greater than those of their peers (Lubinski, 2010).

Spatial ability assessments have been shown to have strong correlations with, and be a possible predictor of, success in engineering graphics courses (Maeda, Yoon, Kim-Kang, & Imbrie, 2013; Sorby, 1999). Several measurement instruments frequently used in engineering education include the Mental Rotations Test (MRT), Mental Cutting Test (MCT), Revised Minnesota Paper Form Board Test (RMPFBT), Differential Aptitude Tests: Spatial Relations (DAT:SR), and Purdue Spatial Visualization Tests: Visualization of Rotations (PVST:R) (Maeda et al., 2013).

Along with holding significance as a factor in STEM education, spatial ability has also been shown to have some levels of malleability with respect to instruction with some training having an overall effect size of 0.47 standard deviations (Uttal, Miller, & Newcombe, 2013). Sorby (2009) demonstrated that spatial skills, as measured with a standard instrument, can be improved with training in an undergraduate engineering class environment. Current literature contends that increased spatial thinking or reasoning abilities provide potential predictive value for success in academic and career pursuits as well as being a demonstrable need as a focus in STEM learning environments.

Instrumentation

The PSVT:R is among the most popular tests within engineering education to measure students' spatial visualization, specifically mental rotation, abilities (Field, 2007). Initially developed by Guay (1976), the PSVT:R is an extended subsection of the Purdue Spatial Visualization Tests (PSVT). The original PVST included three subtests of 12 items each titled Developments, Rotations, and Views. Each subtest also had 30-item extended independent versions: the Visualization of Views (PSVT:V), Visualizations of Rotations (PVST:R) and Visualization of Developments (PSVT:D) (Maeda et al., 2013).

Along with its popularity as an assessment tool in engineering education, the PSVT:R (along with the MCT) also appears to have high construct validity when measuring spatial visualization ability (Branoff, 1998). The PVST:R is also unique due to its use of inclined, oblique, and curved surfaces as they are more demanding to visualize than simple cubically-shaped objects (Yue, 2004).

Part of the impetus for the development of the PVST:R was that other tests may be vulnerable to analytic or non-spatial strategies for the solving of items (Yoon, 2011). Participants may be able to employ strategies other than mental manipulation of objects to solve items, thereby negating a test's capacity to genuinely measure spatial abilities. The PSVT:R was revised by Yoon (2011) in part to address figural errors such as missing lines as well as changes to the format of the instrument to address possible measurement errors and limit the possibility for participant distraction by limiting the number of items per page to one (Maeda et al., 2013).

Whether the original or Revised PVST:R, little empirical research exists into the psychometric properties of the test. While Maeda et al. (2013) describes the Revised PSVT:R as "a psychometrically sound instrument" (p. 763) with respect to first-year engineering students, limited evidence to that claim involves the study described in that paper and the doctoral dissertation of Yoon (2011) in which the Revised PVST:R was developed. However, Yoon (2011), Maeda and Yoon (2011), and Maeda and Yoon (2013) cite a lack of empirical study investigating the psychometric properties of the PVST:R.

Need for Further Research

While some studies focus on engineering students as a general population (Field, 2007; Maeda et al., 2013; Sorby, 2009), few studies focus specifically on engineering graphics courses (Branoff, 1998; Sorby & Baartmans, 2000). As a factor for student success and as a key component of many engineering graphics courses, study into spatial ability training and assessment in these courses is notably sparse. Focused research in this area is needed to determine the impact of spatial ability in this area and the role assessing that ability has on instruction and outcome.

Methods

In this study, the number of factors to retain was examined through multiple methods as there is no singular exacting process (Gorsuch 2003). Because the PSVT was designed to measure one factor, an *a priori* one-factor solution was examined, the scree test (Cattell, 1966; Cattell & Jaspers, 1967) and parallel analyses (Lorenzo-Seva & Ferrando, 2006) were also employed to determine factor retention. The results of the scree test appeared to support a three-factor solution. A parallel analysis suggested a two-factor solution. Therefore, one-, two-, and three-factor solutions were examined.

Data were analyzed using Factor 9.3 (Lorenzo-Seva, & Ferrando, 2006). Raw scores for the PSVT were submitted to unweighted least squares factor analysis with the oblique promax rotation. The promax rotation was selected because any factors resulting from the analysis were hypothesized to be correlated. The polychoric correlation matrix Factor 9.3 generated for the analyses is shown in Table 1. Based on the number of participants, pattern coefficients of .30 or greater were considered to be salient (Gorsuch, 1983; Hair, Anderson, Tatham, & Black, 1998).

	Three-Factor Rotated			h^2
Test Item	**1**	**2**	**3**	
1	0.094	-0.008	-0.07	0.788
2	**1.022**	-0.118	-0.018	1
3	**0.528**	0.067	-0.132	0.275
4	0.208	0.239	-0.066	0.109
5	-0.012	**0.567**	-0.15	0.288
6	-0.076	**0.0484**	0.14	0.282
7	0.179	0.02	0.297	0.152
8	0.033	0.008	0.102	0.014
9	-0.066	0.116	**0.344**	0.147
10	0.26	0.161	**0.5**	0.477
11	0.2	-0.043	**0.317**	0.162
12	0.157	-0.084	**0.387**	0.186
13	0.081	0.039	0.094	0.024
14	0.137	0.144	0.299	0.184
15	-0.037	**0.423**	-0.1	0.159
16	-0.037	0.235	0.099	0.076
17	0.081	**0.512**	-0.056	0.269
18	0.189	0.169	0.181	0.147
19	0.054	-0.03	0.138	0.023
20	-0.041	0.056	**0.35**	0.132
21	-0.047	0.001	**0.387**	0.143
22	-0.033	0.048	0.073	0.009
23	-0.039	-0.107	**0.387**	0.131
24	-0.042	-0.077	0.245	0.052
25	-0.079	-0.076	**0.435**	0.116
26	-0.148	-0.057	**0.522**	0.243
27	0.054	-0.059	0.169	0.032
28	-0.102	-0.06	**0.546**	0.266
29	-0.037	-0.01	0.138	0.017
30	0.009	-0.045	0.212	0.042
Note: Salient pattern coefficients are in bold type.				

Table 1: Pattern coefficients and communalities (h^2) for three-factor solutions.

Results

Table 1 shows the loadings for the three-factor rotated solution. In the three-factor rotated solution, approximately 26 percent of the variance was explained with the first factor accounting for 12 percent and the second factor accounting for eight percent and the third factor accounting for six percent. Two items loaded on factor one and four items loaded on factor two, and 10 items loaded on factor three. The interfactor correlation for factor one and factor two was .21; factor one and factor three was .25; and factor two and factor three was .32. The reliability of the two items for factor one was .99, the four items for factor two was .64, and .75 for the 10 items on factor three.

Conclusion

Prior analysis of the PSVT:R describes the test as loading on a single factor (Maeda, Y., Yoon, S. Y., Kim-Kang, G., & Imbrie, P., 2013). Analysis of 335 first-year graphics communications students shows the PSVT:R loading on multiple factors.

There is evidence that the PSVT:R was a significant predictor of student success in first year graphics courses (Sorby & Baartmans, 2000). However, our analysis demonstrates multiple unknown measured factors. This analysis raises questions as to what the test measures concerning specific constructs. More investigation is needed to determine what factors the PSVT:R consistently measure and its use as a single construct predictor.

References

Branoff, T. (1998). The effects of adding coordinate axes to a mental rotations task in measuring spatial visualization ability in introductory undergraduate technical graphics courses. *Engineering Design Graphics Journal, 62*(2), 16-34.

Field, B. W. (2007). Visualization, intuition, and mathematics metrics as predictors of undergraduate engineering design performance. *Journal of Mechanical Design, 129*(7), 735-743. doi:10.1115/1.2722790

Guay, R. (1976). *Purdue Spatial Visualization Test*. West Lafayette, IN: Purdue Research Foundation.

Lubinski, D. (2010). Spatial ability and STEM: A sleeping giant for talent identification and development. *Personality and Individual Differences, 49*(4), 344-351.

Maeda, Y., & Yoon, S. (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. doi:10.1007/s10648-012-9215-x

Maeda, Y., & Yoon, S. Y. (2011). *Scaling the Revised PSVT-R: Characteristics of the first year engineering students' spatial ability.* Paper presented at the 118th ASEE Annual Conference & Exposition, Vancouver, BC, Canada.

Maeda, Y., Yoon, S. Y., Kim-Kang, G., & Imbrie, P. (2013). Psychometric properties of the Revised PSVT:R for measuring first year engineering students' spatial ability. *INTERNATIONAL JOURNAL OF ENGINEERING EDUCATION, 29*(3), 763-776.

Sorby, S. A. (1999). Developing 3-D spatial visualization skills. *Engineering Design Graphics Journal, 63*(2), 21-32.

Sorby, S. A. (2009). Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education, 31*(3), 459-480. doi:10.1080/09500690802595839

Sorby, S. A., & Baartmans, B. J. (2000). The development and assessment of a course for enhancing the 3-D spatial visualization skills of first year engineering students. *Journal of Engineering Education, 89*(3), 301-307.

Torpey, E. M. (2013). College to career: Projected job openings in occupations that typically require a bachelor's degree. *Occupational Outlook Quarterly, 57*(2), 32-45

Uttal, D. H., Miller, D. I., & Newcombe, N. S. (2013). Exploring and enhancing spatial thinking links to achievement in science, technology, engineering, and mathematics? *Current Directions in Psychological Science, 22*(5), 367-373.

Yoon, S. Y. (2011). Psychometric Properties of the Revised Purdue Spatial Visualization Tests: Visualization of Rotations (The Revised PSVT-R). *ProQuest LLC*.

Yue, J. (2004). Spatial visualization by orthogonal rotations. *Proceedings of the American Society for Engineering Education (ASEE)Annual Conference and Expositions,* Salt Lake City, Utah.