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The Relationship between Spatial Visualization Ability and Students' Ability to Model 3D Objects from Engineering Assembly Drawings

T. J. Branoff
North Carolina State University

M. Dobelis
Riga Technical University

Introduction

Universities have eliminated many courses in engineering graphics and descriptive geometry over the last 30 years and typically replaced them with a single course that is focused on solid modeling and engineering design (Branoff, 2007; Clark & Scales, 2000; Meyers, 2000). The reduction in the number of courses seems to be true internationally. CAD instruction appears to be the main focus of engineering graphics courses that remain in the curriculum, but faculty have many opinions about what is essential when preparing students for careers in engineering and design (Dobelis, Veide, & Leja, 2008; Han, Zhang, Luo, & Luo, 2010; Kise, Sekiguchi, Okusaka, & Hirano, 2008; Kotarska-Bozena, 2008; Suzuki & Schroecker, 2008; Szilvási-Nagy, 2008; Wang & Hao, 2010). With the increase in focus on 3D modeling, are students still able to read and interpret engineering drawings well? Is this ability to read engineering drawings related to spatial visualization ability?

Spatial abilities have been used as a predictor of success in several engineering and technology disciplines (Strong & Smith, 2001). In engineering graphics courses, scores on spatial tests have also been used to predict success (Adanez & Velasco, 2002; Leopold, Gorska, & Sorby, 2001). Other studies have shown that some type of intervention, whether a short course or a semester long course, can improve spatial abilities in students who score low on tests in this area (His, Linn, & Bell, 1997; Martín-Dorta, Saorín, & Contero, 2008; Sorby, 2001).

For this study, the primary research question was, how well do current engineering and technology students read engineering drawings, and is there a relationship between reading engineering drawings and spatial visualization? Can students take the information given on an assembly drawing, visualize or interpret each part, and then create 3D models of the parts in a constraint-based CAD system? Is their ability to do this related to scores on a standard spatial visualization test?

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Method

Participants

During the Fall 2011 semester, sixty-eight students in two constraint-based modeling courses participated in the study. One course was offered at North Carolina State University in Raleigh, North Carolina and the other course was offered at Riga Technical University (RTU) in Riga, Latvia. Both courses covered engineering graphics standards and conventional practices and advanced SolidWorks modeling and drawing techniques.

There was a near equal distribution of the participants between the two universities; however, there was a much higher percentage of females at Riga Technical University (29.4%) than at North Carolina State University (4.4%). A majority of the participants were in their third year of studies (52.9%), but there was also a fair amount of students in their final year (45.6%).

The participants from Riga Technical University were all enrolled in a Biomedical Engineering program (51.5%). A majority of the participants from North Carolina State University were either from Mechanical/ Aerospace Engineering (14.7%) or from Technology Education (19.1%).

Instruments

Modeling Test – Figure 1 shows the modeling test used in this study. Only overall dimensions and a few other dimensions required for installation were given, including thread designations and sizes. All of the information about the form and size of the parts had to be determined from the given views and sections and scaled with the use of a metric ruler. To measure the students' understanding of the assembly drawing, students were required to model the individual parts using 3D solid modeling software.

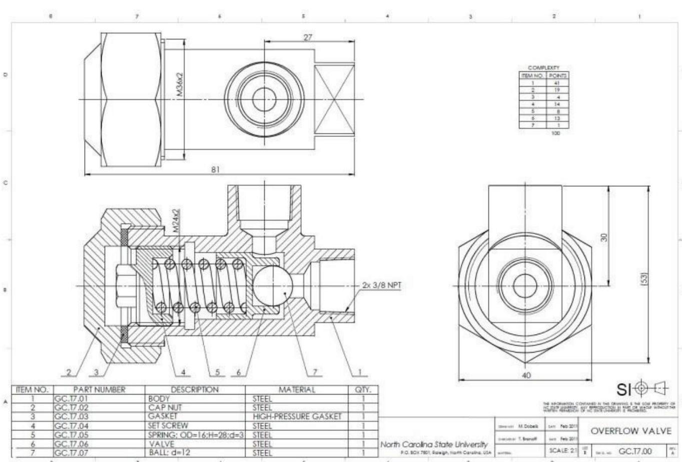

Figure 1. Modeling Test Drawing.

PSVT:R – The Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R) was used to measure students' spatial visualization ability (Guay, 1997). Engineering graphics faculty have used the test since the late 1970s to measure the construct of spatial visualization (Branoff, 2000; Connolly, 2009; Sorby, 2006; Sorby & Baartmans, 2007; Yue, 2008).

Students were administered an electronic version of the PSVT:R within the Moodle learning management system. One class during the semester was dedicated to a practical exercise in reading assembly drawings. After the lecture, students were given the rest of class to model as many parts as possible. Later in the semester students were given the test assembly drawing and asked to model as many parts as possible during the 110 minute class period. Once the data was collected, the researchers evaluated all of the models produced by the students based on the rubrics pilot tested in the spring 2011 semester (Branoff & Dobelis, 2012). The assessment rubric spreadsheet was created to account for model accuracy and time required to model each part.

Results

The data were examined to see if there were identifiable differences in the means between the scores on the modeling test and the scores on the PSVT:R. Tables 1 and 2 display the descriptive statistics for scores on the PSVT:R and the modeling test. Figures 2-3 display scatterplots for these data to provide a visual representation.

Table 1. Scores on the PSVT:R.

School	N	Mean	SD	Min	Max
RTU	35	25.71	5.044	7	30
NC State	33	25.85	3.154	16	30
TOTAL	68	25.78	4.203	7	30

Table 2. Scores on the Modeling Test.

School	N	Mean	SD	Min	Max
RTU	35	53.03	20.792	9	86
NC State	33	47.33	24.757	1	93
TOTAL	68	50.26	22.811	1	93

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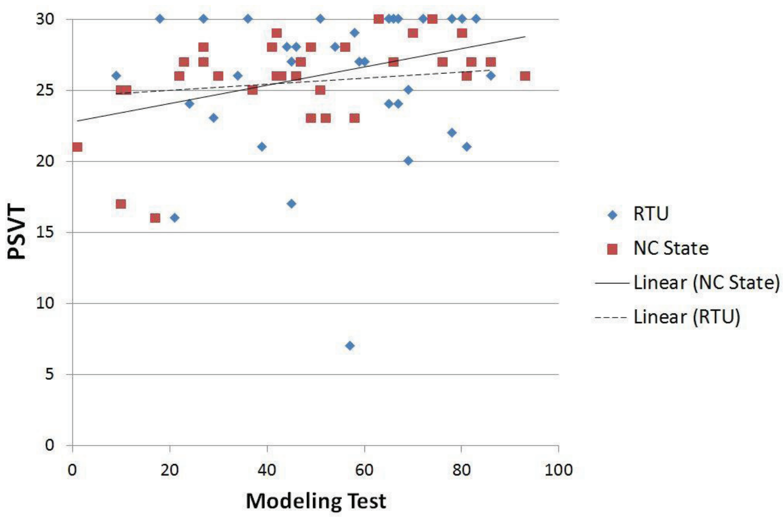

Figure 2. Modeling Test & PSVT:R by School.

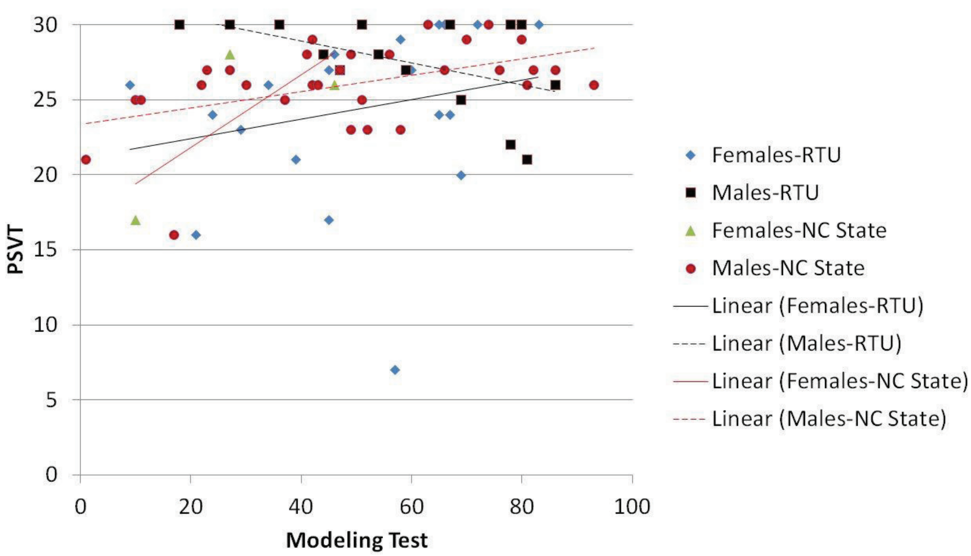

Figure 3. Modeling Test & PSVT:R by Gender.

The scatterplots for the data display a relationship between the PSVT:R and the modeling test. It appears that students who score higher on the modeling test also tend to score higher on the PSVT:R. The scatterplots also reveal some outliers in the data. The standard deviations of the data show that the scores on the modeling test were much more spread out than the scores on the PSVT:R.

The main research question for this study was "is students' ability to interpret and model information from an assembly drawing related to their spatial visualization ability?" Since the data do not meet the assumptions of parametric tests, a non- parametric

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Spearman's Rho was used to test the hypotheses. The analysis revealed a significant correlation between scores on the PSVT:R and scores on the modeling test ($\rho = .258$, $\alpha = .033$).

Discussion

The analysis of the data revealed that there is a significant correlation between students' scores on the PSVT:R and their scores on the modeling test. This makes sense since the interpretation of the information in an assembly drawing requires one to mentally manipulate the two-dimensional information given in the drawing, visualize the part in three-dimensions, and then break down the geometry for so it can be reconstructed in the 3D modeling program. One must be cautious not to assume that a high score on the PSVT:R will assure a student will perform well on the modeling test. The scatterplots revealed a positive correlation between the two variables, but they also show many outliers.

The main research question for this study was whether a relationship exists between reading engineering drawings and spatial visualization ability. In this study students who scored higher on the PSVT:R tended to score higher on the modeling test. Although other factors such as symbol recognition and understanding standards and conventional practices influence how well students read engineering drawings, it appears that spatial visualization ability plays a significant role it how well they visualize part geometry.

One of the main concerns for conducting future studies is the ability to scale-up to handle more students. Although the rubric used in the pilot study and in this study delivered accurate assessments of the students' modeling abilities, the time required to assess student work was very high. This potentially could prevent other faculty from using the instrument. The researchers plan on investigating alternative methods for accurately assessing student models such as automated programs for gathering the desired data from the models.

References

Adanez, G. P, & Velasco, A. D. (2002). Predicting academic success of engineering students in technical drawing from visualization test scores. *Journal for Geometry and Graphics, 6*(1), 99-109.

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.

Branoff, T. J. (2007). The state of engineering design graphics in the United States*, Proceedings of the 40th Anniversary Conference of the Japan Society for Graphic Science*, Tokyo, Japan, May 12-13, 2007. (pp. 1-8).

ISSN: 1949-9167

Branoff, T. J., & Dobelis, M. (2012). Engineering graphics literacy: Measuring students' ability to model objects from assembly drawing information. *Proceedings of the 66th Midyear Conference of the Engineering Design Graphics Division of the American Society for Engineering Education*, Galveston, Texas, January 22-24, 2012.

Clark, A. C., & Scales, A. Y. (2000). A study of current trends and issues related to technical/engineering design graphics. *Engineering Design Graphics Journal, 64*(1), 24-34.

Connolly, P. E. (2009). Spatial ability improvement and curriculum content. *Engineering Design Graphics Journal, 73*(1), 1-5.

Dobelis, M. Veide, G., & Leja, E. (2008). Development of spatial imagination abilities in mechanical engineering students. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 8 pages. ISBN: 978-3-86780-042-6.

Guay, R. (1977). *Purdue Spatial Visualization Test – Visualization of Rotations*. W. Lafayette, Indiana. Purdue Research Foundation.

Han, B., Zhang, H., Luo, X., & Luo, Q. (2010). Engineering graphics education and modern engineering design in China. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 4 pages. ISBN: 978-4-9900967-1-7.

Hsi, S., Linn, M. C., & Bell, J. E. (1997). The role of spatial reasoning in engineering and the design of spatial instruction. *Journal of Engineering Education, 86*(2), 151-158.

Kise S., Sekiguchi S., Okusaka K.,& Hirano S. (2008). Training on three-dimensional computer-aided design for new employees of machine design department and its evaluation. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 7 pages. ISBN: 978-3-86780-042-6.

Kotarska-Bozena L. (2008). Descriptive geometry and 2D-CAD in context of modeling software in higher semesters at the civil and environmental engineering faculty. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 5 pages. ISBN: 978-3-86780-042-6.

Leopold, C., Gorska, R. A., & Sorby, S. A. (2001). International experiences in developing the spatial visualization abilities of engineering students. *Journal for Geometry and Graphics, 5*(1), 81-91.

ISSN: 1949-9167

Martín-Dorta, N., Saorín, J. L., & Contero, M. (2008). Development of a fast remedial course to improve the spatial abilities of engineering students. *Journal of Engineering Education, 97*(4), 505-513.

Meyers, F. D. (2000). First year engineering graphics curricula in major engineering colleges. *Engineering Design Graphics Journal, 64*(2), 23-28.

Sorby, S. A. (2001). Improving the spatial visualization skills of engineering students: Impact on graphics performance and retention. *Engineering Design Graphics Journal, 65*(3), 31-36.

Sorby, S. A. (2006). Developing 3D spatial skills for K-12 students. Engineering Design Graphics Journal, 70(3), 1-11.

Sorby, S. A., & Baartmans, B. J. (2007). The development and assessment of a course for enhancing 3-D spatial visualization skills of first year engineering students. *Journal of Engineering Education, 89*(3),301-307.

Strong, S., & Smith, R. (2001). Spatial visualization: Fundamentals and trends in engineering graphics. *Journal of Industrial Technology, 18*(1), 1-6.

Suzuki K., & Schroecker H. P. (2008). Application of descriptive geometry procedures in solving spatial problems with feature and parametric modelling 3D-CAD. *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 8 pages. ISBN: 978-3-86780-042-6.

Szilvási-Nagy, M. (2008). What kind of geometry engineers need? *Proceedings of the 13th International Conference on Geometry and Graphics*, August 4-8, 2008, Dresden, Germany. e-Publication in CD format. 5 pages. ISBN: 978-3-86780-042-6.

Wang, J. & Hao, Y. (2010). Teaching reform and practice in engineering drawing based on 3D modeling with computer. *Proceedings of the 14th International Conference on Geometry and Graphics*, August 5-9, 2008, Kyoto, Japan. e-Publication in CD format. 7 pages. ISBN: 978-4-9900967-1-7.

Yue, J. (2008). Spatial visualization by realistic 3D views. *Engineering Design Graphics Journal, 72*(1), 28-38.

Dr. Branoff can be reached at ted_branoff@ncsu.edu, Dr. Dobelis can be reached at Modris.Dobelis@rtu.lv