Examining Industry Perspectives Related to Legacy Data and Technology Toolset Implementation

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Abstract

In this paper, results from a subset of the Purdue Spatial Visualization Test and a self-efficacy test developed by the authors are presented to determine whether certain object shapes, orientations, and types of rotations in standard spatial ability tests cause more difficulty than others and whether a solid object, which includes shading to distinguish different surfaces on the object, would have an effect on the spatial ability test results. Lower spatial ability scores were observed for more complex object shapes, orientations, and number of rotations on both tests; however, viewing solid images as opposed to line images did not affect the spatial ability scores. The subjects in this study were engineering students from various disciplines.

INTRODUCTION

One aspect of spatial ability that is critical for engineering students, as well as other scientific fields, is the ability to perceive an object from another perspective. Spatial ability has been shown to be related to both student retention and student achievement in disciplines such as chemistry (Coleman & Gotch, 1998; Carter, LaRussa, & Bodner, 1987), physics (Pallrand & Seeber, 1984) and life sciences (Lord, 1990). In addition, although there is a well-established relation between student achievement and spatial ability in Engineering (e.g., Sorby & Baartmans, 2001; Hsi, Linn, & Bell, 1997; Rochford, Fairall, Irving, & Hurly, 1989), it is unclear whether spatial ability affects retention rates in engineering. For example, Sorby and Baartmans (2001), Hsi et al. (1997), and Kinsey, Towle, O'Brien, and Bauer (2007) found that spatial ability affected retention in engineering whereas Devon, Engel, and Turner (1998) did not find a reliable correlation between spatial ability and retention. While the effect of spatial ability on retention has been disputed in the literature, there has been a consistent finding that spatial ability can be improved through training (e.g., Sorby & Baartsman, 2001; Hsi et al., 1997; Rochford et al., 1989; Poole & Stanley, 1972; Devon et al., 1998; Kinsey et al., 2007; Miller, 1992). To improve spatial ability instruction, which will hopefully retain students in engineering fields, further research into spatial ability is needed. This would include gaining a better understanding of the difficulties students have with respect to spatial skills and devising means to assist students with spatial tasks.

The goal of this research was to determine what types of problems on spatial ability tests cause the most difficulties for participants. This could then lead to improved instructional activities and devices and retention in engineering. In this paper, the effects of object type (geometry, orientation, and shading, i.e. solid versus line representation), and rotation type were investigated. These effects were assessed using both self-efficacy (i.e. self confidence with respect to spatial tasks) questions developed for this research and a subset of Purdue Spatial Visualization Test (PSVT), a test designed to assess an individual's spatial ability.

METHODS

Two web-based tests with automated data collection were used to obtain a measure of a student's spatial ability and self-efficacy. These tests consisted of three dimensional representations of different objects in both solid and no hidden line representations. For the solid objects, surfaces were shaded to assist in distinguishing them. The web-based software recorded the radio button the student selected for each of the test questions. To ensure anonymity, an encrypted university identification code was used as opposed to the student's name for data analysis purposes. Additional data were obtained with respect to the gender, class standing, major, and college of the subjects.

PARTICIPANTS

The web-based tests were administered to 278 students in the College of Engineering and Physical Science (CEPS) and a School of Applied Science at the University of New Hampshire from various engineering majors and undeclared CEPS students during the Fall semester of 2005. Students were enrolled primarily in freshman level introductory courses for the given disciplines and senior level required courses for Mechanical Engineering, Electrical Engineering, and Civil Engineering. The break down of these engineering majors includes Mechanical Engineering (N=91 and 54), Electrical Engineering (N=19 and 17), and Civil Engineering (N=12 and 5) for underclassmen and upperclassmen respectively. The remaining students were from various other engineering and science disciplines. The same questions were presented to all of the students and the solid and line objects and the types of objects were randomly mixed.

MATERIALS

Measure of self-efficacy. The self-efficacy test included three example questions to provide instruction to the student followed by twenty questions. A question began with two images of an object, (Object A) being shown on the screen before (left image) and after (right image) rotation (see Fig. 1). These images were presented for three seconds and then were removed from the screen. This short amount of time allowed the participant to visualize the situation without completely discerning the exact nature of the rotation. Next, a second object (Object B) was displayed in only the before rotation orientation (i.e. the after rotation image is not shown) (see Fig. 2). Object B had nearly the same shape as Object A in Fig. 1, could be displayed in the same or a different orientation as Object A, and was shown without time restriction. Following the presentation of objects, the participant was asked to choose from seven radio buttons on the computer screen as a rating of her/his confidence in being able to rotate Object B in the same manner that Object A was rotated. The seven point scale ranged from "Not at All Confident" for the left most radio button to "Extremely Confident" for the right most radio button. This test procedure was based on a similar technique which was used to assess the self-efficacy of students with respect to solving an algebra problem (Schunk, 1982). This technique provided a measure of participant self confidence related to specific visualization tasks, as opposed to a general response regarding how confident the participant was in performing visualization tasks. Both solid objects (Figs. 1 and 2) and no hidden line objects (Figs. 3 and 4) were used. Furthermore, the objects in Figs. 1 and 2 were aligned with respect to the standard isometric axes of the paper, while the objects in Figs. 3 and 4 were not. Finally, Objects A and B in Figs. 3 and 4 respectively were in the same initial orientation before rotation. Alternatively, Object B in Fig. 2 was not in the same initial orientation as Object A in Fig. 1 before rotation. These types of questions were created to determine if object orientation affected the results obtained from the self-efficacy test. Scores on these self-efficacy questions have been positively correlated with spatial ability scores ($p < 0.01$) (Kinsey et al., accepted manuscript); thus, this test has been validated. Further validation of this measure is currently being conducted.

Figure 1 - Images from the self-efficacy test of a solid object before (left) and after (right) rotation.

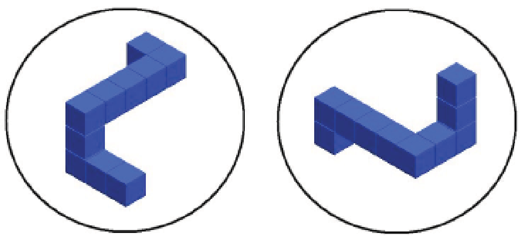


Figure 2 - Question from the self-efficacy test showing an object before rotation only.

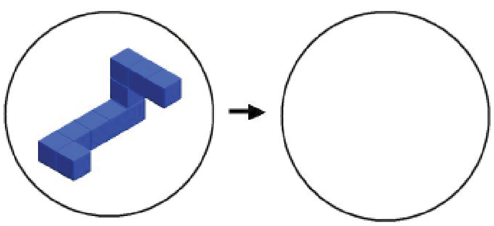


Figure 3 - Images from the self-efficacy test of a no hidden line object before (left) and after (right) rotation.

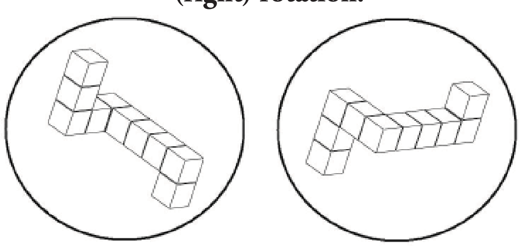
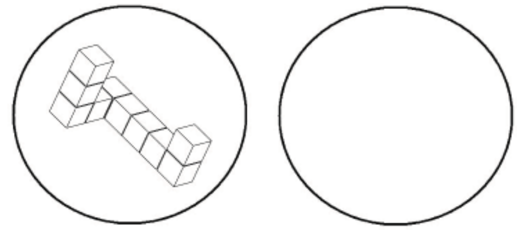


Figure 4 - . Question from the self-efficacy test showing an object before rotation only.



Measure of Spatial Ability. A second test which was administered to measure the participant's spatial ability consisted of forty questions from two different sections of the PSVT (Guay, 1977). Twenty questions were based on the mental rotation of an object section, and twenty were based on the mental rotation of a perspective section. In the mental rotation of an object questions (example shown in Fig. 5), an object was shown in the before and after rotation orientation. A second object was provided with five choices of possible after rotation orientations. The participant was asked to choose the correct after rotation orientation to rotate the second object in the same manner as the first object. The correct answer for the question in Fig. 5 is E. In the mental rotation of perspective questions (example shown in Fig. 6), an object was shown in the center of a transparent cube in an isometric orientation. A dot was present in one of the corners of the cube. The participant was asked to choose from five alternatives to indicate the correct orientation of the object if viewed from the location of the dot. The correct answer for the question in Fig. 6 is A. For both types of PSVT questions, half of the questions were solid objects (see Fig. 5) while the other half were no hidden line objects (see Fig. 6). While this test was a modified version of the original PSVT, the change did not require re-validation of the measure. Similarly, Branoff and Connelly (1999) and Branoff (2002) also modified the PSVT to assess if changes would alter participants' scores.

Figure 5 - Question from the PSVT mental rotation of an object section (Guay, 1977).

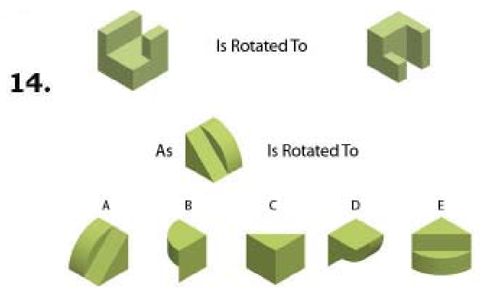
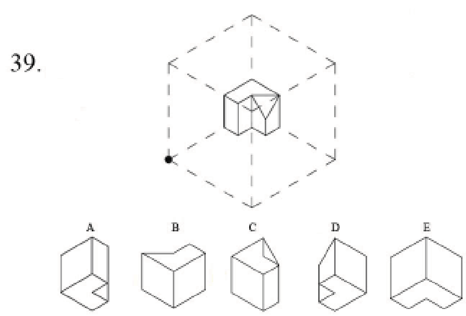


Figure 6 - Question from the PSVT mental rotation of perspective section (Guay, 1977).



Data Analysis. The data collected were the answers from the participants for the twenty self-efficacy and forty PSVT questions in the tests. The questions were categorized based on various object and rotation characteristics, e.g. solid versus line representation objects and single versus double rotations. T-tests were conducted to determine if a statistically significant difference existed between the averaged values from these classifications.

RESULTS AND DISCUSSION

To assess the effect of object type, questions were categorized based on the types of surfaces/features which they contained. The types of objects included in PSVT questions were right angle only (the top object in Fig. 5), cylindrical (the bottom object in Fig. 5), single inclined (the bottom object in Fig. 5), multiple inclined, and oblique (Fig. 6) surface objects. If an object such as the bottom one in Fig. 5 contained two types of surfaces, the data were included in both categories. The average percent correct for each of these question categories is given in Table 1. Because the scores on right angle only questions were higher than all other question types (the lowest p-value < 0.02), all of the other question types were condensed into one category: complex objects. It is noteworthy that there were differences between the question types which were categorized into "complex objects." Scores on cylindrical and single incline surface questions were higher than multiple incline and oblique surface questions. However, scores were equivalent on cylindrical and single incline surface questions ($t(110) = -0.302$, $p > 0.75$) and multiple inclined and oblique surface questions ($t(110) = -1.429$, $p > 0.15$). Such differences in PSVT questions have not been reported previously. This information will be beneficial when developing instructional material to improve the spatial ability of students.

Table 1 - . Comparison between the average percent correct PSVT scores for questions with various surface types.

Surface(s) type	Average % PSVT Score (standard error)
Right Angle Only	76.8 (1.59)
Cylindrical	73.0 (1.31)
Single Incline	73.3 (1.28)
Multiple Incline	61.2 (1.45)
Oblique	63.1 (1.58)
Complex	68.4 (1.22)

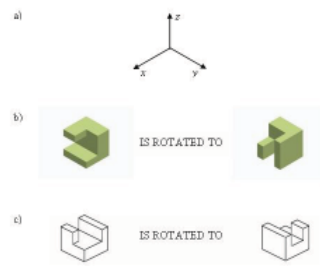
Additional data from the PSVT question results are shown in Table 2. The values reported in this table are the average percent correct for the questions. Participants scored higher on line object questions than solid object questions, although this effect was small and only marginally significant ($t(277) = -1.798$, $p = 0.07$). This is an interesting finding as CAD software packages and textbooks use solid images to assist students in visualizing objects.

Differences were also found with respect to right angle only versus complex objects ($t(277) = 6.207$, $p < 0.01$), single axis rotations versus double axis rotations ($t(277) = 14.399$, $p < 0.01$), and short (90°) rotations versus long (180°) rotations ($t(277) = 8.449, p < 0.01$). However, there was no difference between vertical and horizontal rotation questions ($t(277) = -0.732, p > 0.45$). See Fig. 7 for an isometric coordinate system, which horizontal (x- and y-axes) and vertical (z-axis) rotations are defined with respect to, and questions with horizontal and vertical rotations, as well as 90° and 180° rotations. A horizontal rotation could be with respect to either the x- or y-axis. Note that these results are for the mental rotation of an object section questions since these question categories are not applicable to the mental rotation of perspective questions.

Data from the self-efficacy test were consistent with PSVT results for several measures (see Table 3). The data in this table is the average self-efficacy response out of the seven point scale. Participants rated their self-efficacy higher on line object questions than solid object questions ($t(277) = -3.079, p < 0.01$), single axis versus double axis rotations ($t(277) = 5.945, p < 0.01$), and short versus long rotations ($t(277) = 2.589, p < 0.01$).

Due to the nature of the self-efficacy questions compared to the PSVT questions, other aspects of the questions were analyzed. For example, whether or not the object was oriented with respect to an isometric axis was considered but no difference was observed for the reported self-efficacy scores ($t(277) = 0.736, p > 0.45$). Also, whether or not Object B started in the same orientation as Object A did not cause a difference in spatial ability ($t(277) = 1.482, p > 0.13$). These results are surprising because having the objects oriented with an isometric axis or having Objects A and B start in the same orientation would seem to be easier and thus should have led to higher self-efficacy.

Figure 7 - Representations of a) an isometric coordinate system, b) a 90° rotation about a horizontal, x-axis, and c) a 180° rotation about the vertical, z-axis.



To further investigate these results and to assess the effect of CAD spatial ability instruction on these measures, additional analyses were performed on freshman students from Mechanical Engineering and Civil Technology. Participants were enrolled in a CAD course and were administered the tests at both the beginning and end of the semester (see Tables 2 and 3). The solid object representation may be new to students who have not used CAD software in the past. Consistent with the analysis for all participants, scores on the line object PSVT questions were higher than solid object PSVT questions at the beginning of the semester (see Table 2), although this effect was small and only marginally significant ($t(110) = -1.530, p = 0.13$). By the end of the semester however, this effect was eliminated ($t(110) = 0.599, p > 0.55$). Thus, exposure to the solid objects during CAD use improved the scores with respect to this type of question.

A similar effect was not found with respect to the self-efficacy questions (see Table 3). Participants rated their self-efficacy higher on line object questions compared to solid object questions at the beginning of the semester ($t(110) = -2.623, p < 0.01$) and at the end of the semester ($t(110) = -2.980, p < 0.01$). Thus, participants were not as confident when attempting to rotate solid objects compared to line objects even though PSVT results indicate that their ability was equivalent.

Table 2-The average percent correct score from the PSVT (Guay, 1977). Values in the parentheses are the standard error for the measure.

Object/Question Type	All Subjects (N=278)	All Subjects t-value	Beginning of Semester (N=111)	Beginning of Semester t-value	End of Semester (N=111)	End of Semester t-value
Solid Object	68.0 (1.20)	-1.798	65.9 (1.89)	-1.530	70.0 (2.14)	0.599
Line Object	69.3 (1.32)		68.0 (2.17)		70.6 (2.31)	
Right Angle Only Object	76.8 (1.59)	6.207**	76.1 (2.51)	4.435**	77.7 (2.62)	4.031**
Complex Object	68.4 (1.22)		66.6 (1.96)		70.0 (2.20)	
Single Rotation Question	79.1 (1.14)	14.399**	76.7 (1.82)	8.124**	77.4 (2.11)	9.034**
Double Rotation Question	62.2 (1.39)		60.8 (2.26)		60.1 (2.68)	
Short (90°) Rotation Question	72.2 (1.25)	8.449**	71.0 (2.05)	5.991**	74.2 (2.17)	5.956**
Long (180°) Rotation Question	64.4 (1.33)		62.0 (2.08)		65.5 (2.41)	
Vertical Rotation Question	78.3 (1.54)	-0.732	73.6 (2.56)	-1.739	76.7 (2.66)	-0.294
Horizontal Rotation Question	79.5 (1.25)		77.8 (1.93)		77.6 (2.26)	

*$p < 0.05$
**$p < 0.001$

Table 3- The average self-efficacy score out of a seven point scale. Values in the parentheses are the standard error for the measure.

Object/Question Type	All Subjects (N=278)	All Subjects t-value	Beginning of Semester (N=111)	Beginning of Semester t-value	End of Semester (N=111)	End of Semester t-value
Solid Object	5.20 (0.071)	-3.079**	5.10 (0.120)	-2.623**	5.38 (0.113)	-2.980**
Line Object	5.32 (0.068)		5.26 (0.118)		5.54 (0.100)	
Single Rotation Question	5.37 (0.070)	5.945**	5.32 (0.122)	4.895**	5.59 (0.104)	5.004**
Double Rotation Question	5.11 (0.071)		4.98 (0.125)		5.26 (0.113)	
Short (90°) Rotation Question	5. 31 (0.071)	2.589**	5. 26 (0.124)	2.377*	5. 57 (0.101)	4.007**
Long (180°) Rotation Question	5. 21 (0.068)		5. 10 (0.123)		5. 35 (0.112)	
Objects Aligned with Isometric Axes	5.28 (0.070)	0.736	5.22 (0.126)	1.096	5.52 (0.103)	2.355*
Objects Not Aligned with Isometric Axes	5.25 (0.070)		5.15 (0.120)		5.40 (0.110)	
Objects Initially Oriented the Same	5.30 (0.068)	1.482	5.23 (0.120)	1.065	5.51 (0.108)	1.438
Objects Initially Oriented Different	5.24 (0.072)		5.15 (0.126)		5.42 (0.107)	

*$p < 0.05$
**$p < 0.001$

Data were analyzed with respect to the other types of questions (i.e. number of rotations, distance of rotation, etc.) for the participants enrolled in the CAD courses. The results followed the same trend as reported for all participants (see Table 2) for all of the PSVT question cases and all except for one of the self-efficacy cases (see Table 3). The one case that did not follow the same trend was the self-efficacy of students if the object was oriented with respect to an isometric axis. While participants' data at the beginning of the semester data showed that there was no difference between these types of questions ($t(110) = 1.096, p > 0.25$), participants reported higher self confidence with respect to questions where the object started on an isometric axis by the end of the semester ($t(110) = 2.355, p < 0.02$). This change in effect can be accounted for because of the extensive work during the CAD courses interpreting objects from their isometric orientation. Thus, the participants report higher self-efficacy scores for these types of questions. Note that the scores from the beginning to the end of the semester increased for almost all categories of questions.

CONCLUSION

Web based tests were developed to assess the self-efficacy and ability with respect to spatial tasks of engineering students. The following results were found:

• Using solid objects, which include shading to distinguish different surfaces on the object, did not improve either the self-efficacy or spatial ability of students. To the contrary, scores were higher for line objects than solid objects at the beginning of the semester. However, by the end of the semester, this effect was eliminated. This was a surprising result as CAD software packages and textbooks include solid objects to assist students in visualizing images. A possible alternative cause of this effect is poor image quality of the solid objects; however, the authors do not believe that is a concern.

• PSVT questions with objects that contain more advanced features, such as inclined, cylindrical and oblique surfaces, were more difficult than right angle only objects.

• Questions which include double axis rotations were more difficult than questions with single axis rotations, with respect to both self-efficacy and spatial ability.

• Questions which include longer (180°) rotations were more difficult than questions with shorter (90°) rotations, with respect to both self-efficacy and spatial ability.

• Questions oriented with isometric axes were easier by the end of the semester of a CAD course due to extensive work interpreting isometric views.

Thus, spatial ability questions which cause the most difficulty for students have been identified, as was the stated goal of this work. While many of these results are not surprising with respect to the PSVT questions, the ability of the self-efficacy test to discern these differences further validates this developed assessment. More rigorous validation of the self-efficacy test is currently being conducted. The information obtained through this study is critical to develop optimal instructional curriculum to improve the spatial ability of students in science, technology, engineering, and mathematics (STEM) disciplines and hopefully in turn their retention in STEM fields.

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