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The Effect of Computer-Aided Design Instruction on the Spatial Ability of High School Students

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ABSTRACT:- *Spatial visualization is a skill used to solve problems using concepts of space, visualization, and reasoning. This research project examined the use of Google SketchUp Pro in the computer-aided design (CAD) classroom to improve students' spatial visualization skills. During the quarter students increased their spatial visualization skills as indicated by the results of individual projects and scores on the Purdue Spatial Visualization Assessment: Rotations (PSVT:R).*

Keywords:- *Spatial Visualization, Computer Aided Drafting, CAD, High School, STEM, Engineering*

I. INTRODUCTION

Spatial visualization is a skill used daily at home, at school, and in the workplace to solve problems using concepts of space, visualization, and reasoning. By visualizing relationships of spatial structures in terms of locations, distances, shapes, and patterns, the properties of objects and relationships between objects can be explored and comprehended (National Research Council, 2006).

Spatial abilities are important for academic success in multiple areas including mathematics and science. Poor spatial skills have implications on success rates in college classes (Potter & van der Merwe, 2001). In addition, undeveloped spatial ability can limit career choices especially in the areas of science, technology, engineering, and mathematics (STEM) (Wai, Lubinski, &Benbow, 2009).

Spatial comprehension has been a research topic in cognitive psychology for decades (Wai, Lubinski, &Benbow, 2009). Child psychologist, Jean Piaget, stated that the regarding development of a child's intelligence and cognition "the problem of space must surely rank as of the highest importance" (Piaget and Inhelder, 1960, vii). Not long ago, spatial cognition research was extended to computer-based visualizations (Velez, Silver, &Tremaine, 2005).

Spatial comprehension is an ability and a skill. Educators have long debated whether spatial ability is separate from other modes of cognition (Lord, 1985; Lord, 1990). There is considerable evidence that spatial thinking can be taught to students using appropriately designed tools, technologies, and curricula (Ho & Eastman, 2005). Identifying techniques that aid in development of spatial abilities will benefit students. The study of computer aided design and drafting (CADD) may promote the development of spatial ability in students (Basham, 2007; Guidera, 2002; Potter & van der Merwe, 2001).

CAD classes are electives for high school students in Iowa. There are many reasons why high school students take CAD classes: to explore design as a potential occupation, to complete their technology requirements, because they enjoy interacting with a computer, or simply to complete their schedule and avoid a study hall. Students do not sign up for CAD to expand their spatial visualization skills. A major characteristic of 3D CAD modeling is manipulation of geometric shapes using spatial ability (Basham, 2007). Through this manipulation of geometric shapes, students' spatial visualization skills might increase.

1.1 STATEMENT OF THE PROBLEM

The purpose of this study is to assess whether completion of a CAD unit has effect on the development of spatial ability for high school students.

1.2 RESEARCH QUESTIONS

The main research question addressed in this study was: Does instruction of a CAD unit (independent variable) have an effect on spatial ability as indicated by the Purdue Spatial Visualization Assessment: Rotations (PSVT:R) (dependent variable)?

In addition, three subquestions have been identified including:

1. If change in the PSVT:R occurs during the CAD unit, what is the extent of that change?
2. If change in the PSVT:R occurs during the CAD unit, is there a relationship between mathematical ability as measured by the Iowa Assessments and the change?
3. Do students who score higher on the PSVT:R Pre-assessment make the most gains on the Post-assessments?

1.3 HYPOTHESIS

The first null hypothesis is that the CAD unit will have no effect on spatial ability as indicated by the PSVT:R. The alternative hypothesis is that the CAD unit will have an effect on spatial ability as indicated by the PSVT:R.

The second null hypothesis is that higher mathematics ability as measured by the Iowa Assessment will not correlate with the change in spatial ability as indicated by the PSVT:R. The second alternative hypothesis is that higher mathematics ability as measured by the Iowa Assessment will correlate with the change spatial ability as indicated by the PSVT:R.

In addition, two qualitative measures will be examined. An examination of students' ability to edit sketched objects using modifying commands such as move, offset, break, copy, mirror, rotate, scale lengthen, divide, and measure to change the object of focus will be measured using a rubric. An additional outcome will be completion of a 3D Model themed for business proposals, engineering prototypes, or video game design purposes. These are also evaluated using rubric.

1.4 LIMITATIONS

The results of this study may be limited. The intact classroom of students who are selected for the sample are taking an introductory CAD class in a traditional teacher led classroom. Selection bias may be a concern because an intact classroom was chosen and most of those in the sample were male. There may be something unique about the students choosing to take the introductory CAD class rather than a different elective. In addition, results may not generalize to students receiving modular or online instruction. The length of the study may be insufficient to show changes in spatial ability. The use of the pre-assessment may provide a threat to validity because students may remember items from the pre-assessment during the post-assessment. Students may have their awareness of the topic heightened due to the pre-assessment.

1.5 DEFINITIONS OF TERMS

2-Dimensional (2D): objects that are constructed on two planes (X and Y). A 2D view shows a thin slice through a scene or a front, back, right, left, top, or bottom (Melanie, Kirkpatrick, Atkins, & Moller, 2006).

3-Dimensional (3D): objects that are constructed on three planes (X, Y and Z). The computer screen cannot provide full 3D representation, but rather must project 3D location on to the flat computer screen. This is not a true 3D, but for the purpose of this study, it will be called 3D. A 2D drawing program can be used to illustrate a 3D object; but, in order to interactively rotate an object for different views, the object must be generated as a 3D drawing in a 3D drawing program (Melanie, Kirkpatrick, Atkins, & Moller, 2006).

CADD: acronym for computer-aided design and drafting. CADD systems are computed-aided design (CAD) systems with additional drafting features.

Spatial ability: the ability to generate, retain, retrieve, and transform well-structured visual images (Lohman, 1993); the mental manipulation of objects and their parts (Olkun, 2003). Spatial ability as measured by the PSVT:R was chosen for use as the dependent measure in this study. The PSVT:R was designed to measure the participants' ability to visualize the rotation of 3-dimensional objects.

Spatial orientation: comprehension of the arrangement of objects and the aptitude to remain unconfused by the changing perspective in which a spatial configuration may be presented (McGee, 1979; Hegarty& Waller, 2004).

Spatial perception: ability to determine spatial relations.

Spatial reasoning: methods and tools that represent or process spatial information to develop, clarify, or predict new spatial knowledge (Basham, 2007).

II. LITERATURE REVIEW

1.6 INTRODUCTION

This research project is focused on the use of CAD to improve students' spatial visualization skills. The literature review centers on understanding spatial ability and the importance of developing spatial ability in high school students. The relationship between spatial ability and gender as well as spatial ability and mathematics ability are explored. Finally, studies that were designed to investigate the improvement of spatial ability in students are considered.

1.7 NEED FOR SPATIAL ABILITY

According to Lohman (1993), "spatial ability is the ability to generate, retain, retrieve, and transform well-structured visual images" (p. 3). Olkun (2003) added that it is the mental manipulation of objects and their parts. Spatial ability includes factors of spatial relations and spatial visualization (McGee, 1979; Olkun 2003). In the spatial domain, researchers found spatial cognition is not a unitary construct, but can be divided into many factors in a hierarchical structure and different factors can be examined with different assessments (Ho & Eastman, 2005; Lohman, 1988). Although the number of factors varies from model to model, the three most commonly identified spatial factors include spatial visualization, spatial orientation, and speeded rotation (Lohman, 1988). "Once relegated to lower-order processing and concrete thought, spatial abilities are now understood as important for higher-order thinking in science and mathematics, for the ability to generate and appreciate metaphor in language, and for creativity in many domains" (Lohman, 1993, p. 13). This review of literature will focus on spatial ability and the improvement of spatial skills though instruction in CAD.

1.7.1OCCUPATIONS

Even before many modern advances in technology, Smith (1964) listed 84 different careers for which spatial skills play an important role. The list includes a high proportion of scientific and technical occupations. He states that "the U.S. Employment Service regards high spatial ability as a prerequisite for success in the majority of technological and scientific occupations" (Smith, 1964, p. 155). Later, Morris (2007) composed a list of occupations he believed needed spatial intelligence, defined as the ability to perceive the visual world internally. The diverse list includes artists, carpenters, engineers, pilots, surgeons, and web designers. For technical professions such as architects and engineers spatial visualization skills and mental rotation abilities are extremely important. Spatial skills have a direct correlation to success in a variety of careers including engineering and science (Sorby, 2007). Sorby (2000) noted that spatial skills are related to the ability to effectively learn and to use computer aided design software.

1.7.2EDUCATIONAL ATTAINMENT

Tolar (2007) used structural equation modeling to assessment the effects of algebra experience, working memory, 3D spatial abilities, and computational fluency on algebra achievement. The study found that 3D spatial abilities had a direct effect on algebra achievement. Wai, Lubinski, and Benbow (2009) tracked high school students over an eleven-year period. Their results showed that spatial ability plays a critical role in developing expertise in STEM. Neglecting instruction in spatial competence could discriminate against the less spatially minded student, erecting a barrier that may hinder success in future mathematics classes (Rosser, 1980).

Spatial ability may be a factor in prediction, real or perceived, of ability to do well in a technology education class. The purpose of a study by Rafi and Samsudin (2007) was to examine factors that may influence students' perceived ability or self-efficacy to learn engineering drawing. Two hundred twenty-four 10th grade students from Malaysia taking an engineering drawing course participated in the study. The student's perceived ability to learn the nine topics of engineering drawing curriculum was measured using a student survey and the student's spatial experience was measured using the Spatial Experience Questionnaire (SEQ). For all topics the correlation for perceived ability to learn and spatial experience was moderate and statistically significant. Using an ANOVA and with other variables held constant, the scores on perceived ability to learn all topics of Engineering Drawing were positively related to spatial experience and to previous mathematics achievement.

Smith (2009) studied 154 college pre-engineering students enrolled in a fundamentals electronics course to examine the correlation between a student's spatial ability assessment score measured by the PSVT:R and a student’s cumulative score for the semester in an electronics fundamentals course. Other variables including gender, major, age, and GPA were also examined. The study found a highly significant correlation between spatial ability and achievement in the course. There was a significant positive correlation between GPA and spatial ability, that is, pre-engineering students with high GPAs also had high spatial ability. Spatial ability accounted for a significant amount of the variance in the semester scores suggesting that spatial ability provides prediction of doing well in an electronics fundamentals course above and beyond what GPA predicts alone.

The Iowa Core passed by the Iowa legislature and signed into law by Governor Chet Culver in spring 2008 recognizes that spatial abilities are needed by Iowa students. The Iowa Core, mandated for implementation in all Iowa public high schools by 2012 and in elementary and middle schools by 2014, focuses on a set of essential concepts and skills in literacy, math, science, social studies, and 21st century learning skills (Iowa Department of Education, 2008). The Iowa Core is not course-based, but is a student-based approach designed to support high expectations for all students. In the Iowa Core, spatial abilities are referenced in the areas of mathematics, science, and social science. For example, according to the Iowa Department of Education (2010), in geography students should be able to: “Understand the use of geographic tools to locate and analyze information about people, places, and environments”. Some of the tools geographers use to make sense of the world include maps, globes, photographs, and geospatial technologies. These tools are essential to portraying, analyzing, evaluating and predicting human and physical patterns and processes on the Earth’s surface. These tools also play a critical role in helping people make sense of a complex world from a spatial perspective (Iowa Department of Education, 2009, p. 23).

1.8 SPATIAL ABILITY AND GENDER

Gender may be a factor in increasing spatial abilities in the classroom. There is evidence that males outperform females on a diverse set of spatial assessments that require manipulation and transformations of geometric figures and forms (Moffat, Hampson, &Hatzipantelis, 1998). McBurney, Gaulin, Devineni, and Adams (1997) found females to be superior on a assessment of spatial memory, while males were superior on a assessment of mental rotation. Even though spatial ability differences between males and females are widely acknowledged, there is considerable disagreement as to the magnitude of these differences (Linn and Petersen, 1985). The results of their meta-analysis indicates that large sex differences favoring males are found on measures of mental rotation, but smaller differences are seen on measures of spatial perception.

According to Sorby (2007), Michigan Technological University (MTU) has been offering a special course, engineering graphics, to help develop 3D spatial skills of engineering students since 1993. With the development of new multimedia software and workbook, the spatial skills course at Michigan Tech was modified in 2000. Approximately 160 volunteer MTU students participated in this study and were randomly assigned to one of four groups, balanced for gender and initial PSVT:R score. The first group went through the ten week spatial training using the software only. The second group used only the workbook during the training sessions. The third group used both the software and the workbook. The fourth group constituted the comparison group for the study. The comparison group underwent no spatial skills training. All four groups were administered the PSVT:R as the dependent variable post-assessment. The data from this analysis was analyzed using a regression model. Both groups that used the workbook were significantly better than the control group on the PSVT:R post-assessment. The workbook-only group and workbook-and-software group were not significantly different, and the control group and software alone group were not significantly different. Sorby concludes that for women, and for some men, the engineering graphics class helps develop 3D spatial skills.

Deno (1995) studied whether variations in performance of engineering students on a measure of spatial visualization were related to prior spatial experiences and to the developmental period when the prior experiences occurred. Nonacademic activities had a positive significant relationship to spatial visualization ability for men, but not for the women assessed.

1.9 SPATIAL ABILITY AND MATHEMATICS ABILITY

The relationship between spatial ability and mathematics ability has been debated for many years. Newcombe and Hutttenlocher (2000) state that spatial ability is an important and distinct aspect of human intelligence. That is, spatial ability is separate from behavioral, computational, and neurological cognitive activities. Wai, Lubinski, and Benbow (2009) discuss three content domains which together form the construct of general intelligence: mathematical, spatial, and verbal. When Howard Gardner (1993) proposed eight separate intelligences, he included visual-spatial and logical-mathematical intelligence separately. However, Lohman (1993 and 1988) noted that a large proportion of performance on spatial assessments, particularly complex assessments, can be explained by a measure of general intelligence.

According to some research there is a strong positive correlation between mathematic achievement and spatial ability (Keller, Wasburn-Moses, & Hart, 2002; Tartre, 1990). Developing spatial sense, along with number sense, is a basic goal of mathematics instruction that develops skills in problem solving in particular and doing mathematics in general (Basham, 2007).

Using case studies, Erbilgin and Fernandez (2004) studied how eighth grade mathematics students at different spatial ability and achievement levels use multiple representations. The findings suggest that students at different levels of achievement and spatial ability used multiple representations differently. High spatial ability students were found to have had access to more multiple representations than low spatial ability students. Similarly, high achieving students had more access to multiple representations than low achieving students. However, the use of different representations appeared to help all students. The authors conclude that when students learn a concept with more than one representation, they can make connections between them and improve their mental schemes which results in better learning.

Weiner and Robinson (1986) studied mathematically gifted adolescent boys and girls to determine if there were significantly different in cognitive abilities and personality factors and to determine whether cognitive abilities and personality factors were accurate predictors of mathematical achievement. “For both the girls and the boys, neither spatial reasoning ability nor personality factors significantly predicted mathematical achievement” (Weiner & Robinson, 1986, p. 83).

1.10 IMPROVING SPATIAL ABILITY

Spatial ability can be improved with practice. Spatial abilities of both males and females improve as they become more involved with such tasks as model building, working with 3-dimensional objects, and solving spatial visualization problems (Skolnick, Langbort, & Day, 1982). Engineering drawing tools such as CADD provides one way for students to improve spatial ability (Olkun, 2003). Method of instruction is a factor in increasing spatial abilities in the classroom. Basham (2007) used a quasi-experimental design to examine the development of spatial abilities of ninth grade Technology Discovery students in 14 Mississippi schools between three different instructional methods (teacher and module instructional method, module only instructional method, and existing material instructional method with Pro/Desktop® 3-D CADD solid modeling software. A control group of students that received no instruction using CADD software was included. The main research question asked if differences existed by instructional treatment method when spatial ability pre-assessment scores, gender, ethnicity, co-registration in art, and co-registration in geometry were controlled. An analysis of covariance was conducted to analyze the data using the pre-assessment as the covariate and instructional method as the fixed factor. The dependent variable was the student score on the Purdue Visualization of Rotations Assessment. A statistically significant difference existed depending on the method used to instruct students on the use of 3-D CADD modeling software. The instructional consisting of method of teacher-led instruction using the software in a design lesson, followed by student-directed modular instruction, was found to be effective. No affects of the additional variables was found.

Baldwin and Hall-Wallace (2002) studied interventions to improve spatial skills which included having a subgroup of the high school and college students complete a set of Geographic Information System (GIS) activities. They concluded that developing spatial ability requires more interactive learning and manipulation of objects or images than is offered in a typical lecture style classroom. In addition, there may be differences in effectiveness of methods of teaching for students dependent upon their initial spatial ability (Baldwin & Hall-Wallace, 2002).

A study by Keehner, Montello, Cohen, and Hegarty (2004) was designed to investigate the roles of interactivity and spatial visualization ability in the understanding of 3D computer visualizations. Sixty participants, all undergraduate students, were randomly allocated to one of two conditions. The treatment group was allowed to rotate the computer visualization at will via keyboard controls during the drawing task. The control group had no control over the movements. A Mental Rotation Assessment and Guay’s Visualization of Views Assessment measured the dependent variable, spatial ability. No significant difference between the treatment and control conditions was found in an ANOVA. The authors noted that high- and low-spatial participants differed significantly in the passive condition, but not in the active condition. That is, when participants were allowed to manipulate the 3D model, the performance means of high and low spatial individuals were closer. The conclusion was that “while low-spatial participants were helped by interactivity, this benefit did not extend to high-spatial individuals” (Keehner et al., 2004, Discussion section, 1).

1.11 2D COMPARED TO 3D

While several papers discuss improvement of spatial ability, few studies were located that focused on the differing aspects of 2D and 3D CAD programs. 2D and 3D spatial visualization and reasoning are core skills that all students should develop (National Council of Teachers of Mathematics, 2000). Computer-based learning environments often include symbolic as well as static and dynamic representations; these are often combined with the possibility of modifying the representations interactively. When computer software allows students to see a solid represented in several possible ways on the screen and to transform it, students are aided in acquiring and developing abilities of visualization in a 3D context (Christou et al., 2007; Melanie, et al., 2006). Wang, Chang, and Li (2007) investigated the comparative efficacy of 2D- versus 3D-based media design for improving spatial visualization skills. While they found no significant differences, their study of undergraduate students was small (n = 23) and short with the subjects receiving the treatment for less than 35 minutes.

III. METHODS

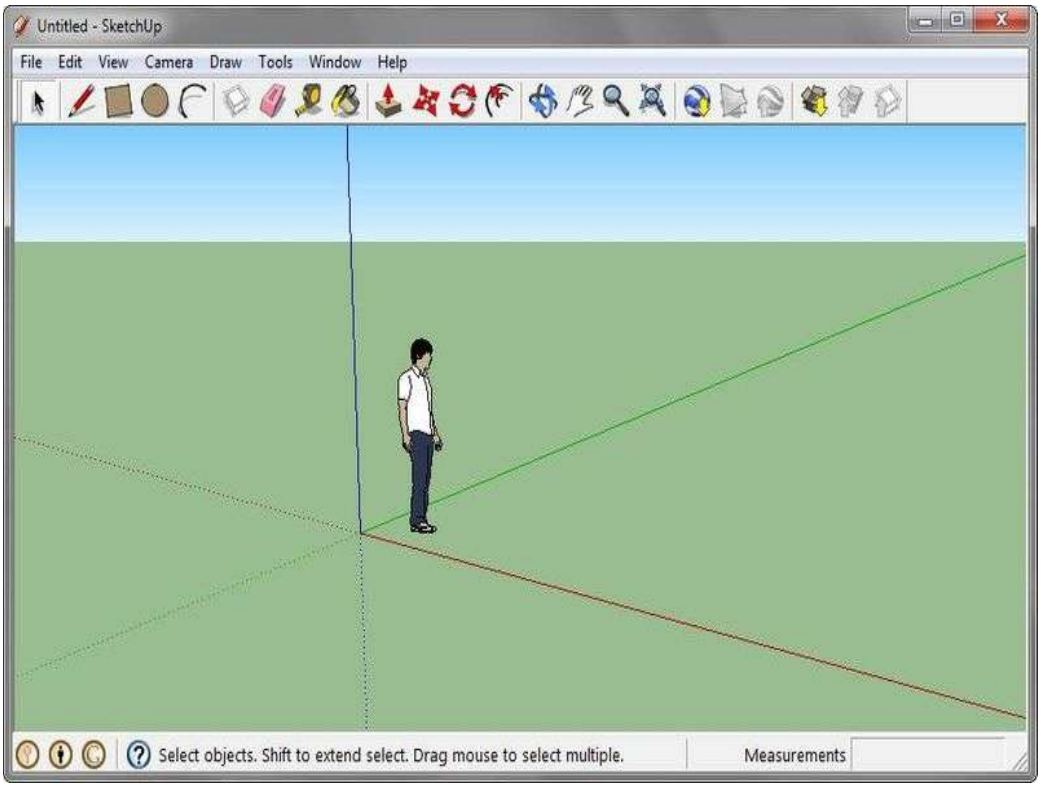
1.12 DESIGN

The purpose of this quasi-experimental study is to assess whether completion of a quarter long CAD unit (independent variable) has an effect on the development of spatial ability for high school students. The study was a pre-assessment-post-assessment design using the PSVT:R as the dependent measure. Additional data collected included the students’ Iowa Assessments: Mathematics results and reviews of student sketched objects portfolios and a 3D model project.

During the first week of the quarter, all students were administered the PSVT:R pre-assessment. The students completed a 2D unit and a 3D unit as part of their quarter of class work. Google SketchUp, an open source software, was provided and used by all students. The classroom is equipped with 25 iMac Computers. All computers have Google SketchUp Pro 7.0 installed. SketchUp was suggested at a meeting of technology teachers held at the Heartland Area Education Agency. The teacher attended a professional development class on SketchUp and was trained on methods of implementing the software in the CAD classroom. During the last week of the quarter, all students were administered the PSVT:R post-assessment.

1.12.1 GOOGLE SKETCHUP PRO.

Google SketchUp Pro is 3D modeling software marketed to professionals including architectural, civil, and mechanical engineers, filmmakers, and game developers as well as educators. SketchUp is fairly easy and intuitive. Using the 3D models, students make informed decisions, communicate project details, and share ideas with others. Every SketchUp model is made up of just two things: edges and faces. Edges are straight lines, and faces are the 2D shapes that are created when several edges form a flat loop. For example, a rectangular face is bound by four edges that are connected together at right angles. To build models in SketchUp, students draw edges and faces using a few tools. Students can extrude any flat surface into a 3D form with SketchUp's push/pull tool. SketchUp has an interactive sections feature to temporarily cut away parts of the design, enabling students to look at the interior. SketchUp lets students “get inside” their model (Fig.1) with a set of simple navigation tools designed to give a first-person view not unlike playing a video game.



Select objects. Shift to extend select. Drag mouse to select multiple.

Figure1: Screen shot of SketchUp

1.12.2 TEACHING STRATEGIES

The students have a 3D unit as part of their class work. The purpose of the 3D Modeling is to provide students with an introduction to concepts for manipulating objects in a 3D environment. During the class students create 3D Models themed for business proposals, engineering prototypes, or video game design purposes. A 2D unit is also included as part of their class. This includes an introduction to architectural design using different architectural resources to give the students a perspective of how houses are built and designed.

While a variety of instructional strategies are used in the classroom including direct instruction, tutorials, drills, interactive video, simulation and games, for this class the emphasis is on guided practice in 2D and 3D drafting fundamentals coupled with a broad range of technical drawing exercises and experiences using the software. Students are given formative feedback about their daily work. Content is modified to meet student needs in terms of those who struggle with the concepts as well as those who need greater challenge. An array of product options is routinely offered to engage the students.

1.13 PARTICIPANTS

The students included in this action research project attend Dallas Center-Grimes High School in central Iowa. Located just minutes northwest of the Des Moines metro area, the Dallas Center-Grimes School District serves approximately 1,900 students. The high school has a 2011-2012 enrollment of 598 students in grades nine through 12. Ninety-four percent of the students are white, two percent are Hispanic, two percent are Asian, and two percent are of other background. Approximately 13.4 percent receive free or reduced price lunch. Dallas Center and Grimes offer a small town environment that provides a strong sense of community.

The students selected are enrolled in a one semester long Introduction to CAD class. The sample size is 22 students. The sample consists of eleven freshmen, nine sophomores, and two juniors. The selected students reflect the ethnic and socioeconomic demographics of the high school. All are white except one Hispanic student. Three of the students receive free or reduced price (13.6 percent). Almost the entire sample is comprised of male students (21 students).

The Introduction to CAD course is designed to survey the different options in the computer aided drafting and design world. Students learn about architectural, presentational, and technical drafting during this class. During the course, students will learn how tothink using 2D and 3D drafting fundamentals. Software used in this course includes ArchiCAD, Google SketchUp , Solid Works and GoogleEarth. Students taking the course will have instruction in both 2D and 3D modeling.

1.14 MATERIALS

The three measures of improved spatial visualization skills were included in this study: editing sketched objects, completion of a 3D model using the CAD software, and the PSVT:R assessment.

1.14.1 SKETCHED OBJECTS

The students will learn and apply computer aided design techniques and principles to create drawings by generating, moving and editing the basic geometric elements. To demonstrate their ability to edit sketched objects, students must use modifying commands such as move, offset, break, copy, mirror, rotate, scale lengthen, divide, and measure to change the object of focus. In addition to receiving feedback from me, a simple rubric helps students evaluate their own designs.

1.14.2 3D MODEL

Satisfactory completion of a 3D Model themed for business proposals, engineering prototypes, or video game design purposes is another measured outcome. These are also evaluated using rubric.

1.14.3 PURDUE SPATIAL VISUALIZATION ASSESSMENT: ROTATIONS

The PSVT:R was chosen for use as the dependent measure in this study and will be used for both the pre-assessment and post-assessment. The PSVT:R was designed to measure the participants' ability to visualize the rotation of 3-dimensional objects (Fig.2). The PSVT:R can be administered as a group assessment and is appropriate for high school age students (Guay, 1980). The assessment has 28 items and has a time limit of 30 minutes. Scores recorded will be number correct. Bodner and Guay (1997) state that the PSVT:R is a valid measure of spatial ability. The assessment shows reliability when different samples of similar populations are assessed. Reliability for the PSVT:R was reported by Bodner and Guay to be around .80 using both Kuder-Richardson 20 internal consistency assessment values (range .78 to .80) and split half reliabilities (range .78 to ,85). In addition, Bodner and Guay note that the assessment has been shown to be unlikely to be confounded by analytic processing strategies. They also reported that the PSVT:R had high correlations with similar instruments measuring visualization. The directions for the PSVT:R exam tell the student to:

> (1) study how the object in the top line of the question is rotated, (2) picture in your mind what the object shown in the middle line of the question looks like when rotated in exactly the same manner, and (3) select from among the five drawings (A, B, C, D, or E) given in the bottom line of the question the one that looks like the object rotated in the correct position. To restrict analytical processing, a time limit…is strictly enforced (Bodner&Guay, 1997, p. 8).

The PSVT:R was often used in the literature to measure spatial ability (Basham, 2007; Sorby, 2007). In addition, the authors give free permission to use the PSVT:R (Bodner&Guay, 1997).

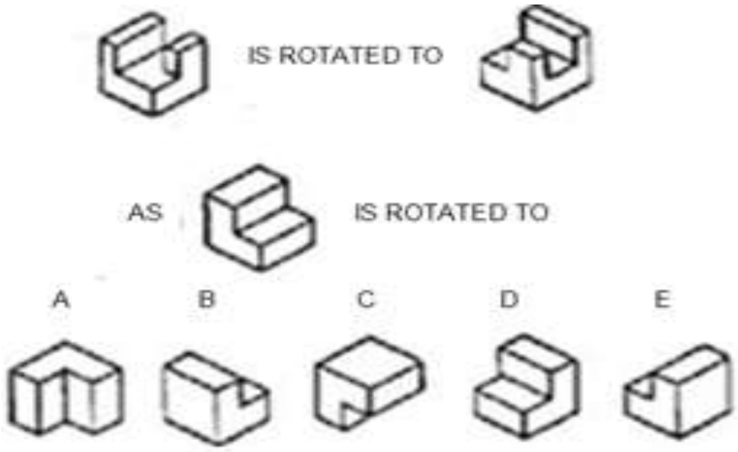


Figure2: Example from the PSVT:R. (The answer is D.)

1.14.4 IOWA ASSESSMENTS

The Iowa Assessments: Mathematics Concepts and Problem Solving is a 40 minute, 40 question, multiple choice assessment taken by most Iowa high school students in grades 9 and 10 and required for almost all students in grade 11. The assessment questions emphasize the student's ability to solve quantitative problems and are classified into five content areas: number sense and operations, algebraic patterns and connections, data analysis/ probability/statistics, geometry, and measurement.The assessment was designed to "provide objective, norm-referenced information about high school students' development in the skills that are the long-term goals of secondary education" (Forsyth, Ansley, Feldt, &Alnot, 2001, p. 1). The Kuder-Richardson Formula 20 was calculated at 0.892 for this assessment (Forsyth, Ansley, Feldt, &Alnot, 2003).

1.15 DATA ANALYSIS

Descriptive statistics including means, medians, skew, and standard deviations will be computed for the PSVT:R pre-assessment and post-assessment and for the Iowa Assessments: Mathematics. In addition, histograms will be constructed as part of a check to be sure that the assumption of normalcy is confirmed.
To analyze null hypothesis #1, that the CAD unit will have no effect on spatial ability as indicated by the PSVT:R, a dependent t-assessment will be completed using the PSVT:R pre-assessment and post-assessment results.

To analyze null hypothesis #2, that higher mathematics ability as measured by the Iowa Assessments will not correlate with the change spatial ability as indicated by the PSVT:R, the Pearson Product Moment Correlation between the Iowa Assessments: Mathematics and the change in the PSVT:R (post-assessment – pre-assessment) will be computed.

The two qualitative measures will be examined using rubrics. An examination of students' ability to edit sketched objects using modifying commands and completion of a 3D Model themed for business proposals, engineering prototypes, or video game design purposes. Scores on the rubric measures for all students will be summarized.

IV. RESULTS

1.16 ANALYSIS OF NULL HYPOTHESIS #1

The results of the PSVT:R for the 22 students were examined. For the pre-assessment the mean raw score was 15.7 items correct (out of 28) with a standard deviation of 6.0. The range was 25 with a minimum number correct of 0 and a maximum of 25.

On the post-assessment the mean raw score was 20.7 items correct (out of 28) with a standard deviation of 5.8. The range was 23 with a minimum number correct of 5 and a maximum of 28.

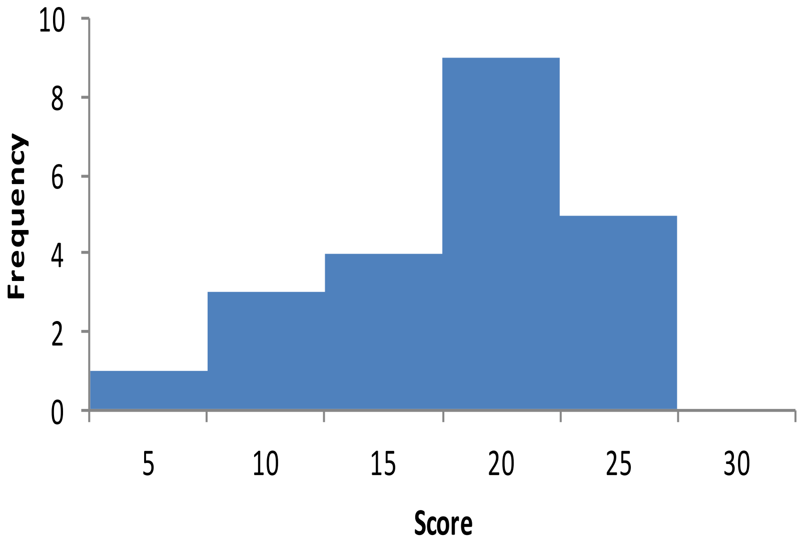


Figure 3: PSVT:R Pre-assessment Scores

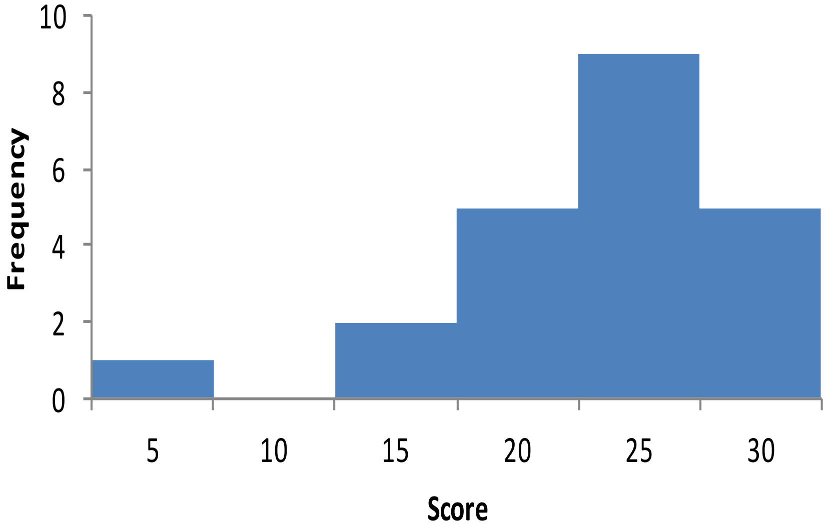


Figure 4: PSVT:R Post-assessmentScores

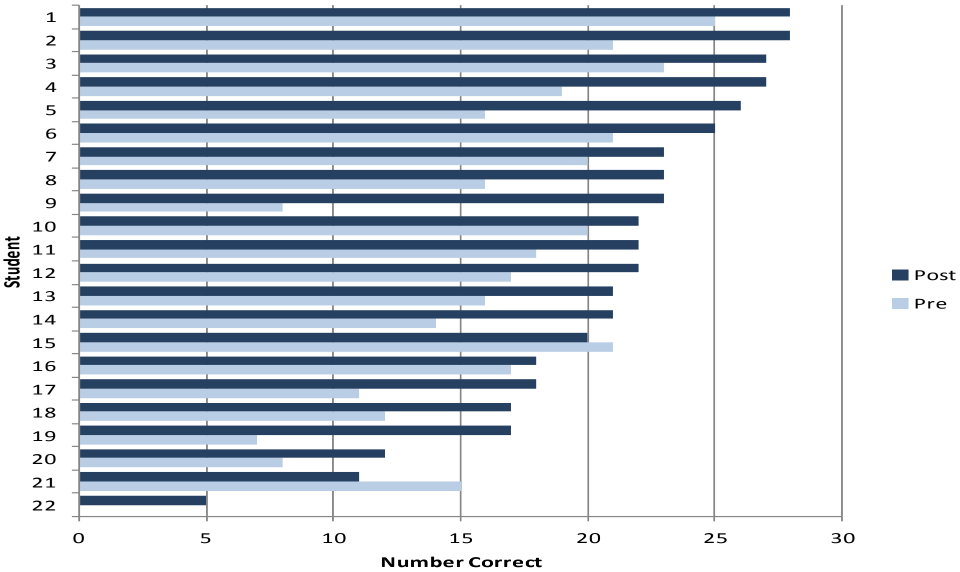


Figure 5: Pre and Post Scores by Student

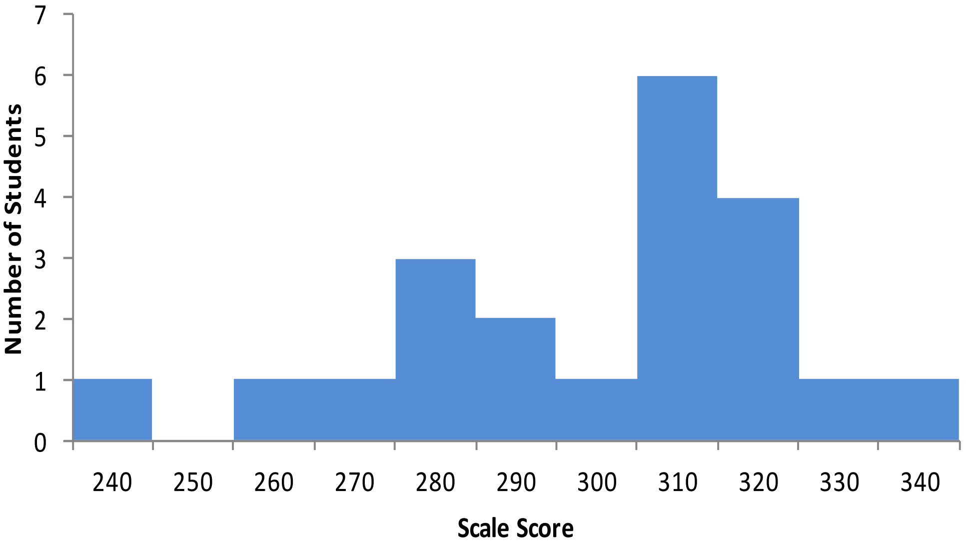


Figure6: 2011-2012 Iowa Assessments: Mathematics

When the results of the post-assessment were compared to their pre-assessment, 20 of the students improved. Two students had lower post-assessment scores than pre-assessment. The correlation between the two assessments was high, 0.78. The dependent t-assessment results were a t = 5.98 ($p < 0.001$). This is evidence that the post-assessment scores were significantly higher than the pre-assessment scores.

1.17 ANALYSIS OF NULL HYPOTHESIS #2

Twenty-one students also completed the Iowa Assessments in Mathematics. The mean scale score on this assessment was 295 with a standard deviation of 24.5. The median scale score was 304. The curve is somewhat negatively skewed (-0.95). The range was 104 with a minimum scale score of 231 and a maximum of 335.

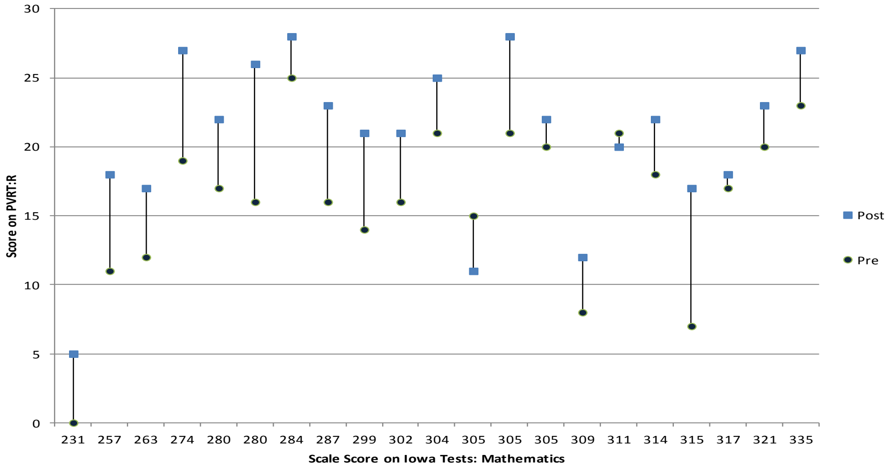


Figure 7: Pre-assessment and Post-assessment Scores on the PVRT:R Compared with Score on the Iowa Assessment: Mathematics

Table 1: Correlation of PSVT:R with Iowa Assessments: Mathematics

Measure	**Correlation with Iowa Assessments: Mathematics**
Pre-assessment	0.52*
Post-assessment	0.34
Change (Post-assessment – Pre-assessment)	-0.31

***Significant at .05.**

While there was a linear correlation between the score on the Iowa Assessments: Mathematics and the PSVT:R pre-assessment, the correlation between the score on the Iowa Assessments: Mathematics and the change from pre-assessment to post-assessment on the PSVT:R was not significant (r = -0.31, p = 0.17).

V. DISCUSSION

At the end of teaching learning process the students were evaluated for their proficiency in spatial visualization using the three outcomes: editing models, 3D project, and the PSVT:R. I also informally surveyed the students on their experiences. The analysis of the data has indications that all of the students were able to improve their visual perception ability as demonstrated by their progress on their projects and models.

Lower ability students found SketchUp a little more difficult to navigate than the other students. It seems more challenging for them to image 3D objects from the 2D planning process. Additional work samples, of my own or other students, were important to help these students to perceive what the products should look like. These students also were more easily frustrated by the process of using the software. They needed more encouragement and support. The software could be more intuitive to help low ability students complete their design ideas effectively. In addition, the students with the lowest visual perception ability had the most trouble using the mouse effectively. Perhaps using a touch monitor would work better for some students.

The software proved to be reliable. Students could advance at their own pace. This lowered frustration for both the higher ability students as well as the lower ability students. While some students could master the software quickly, others needed more time to understand each step before progressing on to the next.

This study found that students in the Introduction to CAD class had different levels of spatial ability at the beginning of the class. Significant differences were found on the PSVT:Rassessment of spatial ability from the pretest to the post-assessment of the students during the nine week CAD unit. Students with a low beginning spatial ability and students with high beginning spatial ability both showed improvement. After instruction, almost of the students profited and the gain was not limited to those with high mathematical ability. Enrollment in a CAD class which includes interaction with computer aided design techniques and principles to create drawings by generating, moving and editing the basic geometric elements appears to be an efficient way to increase spatial ability.

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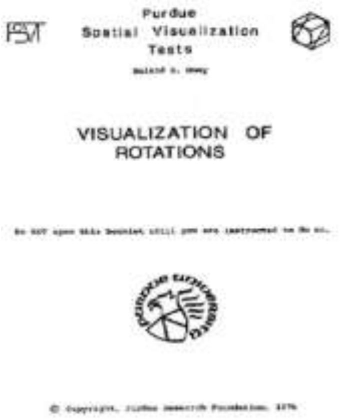
APPENDIX A: PURDUE SPATIAL VISUALIZATION ASSESSMENT: ROTATIONS (PSVT:R)


PSVT
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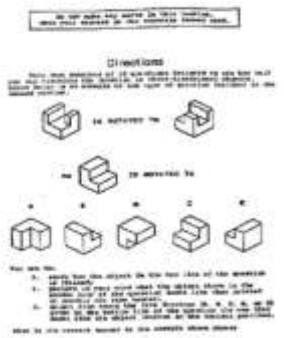
Spatial Visualization
Tests

VISUALIZATION OF
ROTATIONS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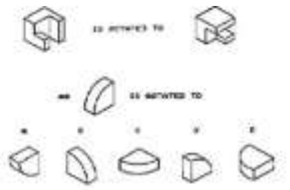

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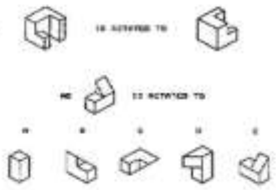

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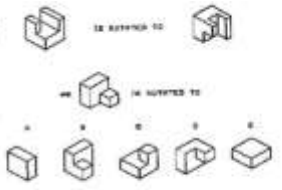

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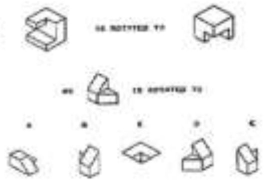

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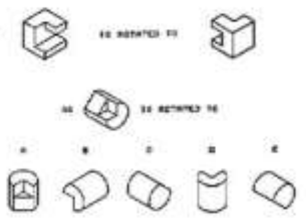

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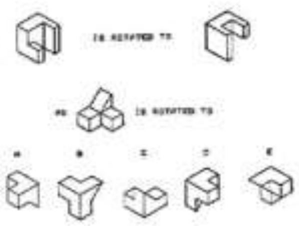

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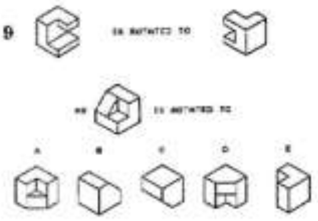

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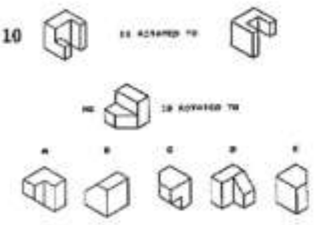

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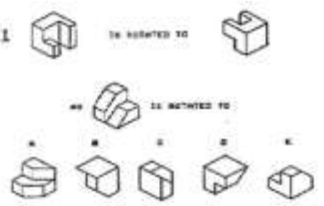

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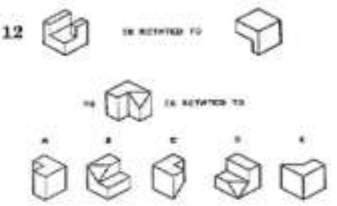

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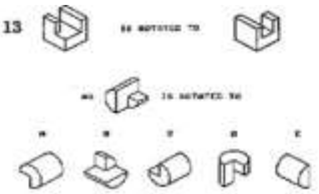

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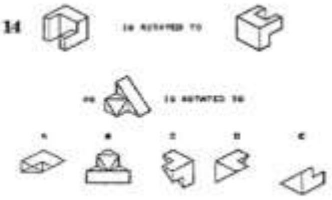

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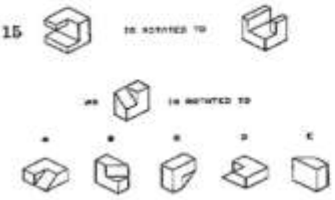

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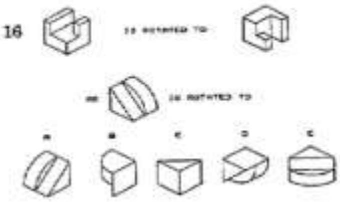

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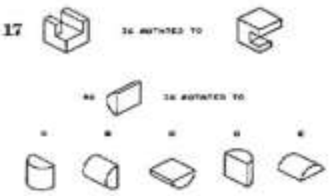

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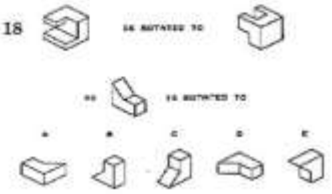

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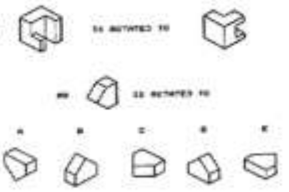

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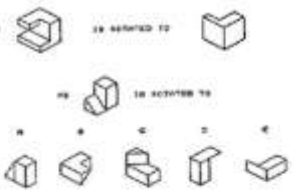

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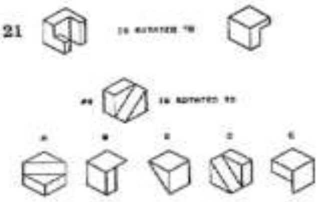

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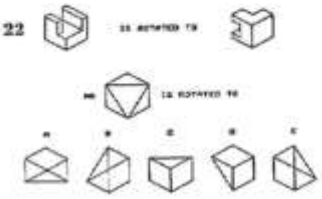

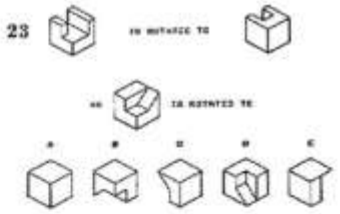

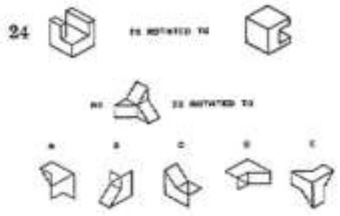

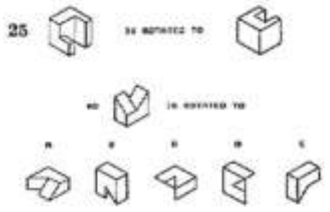

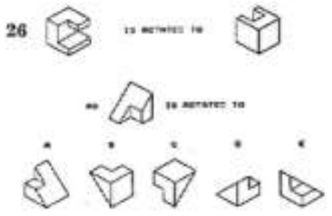

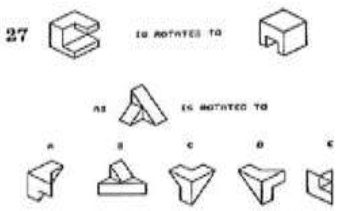

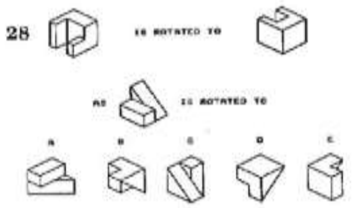

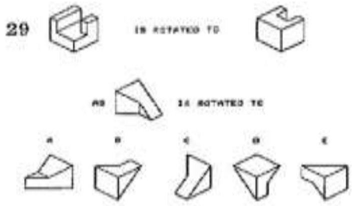

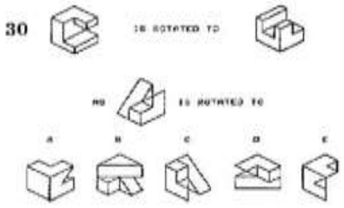

Key for the Purdue Spatial Visualization Assessment: Rotations

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2. D
3. A
4. B
5. E
6. C
7. C
8. D
9. B
10. E
11. B
12. A
13. C
14. D
15. B
16. E
17. A
18. E
19. D
20. E
21. B
22. C
23. A
24. E

25. B
26. C
27. D
28. D
29. E
30. E