MEASURING THE DIFFERENCES IN SPATIAL ABILITY BETWEEN A FACE-TO-FACE AND A SYNCRONOUS DISTANCE EDUCATION UNDERGRADUATE ENGINEERING GRAPHICS COURSE

by

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ABSTRACT

Measuring the Differences in Spatial Ability Between a Face-to-face and a Synchronous Distance Education Undergraduate Engineering Graphics Course

by

Scott D. Greenhalgh, Doctor of Philosophy

Utah State University, 2011

Major Professor: Dr. Gary Stewardson
Department: Engineering and Technology Education

Distance education is growing at colleges and universities throughout the United States. Engineering graphics laboratory courses are unique in their focus on skills and design with an emphasis on a hands-on approach when compared to many subjects that focus on mastering information. Most studies in the literature focus on how distance learning has impacted traditionally lecture-based curricular approach and not on classrooms that are traditionally laboratory based as would be typically found in many engineering graphics courses. This study measured and compared spatial ability as it is an essential component to engineering graphics, and has a highly correlated measure of success in engineering and other science, technology, engineering, and math (STEM) disciplines. This study's purpose was to measure and compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability.

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The differences found in the change of spatial ability between students taking an engineering graphics course by means of synchronous distance education and face-to-face courses were found in students with a low beginning spatial ability. Students with a low beginning spatial ability showed greater improvement in spatial ability in the face-to-face courses (m = 3.50, SD = 1.93), than in the synchronous distance education courses (m = 1.39, SD = 2.25).

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PUBLIC ABSTRACT

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by

Scott D. Greenhalgh, Doctor of Philosophy

Utah State University, 2011

Major Professor: Dr. Gary Stewardson
Department: Engineering and Technology Education

A study was conducted in the Engineering and Technology Education Department at Utah State University by Scott Greenhalgh and Gary Stewardson to measure and compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. This study is unique because it involves laboratory classes in a science, technology, engineering, and math (STEM) field with greater emphasis on hands-on laboratory experiences and skills rather than mastery of information and knowledge. The potential for impact of the study extends beyond a few courses in a specific field. There are approximately 400,000 students enrolled in engineering programs across the United States each year and nearly all of these students take a graphics course. In addition to engineering, graphics courses are foundational in many technology fields such as drafting, design, architecture, construction,

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manufacturing and industrial fields. This equates to thousands of graphics courses taught in both secondary and post-secondary schools across the nation each year. Distance education opportunities have the ability to bring access to many students who do not otherwise have the opportunity to take those courses, but the strengths and limitations of distance education courses must be studied in order to guide educators how to best serve students.

The findings of the study showed that for students of medium and high beginning spatial ability levels, there were no statistically significant differences in improving spatial ability when comparing a synchronized distance education course to a face-to-face course. If educators and curriculum developers wish to explore a synchronized distance education course that may improve access to more students than might have the ability to attend a face-to-face course, then a synchronized distance education course provides a comparable educational experience to a face-to-face course when looking at improving spatial ability for students who begin with a medium to high spatial ability. For students beginning with a lower spatial ability, it is recommended that those students are placed in a face-to-face course. Spatial ability has been correlated to success in many STEM fields, and it is recommended that curriculum developers and educators account for this ability when making curricular decisions.

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LIST OF ACRONYMS

American Society of Engineering Educators	ASEE
Computer Aided Drafting	CAD
Engineering and Technology Education	ETE
Mean	M
National Academy of Engineering	NAE
Number in Sample	*N*
Purdue Spatial Visualization Test of Rotations	PSVT:R
Standard Deviation	SD
Science, Technology, Engineering, and Math	STEM
Utah State University	USU

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CHAPTER I

INTRODUCTION

Distance learning has grown dramatically in the past decade in most fields of study in post-secondary education. Advantages of distance education include having the ability to reach a greater number of students who may have limited access to educational opportunities and minimizing costs related to overhead and facilities. One area which is slow to accept distance education is laboratory classes in science, technology, engineering, and math (STEM) fields with an emphasis on hands-on laboratory experience. There have been several reasons for the slow acceptance of distance education in these fields. Some educators feel that having a teacher present to teach and oversee hands-on curricula and projects is vital for giving demonstrations and presentations, providing clarification on processes, and giving timely feedback in a laboratory setting. Additionally, many STEM laboratories must have an instructor present due to concerns of laboratory safety, and the maintenance and upkeep of tools and equipment (Ma & Nickerson, 2006). The removal of the physical presence of the instructor can make many STEM educators apprehensive to implement distance classes with hands-on laboratory activities. This limits the laboratory experiences and course options for students who may only have access to education through distance courses.

Not all STEM laboratories, however, face all of these issues. One instance where a distance education course is possible with a STEM laboratory experience is engineering graphics. This is possible due to a minimal safety risk and minimal required equipment upkeep. In 2004, a study of 51 colleges and universities showed that 21% of those

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schools offered a distance education engineering graphics course (Clark & Scales, 2006), and a 2008 survey of 56 engineering graphics instructors showed 32% colleges and universities surveyed offered a distance education engineering graphics course (Downs, 2009). One difficulty faced in comparing various engineering graphics courses is a lack of a standard criteria for evaluating laboratory activities (Ma & Nickerson, 2006) and finding a test instrument which meets the criteria for quality research. Even without a set of clearly defined universal objectives in engineering graphics courses, "the development or improvement of 3-D spatial visualization is often cited as one of the major goals in engineering design graphics education" (Sorby, 1999). As a result of interest in testing spatial ability, the ability to mentally represent and manipulate two- and three-dimensional objects, psychologists and educators have developed an array of spatial ability tests. These tests provide researchers an effective instrument which can be used to assess if the absence of the physical presence of the instructor in the classroom has any effect on the outcome of spatial ability in an engineering graphics course.

Prior researchers have found a correlation between spatial ability and academic achievement. According to Piaget and Inhelder (1948), spatial ability is a measurement of intelligence and is a component of intelligence testing. One aspect of spatial ability is the ability to mentally represent and manipulate two- and three-dimensional objects accurately and is critical for the success of designers and engineers (Potter, 2009). Because of the high correlation between spatial ability and success in engineering, some universities have focused on the importance of improving spatial ability within engineering graphics courses (Leoplold, Gorska, & Sorby, 2001).

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Researchers have looked at ways to improve spatial ability in the past 20 years. The researchers have found factors as well as interventions which correlate to spatial ability and improving spatial ability. Many of these curricular strategies are instructor centric or are untested in the physical absence of an instructor. One challenge for an instructor interested in a distance course is how to improve the spatial ability of the students in the course without being present to assist in explanations and demonstrations.

Additionally, the literature identifies noncurricular factors impacting spatial ability including: gender, hobby and leisure activities, prior graphics experience, prior experience with virtual software and games, and prior experience with object modeling (Feng, Spence, & Pratt, 2007; Potter, van Der Merwe, Kaufman, & Delacour, 2006; Schribner & Anderson, 2005; Voyer, Voyer, & Bryden, 1995). Identifying and statistically accounting for these noncurricular factors is important to accurately determine any effect the presence of an instructor has on spatial ability within a beginning engineering graphics course. In order to identify the effects of the physical presence of an instructor may have in increasing the spatial ability of beginning engineering graphics students, a quasi-experimental study was designed to account for noncurricular factors and quantify the effects of the physical presence of an instructor. The study is designed to gather and analyze data identifying the effect size of various factors associated with spatial ability that will be internally consistent, valid, reliable, and useful to curriculum designers and instructors in making curricular decisions about the potential for distance courses in engineering graphics and drafting courses.

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Statement of Purpose

The purpose of the study was to measure and compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. Additionally, the study looked at noncurricular factors and how any potential differences in spatial ability were impacted by these factors (including interactive effects). The noncurricular factors include: age, gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling.

Research Questions

The following research questions were addressed in this study.

1. Is there a statistical measure of change in the spatial ability of students in a synchronous distance education engineering graphics course? This will be tested against the null hypothesis that there is no change in spatial ability in a synchronous distance education engineering graphics course.

2. Is there a statistical measure of change in the spatial ability of students in a face-to-face engineering graphics course? This will be tested against the null hypothesis that there is no change in spatial ability in a face-to-face engineering graphics course.

3. Is there a statistical difference between the change in the spatial ability of students in face-to-face and synchronous distance education engineering graphics course? This will be tested against the null hypothesis that there is no difference in change in

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spatial ability in a face-to-face engineering graphics course when compared to a synchronous distance education engineering graphics course.

4. Is there a statistical difference in the change in spatial ability for various student populations in both face-to-face and synchronous distance education courses when factoring in the noncurricular factors of: gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling? This will be tested against the null hypothesis that there is no difference in change in spatial ability in a face-to-face engineering graphics course when compared to a synchronous distance education engineering graphics course after performing a partial regression of noncurricular factors.

Need for the Study

Distance education is growing at colleges and universities throughout the United States. Allen and Seaman (2008, 2010) have found that the number of students taking distance education courses have grown 12-17% every year since 2004 versus less than 1% annual growth for traditional (face-to-face) courses. Engineering graphics laboratory courses are unique in their focus on skills and design with an emphasis on a hands-on approach when compared to many subjects that focus on mastering information. Most studies in the literature focus on how distance learning has impacted traditionally lecture based curricular approach and have not focused on classrooms that are traditionally laboratory based as would be typically found in many engineering graphics courses. This study measured and compared spatial ability as it is an essential component to

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engineering graphics, has a highly correlated measure of success in engineering and other STEM disciplines (Smith, 2009).

The literature has numerous studies identifying a correlation between spatial ability and academic success in a wide array of STEM subjects as well as creativity, and practical and mechanical aptitudes. This body of research has begun to transfer into curricular changes at some universities that are now looking at improving spatial ability of engineering students. For example, Michigan Technological University encourages new students who score low on a spatial ability test to enroll in an optional class/workshop focused on improving spatial ability (Leoplold et al., 2001). However, there is little room left in a rigorous engineering program of study for new courses. The solution is in looking to existing courses which could be modified to add the improvement of spatial ability without impacting the current course goals. One such course is engineering graphics. As nearly all engineering programs required a graphics course, one could broaden the impact of the graphics course to not only teaching graphics but also focus on improving the spatial ability of students which studies show should result in academic and professional success, and may lead to higher student retention (Smith, 2009).

The potential for impact of the study extends beyond a few courses in a specific field. There are approximately 400,000 students enrolled in engineering programs across the United States each year (National Science Foundatio [NSF], 2010) and nearly all of these students take a graphics course. In addition to engineering, graphics courses are foundational in many technology fields such as drafting, design, architecture,

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construction, manufacturing and industrial fields. This equates to thousands of graphics courses taught in both secondary and post-secondary schools across the nation each year. Distance education opportunities have the ability to bring access to many students who do not otherwise have the opportunity to take those courses.

A study is needed to identify the impact of the physical presence of an instructor versus a distance education course on the spatial ability of students in an engineering graphics course. This study will be useful in identifying if remedial measures are needed to improve the spatial ability for students or specific student populations in both distance education and face-to-face classrooms. The study needs to utilize an appropriate design which can account for all the various factors while maintaining validity and reliability. Additionally, the study must be able to account or control for the various factors including varied student populations, curricular approaches, teacher and institutional differences, testing strategies, statistical analysis and prior experiences.

Study Limitations

There are many types of STEM laboratories that all vary both between disciplines and within disciplines. Likewise, there are many different types and approaches to distance education. With many possible combinations, this study is limited to investigating one construct (spatial ability) within one type of a STEM lab (engineering graphics) with one type of distance education (video enhanced synchronous correspondence). The survey of noncurricular factors is limited to some of the most prevalent factors already identified in the literature which may contribute to spatial

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ability. Due to controls in the survey design, especially using the same instructor at the same university as a control, generalizations from the study may show some limitations due to demographic and program differences at other programs and courses. As grading can be a highly subjective measurement, this study will focus on a cognitive construct which is an important aspect of the goals of an engineering graphics course.

Study Assumptions

One major assumption inherent in this study was that the students participating in the study responded truthfully and accurately to all survey questions. In order to meet these assumptions, it was important for students to take the questionnaire seriously (Suskie, 1996). This was addressed by informing the students that actions may be taken as a result of the findings. Additionally, the truthfulness of the response may be inhibited if they believe their response is not anonymous. Students were explained how the data would be analyzed and coded in order to protect student anonymity. Additionally, the students were provided a letter of information explaining the study, student rights as participants in the study, and the usage of the data being collected.

Procedure Summary

Students who participated in this study completed a pre- and posttest of a spatial visualization test of rotations along with a survey identifying noncurricular activities, interests, and key demographic information. The following steps were performed in pursuit of this study.

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1. A problem was identified showing a need for a study which can compare effects of distance education in a beginning engineering graphics course.

2. A review of literature was performed to verify the problem. No comprehensive study was identified comparing distance education courses to face-to-face courses in a beginning engineering graphics course.

3. A reliable test was identified (the Purdue Spatial Ability Test of Rotations) and the right to use the test was obtained.

4. A survey was created to collect the noncurricular activities and interests along with key demographic information of students.

5. An appropriate student sample for the study was identified.

6. An appropriate experimental design was created to meet the needs of the study.

7. Approval to perform the research study was sought from the Institutional Review Board (IRB) for the protection of human participants at Utah State University (USU).

8. The spatial ability test (pretest) was given to student participants in the first week of fall semester 2010.

9. The survey of student demographics and noncurricular activities and interests, and the second spatial ability test (posttest) were given to student participants in the last week of fall semester 2010.

10. The spatial ability test (pretest) was given to student participants in the first week of spring semester 2011.

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11. The survey of student demographics and noncurricular activities and interests, and the second spatial ability test (posttest) were given to student participants in the last week of spring semester 2011.

12. The data from the pre- and posttests along with the survey data was compiled, coded for student protection, and reviewed for completeness, and accuracy.

13. The data was entered into SPSS statistical software for analysis.

14. Conclusions were drawn from the review and analysis of the data.

Definition of Terms and Acronyms

Asynchronous distance education: Asynchronous distance education occurs when the teacher and students interact in different places and during different times.

Cognition: The study of how humans perceive, remember, learn, and think.

Distance education: A field of education that focuses on teaching methods and technology with the aim of delivering curricula to students who are not physically present in a traditional educational setting such as a classroom. This study will utilize a video enhanced synchronous distance education course.

Haptic learning: Haptic learning is learning through the sense of touch rather than the sense of sound (auditory) or sight (visual).

IDEO: IDEO is an international design and innovation consultancy founded in Palo Alto, California. IDEO is not an acronym.

NAE: The National Academy of Engineering

NCTM: National Council of Teachers of Mathematics

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NSF: The National Science Foundation

PSVT:R: The Purdue Spatial Visualization Test of Rotations.

Spatial ability: The ability to mentally represent and manipulate two and three-dimensional objects. This study will focus on the rotational manipulations of three-dimensional objects.

STEM: The integration of the fields of study of Science, Technology, Engineering, and Mathematics.

Synchronous distance education: Synchronous distance education occurs when the teacher and students interact in different places but during the same time.

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CHAPTER II

REVIEW OF LITERATURE

Distance Education

Distance education is a field of education that focuses on teaching methods and technology with the aim of delivering curricula to students who are not physically present in a traditional educational setting such as a classroom. Independent research by the Sloan Foundation estimated that 4.6 million Americans took distance education courses in the fall of 2008 (Allen & Seaman, 2010). The same researchers also found that the growth of distance education (also know as e-learning) has grown 12-17% every year since 2004 versus less than 1% annual growth for traditional (face-to-face) classrooms (Allen & Seaman, 2008, 2010).

Technical Context

Correspondence courses through traditional mail constitute the first example of distance learning. Corresponding through letters and assignments from mentors to pupil predate modern universities and formal schooling. This education was once so commonplace that critiques of modern public schooling refer to this type of education as a "classical education" as it was most commonly seen during the age of enlightenment (DeMille, 2000). Mediums of educational correspondence were enhanced and expanded by technological innovations. Correspondence was enhanced with instantaneous communication through e-mail and the telephone; audio and video recordings enhanced the message of authors and experts, and video conferencing allowed students into the

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classroom from across the globe (Means, Toyama, Murphy, Bakia, & Jones, 2009).

One must be weary of the false tendency to present distance education and traditional classrooms as dichotomous factors. A truer nature of formal schooling spans a wide array of distance and virtual mediums thus giving room for web facilitated and hybrid courses across the delivery spectrum. Colleges and universities began supplementing course materials with online activities and deliveries as early as the late 1980s. With this caveat in mind, a working definition of an online course in distance education is where the students have one or fewer face-to face meetings with the instructor. One of the first all-online courses was taught in 1992 at the State University of New York at Plattsburgh by Dr. William Graziadei (1993). In less than 10 years, the number of students taking online courses expanded to over 1.6 million or just less than 10% of the student population. Much of this expansion can be attributed to technological advances such as wireless internet and greater access to the internet, and the development of commercial software (e.g., blackboard, webct, and wimba) such as discussion boards, newsgroups, chatrooms, and webcasts designed specifically for educational purposes. Courses that are taught at a specified time are considered synchronous and courses that allow students to participate in the course within a specified time window are considered asynchronous. This study investigated and undergraduate engineering graphics course that utilized a synchronous approach.

Social Context

Since the inception of public education in the United States and the passing of the Morrill Act of 1863 expanding higher education, formal schooling in American has

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typically occurred within a classroom and a teacher interacting directly with students. As public schooling expanded in the United States following industrialization, the experiences of socialization through formal schooling have become such a ubiquitous part of the American experience that students who do not have this experience are often considered not fully socialized into American culture (Macionis, 2006; Medlin, 2000). The interactions of students in an online environment are different from a traditional classroom in many respects. Spontaneous group work and activities must be carefully planned in accordance with technological constraints. Student populations can shift in an online setting. The online environment, along with the convenience of a self selected time and location, can be more conducive to students who may have a difficult time attending traditional classrooms such as persons with full-time employment, young children to care for, and disabilities.

Advantages of Distance Learning

One surprising impact of online learning is that students perform as well as or better than their counterparts on meeting measurable learning objectives. This was determined through a meta-analysis of 99 experimental and quasi-experimental studies comparing online courses to equivalent face-to-face courses (Means et al., 2009). The meta-analysis yielded highly significant (p = .01) results with an overall small to medium (d = .35) effect size (Cohen, 2008). The meta-analysis suggests that distance education courses promote better learner reflection and other meta-cognitive activities through course structure and assignments.

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The outstanding positive impact of distance education is a more educated society when online classrooms provide opportunities for higher education for individuals who would otherwise be limited (Greer, 2010). This impact is found on an individual level, as well as on a societal level. With various competing philosophical purposes of education, the impact of adding distance education in addition to existing face-to-face courses must be examined within several competing paradigms. The three paradigms to be addressed are namely: democratic equality, social efficiency, and social mobility (Labaree, 1997; Schiro, 2008).

Democratic equality

The purpose of schools in a democratic equality paradigm is based off of the value for democracy and the belief that a democracy functions best with an educated populous. Many would go so far as to say that a democratic society cannot exist without a population educated in the ways of democracy. Therefore, a more and better educated society should translate into a healthier democratic society. Ideals within a democrat equality paradigm demand equal opportunities for all members within a society. If online classrooms can service a broader demographic with comparative results, then online classrooms may be integral to education in the United States for those who see the purpose of education through the lens of democratic equality.

Social Efficiency

Social efficiency approaches public education with completely different goals and values. Social efficiency is built around economic ideals and values rather than political.

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The national economy and prosperity benefit from having an educated and efficient workforce. Schools are then an investment into human capital with expectations for a return on the investment. At a time when most institutions are facing budget cuts, a reduction in the cost of education results in a more efficient educational system as long as outcomes (vocational, income, and production) are comparable to traditional classroom settings. Many schools have looked to online courses as a response to budget cuts and a rapidly growing student population (Allen & Seaman, 2010).

Social Mobility

Social mobility advocates that schools should provide students with the tools and knowledge they need to get ahead. Schools are then no longer for the public good as in social efficiency and democratic equality, but are for the individual who can be regarded as a consumer. When looking at the impacts of online classrooms through the eyes of social mobility, one must specify the condition of the individual evaluating the innovation. For example, one who attends online course because of time constraints due to employment would find online courses giving them an advantage to get promotions, better pay, or a better job. For that individual, online courses provide greater social mobility. However, online courses may not always provide greater social mobility. To the individual attending a college with traditional classrooms and courses, online courses would decrease social mobility as online classes increase competition for employment and advancement after college. Because social mobility is heavily dependant on the individual and their circumstances, it is not possible to generalize the impacts of online courses in an objective statement making any overall claim a moot point. However, one

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could critically analyze the position of claims made about online education based upon their position in regards to educational experiences and their social mobility as being a source of bias (Giroux, 2004).

Negative Impacts and Criticism

Before the positive effects of online classes are completely accepted, it is necessary to examine the validity and reliability of the studies conducted. The first issue stems from students having reported spending more time on task in online courses when compared to traditional classrooms. If one can accept the premise that more time spent on task will result in higher academic achievement, then one must ask the question if the findings of the meta-analysis stem from a contrast in time invested rather than delivery mediums. Secondly, a strong question of researcher bias must be questioned as many researchers served duel roles as experimenter and instructor for both online and face-to-face courses (Means et al., 2009). It was found that 24% of chief academic officers, who served in schools with online courses considered online courses to be academically superior, compared to 7% for those from institutions not offering online courses. On the flipside, 58% of chief academic officers at institutions who did not offer online courses considered online courses to be inferior to face-to-face courses compared to 14% for those at institutions with online courses (Allen & Seaman, 2010).

The greatest criticism of distance education comes from educational objectives not easily or objectively measured as outlined by two major meta-analyses of online learning (Allen & Seaman, 2010; Means et al., 2009). Both looked only at quantitative

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and objective outcomes. So much of the educational literature values objectives which are not easily measurable such as cognition and metacognition, affective traits (McMillian, 2001), team work and communication skills (National Academy of Engineering [NAE], 2004), and integration into a culture of professionals (Herschbach, 2009). This research will focus specifically on the cognitive construct of spatial ability.

Distance Education and Hands-On Classes

Trends of growing numbers of courses, student, teacher, and institutions show that online learning will be a major part of education in the 21st century. Studies of students' academic achievement in online courses show a positive effect in the method of delivery, and online classrooms progress in the educational goals of social efficiency, and democratic equality. The introduction of distance education into hands-on laboratory classes has been slow for many reasons. The first reason centers on laboratory equipment. Some laboratories must have an instructor because some of the procedures may be unsafe if followed incorrectly. These laboratory based courses will most likely never be delivered through distance learning in their entirety because of safety and legal concerns unless a technician is physically present. Likewise, instructors may be seen as necessary in laboratories with delicate and expensive equipment that requires care in use and maintenance. Some lab procedures may be sequential and process heavy. Any deviation from the process may result in the failure of the lab experience. For this reason, some instructors find it necessary to be present in the laboratories. Educators have looked at how to offer the same courses and material in STEM laboratories without the direct

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hands-on element. This has resulted in computer simulated laboratories. Computer simulated laboratories have addressed many of the concerns of implementing distance education into STEM laboratories.

There is an active debate about the use of simulated laboratories in STEM areas which embeds distance education. Advocates for hands-on experiences emphasize design and skills while those who support simulated remote and simulated labs focus on conceptual understanding (Ma & Nickerson, 2006). The arguments rely on the cognitive distance of the knowledge transfer. Advocates for a hands-on approach claim simulated laboratories are too far from real word experiences to have the same value as hands-on laboratories. However, some simulated distance laboratories are not too different in such cases as robotic controls and remote manufacturing. Likewise, there is little difference in software and equipment between a drafting and engineering graphics labs and a home computer. Many engineering professors believe that laboratory experiences are a way to connect to future employment and application (Faucher, 1985). Advocates for simulated laboratories claim that simulated experiment and activities are as effective as traditional hands-on labs, take less time to conduct, and have lower equipment costs and require less building space (Shin, Yoon, & Lee, 2002). Detractors argue that over exposure to simulated labs disconnects students from the real world (Magin & Kanapathipillai, 2000). Additionally, a lack of unifying criteria within STEM laboratories and inconsistency among various labs and lab experiences fuel the debate between hands-on and simulated laboratories.

Engineering graphics distance education. Some case studies have looked at

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distance education engineering graphics classes and compared that to face-to-face courses and have found similarity in curriculum, goals, and objectives among them. One difficulty encountered in these studies is a lack of standards or criteria for evaluating laboratory activities (Ma & Nickerson, 2006) and finding a test instrument which meets the criteria for quality research. Totten and Brandoff (2004) identified three major challenges in creating an engineering graphics distance education course. Those challenges are: "finding appropriate ways to demonstrate CAD software, preparing materials that are graphic intensive, and determining adequate methods to evaluate student work" (p. 9). Evaluating and providing immediate feedback from the instructor is one challenge to conducting a distance education engineering graphics course. In a follow-up study of distance education engineering graphics courses, Brandoff (2006) found no significant differences in formative and summative measurements of instructors when comparing a community college distance education course to a similar face-to-face course. Issues of this study were the small sample size (26 participants), and the various assessment tools such as tests scores and assignments. The research focused on technological issues such as how students were accessing the data, available bandwidth from internet service providers, and the location where data was accessed. A follow-up study of 22 distance engineering graphic students looked at online assessments (quizzes) of the information presented in online materials and from the course textbook. This study found no correlation between the mean of these assessments and course projects, mid-term and final exams, and homework means (Brandoff, 2007).

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Spatial Ability

Spatial ability, spatial perception, spatial intelligence, and spatial visualization are terms used to describe the ability to mentally visualize and manipulate three-dimensional objects within the mind. The National Council of Teachers of Mathematics (NCTM, 2000, p. 42) in *Principles and Standards for School Mathematics* gives a definition for spatial visualization as "building and manipulating mental representations of two- and three-dimensional objects and perceiving an object from different perspectives" (p. 42).

Spatial ability is a key component of graphic fields such as design and engineering. High spatial ability allows the inventor, designer, and engineer a greater ability to work and manipulate three dimensional objects. Engineering and technical graphics have been described as a means whereby one person can convey mental images to another person (Ferguson, 1992).

Origins with Piaget

The study of spatial ability began with Jean Piaget as he began to look at the development of visual imaging in children. To study spatial ability, Piaget and Inhelder (1948) created the Water Level Task. This test was based on the principle that water will always rest level regardless of the orientation of the container. One example of a test question of the Water Level Task was to correctly identify how water would be represented in a glass. The glass would be rotated in different orientations with the student being required to identify how water would lay in the glass. Correct answers had the water being represented horizontally, and most of the incorrectly chosen examples

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had water parallel to the bottom of the rotated glass rather than horizontal. One of the findings of his studies was that the younger students were not as successful with this test. Piaget continued to explore the development of spatial abilities in children. Some of his findings include that mental imagery skills develop through action and activities often involving imitation through copying and sketching (Piaget, 1969). He then went on to categorize spatial ability into three types of visual images: static, kinetic and transformational. Static images are constant in space and shape, kinetic images are constant in shape but not in space, and transformational images are not constant in shape (Piaget & Inhelder, 1971). These concepts provide the foundations for many of the tests of spatial ability including mental cutting tests and rotational tests. Many researchers have built upon Piaget's work in the following four decades by looking at high and low spatial abilities, the cognitive aspects of spatial ability, and correlations between spatial ability and academic achievement.

Cognition and Spatial Ability

Cognitive scientists have looked at how people create, modify, and remember mental images. Roger Shepard was one of the early researchers to look at spatial abilities from a cognitive standpoint. Some of his important findings include how people mentally rotate three dimensional images. He found that mental rotations correspond to or imitated the actual physical rotation and information about the object's structure is retained throughout the rotation (Shepard, 1978). Shepard continued his work and produced many of the theories underlying current research on spatial visualization and ability. Some of his findings include: time as a factor of spatial rotations, the rotations of mental objects,

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and the manipulations of mental objects. The majority of his research was summarized in 1984 leaving future researchers a strong base upon which to build (Cooper & Shepard, 1984).

Spatial Ability in Embodied Cognition

Many current researchers look at spatial ability through the lens of embodied cognition. These researchers and theorists hold that people develop spatial perception through experiences with the physical alignment and interactions of objects in real life. Spatial ability extends past the mind's ability to conceive concrete physical object and allows one to interact and experiment with conceptual objects. Spatial ability is a part of most intelligence tests, and is included in Gardner's theory of multiple intelligences (Gardner, 1983). Spatial ability is considered to be linked with creativity. Famous inventors and thinkers such as Albert Einstein and Nikola Tesla have credited their success to the ability to visualize mechanical and abstract representations of their discoveries. The NCTM (2000) claimed that "geometric modeling and spatial reasoning offer ways to interpret and describe physical environments and can be an important tool in problem solving" (p. 43). The NCTM went on to state that geometric and spatial skills aid in problem solving and representing problem solving within and outside of mathematics and in classroom and real-world contexts.

High and Low Spatial Abilities

Most researchers categorize individuals as having high or low spatial ability even though ability is represented best as a normally distributed spectrum rather than a

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dichotomy (Smith, 2009). The focus on the ends of the spectrum is common in cognitive science studies as the differences between the two groups is more noticeable. A good example of this is the various studies in differences between experts and novices even though there is much territory in between the two (Dreyfus & Dreyfus, 1986). Many of the early studies showed the difference to be in the structuring of images (Cooper, 1982). Spatial images are seen by persons of higher spatial abilities as “chunks” of familiar pieces of data. Oberauer and Svetlana (2009) define chunks as “a unit that contains information of separable elements, but whose elements cannot be accessed or manipulated separately unless the chunk is unpacked” (p. 64). Theorists in cognition studies dealing with experts and novices have found that experts tend to dissect materials into chunks of familiar data.

By organizing the material into several chunks, experts can devote greater amounts of working memory to solving problems. On the other hand, novices attend to all of the individual details leaving little room in working memory for problem solving (Dufresne, Gerace, Hardiman, & Mestre, 1992). As stated, persons with high spatial ability chunk data into similar and familiar geometric shapes. Persons chunking the data were more accurate in restructuring and remembering a complex polygon than those who tried to remember the shape as is (Cooper, 1982). The limit to how many chunks can be created and utilized at one time is a current area of focus for cognitive scientists (Oberauer & Svetlana, 2009). Expanding the capabilities of an individual’s working memory by efficiently chunking spatial data shows several benefits. Working memory is in important part of processing relational data including shape, space, time, and causality

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(Zwaan, Magliano, & Graesser, 1995). Additionally, working memory is involved in deductive as well as inductive reasoning (Johnson-Laird, 1983).

Spatial Ability Correlations

Spatial ability is correlated with achievement in many academic fields. Some of the most pronounced and widely studied are within the areas of STEM and design fields. Smith (2009) conducted a comprehensive meta-analysis of spatial ability correlational studies to academic ability and achievement. The criteria set for the meta-analysis were:

- The study had to be experimental or quasi-experimental in design.
- The study must utilize a form of the Purdue Spatial Visualization Test. This could be the rotational or visualization test.
- The study had to report effect sizes (correlation).
- All studies were evaluated for design quality and threats to reliability and validity.

Only studies that received a grade of good or fair were included (Smith, 2009, pp. 18-20). Smith found that of the 21 studies that met the criteria, all studies showed a positive correlation between spatial ability and academic achievement or ability. Most studies used the test of rotations and only three studies utilized the visualization test. The mean of the studies showed a correlation (Pearson r) of .349.

Improving Spatial Ability

One of the most important aspects of spatial ability in the literature is the reoccurring conclusions that spatial ability can be improved through exercises and

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instruction. Several interventions and factors of improving spatial ability have been explored. These interventions include: entire courses devoted to spatial ability, three-dimensional and virtual environments, video games, traditional drafting courses, and the implementation of physical models for representation in a drafting course.

Drafting courses. The most pronounced application of spatial ability is found within drafting and technical graphics courses. These courses are foundational to a broad spectrum of majors and careers such as: designers, drafters, engineers, architects, and technicians. Some definitions of engineering graphics express the transfer of mental images from one person to another (Ferguson, 1992). Most drafting and graphics courses follow a similar format. Students are regularly required to create orthographic projections from a given isometric drawing with dimensions given. This may extend into sections and auxiliary views later in the course, and then creating isometric drawings from given orthographic projections. Depending on the breath of the course, axonometric drawings and descriptive geometry problems may also be included. This is generally considered the baseline from which interventions regarding spatial ability are measured. Courses taught in this manner can be considered the control group to which the intervention group is compared (Potter, 2009).

For courses to be effective in improving spatial ability, the course must focus on using perception and mental imagery in three dimensional representation. One South African study found a statistically significant increase in student pass rates for first year engineering students from 64-76% by changing the focus of the course (Potter & Van Der Merwe, 2003) and another statistically significant increase to 88 percent through the

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addition of student tutors (Potter et al., 2006). The success of the course adjustments in the prior example came from addressing the verbal components involved with learning drafting (Potter & Van Der Merwe, 2003).

Hauptman (2010) stated that many students have a difficult time understanding three-dimensional images. Those difficulties include:

- The transition from two dimensional constructs to imaging and manipulating three-dimensional objects is neither natural nor easy (Guttierez, 1996).
- Students are unable to make accurate drawings of spatial objects (Hauptman, 2010, p. 123).
- Students lack the vocabulary to effectively communicate in spatial geometry (Hauptman, 2010, p. 123).
- Students have insufficient interactions with three-dimensional objects (Hauptman, 2010, p. 131).
- Too little attention is paid to verbal processes involved in learning three-dimensional geometry (Hauptman, 2010, p. 131).

Three-dimensional virtual environments. Studies have shown that courses heavy in two-dimensional object replication and analysis do not significantly enhance a students spatial abilities (Garrity, 1998; Gurney, 2003). Virtual environments are claimed to extend beyond the typical representations of lines in engineering graphics by creating a more realistic environment. This claim for effectiveness reaches back to the theoretical groundwork of embodied cognition. The virtual environments that were studied having impacts on spatial abilities fit into two categories for educators: tools that are commonly

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used in instruction such as three-dimensional CAD software, and hobbies and play outside of educational settings such as games and media.

CAD modeling. With the usage of three dimensional CAD applications, complex models and ideas can be created on the computer. These tools allow designers to experiment with forms without the use of a physical model. A key advantage is the ability of the software to allow the comparison of concepts without having to create additional models from the beginning (Haik, 2003; Kvan & Kolarevic, 2002).

The use of CAD has changed the design process, as many designers now think through the computer. CAD has been claimed to narrow the gap between representation and building (Ryder, Ion, Green, Harrison, & Wood, 2002). Also known as virtual models, the major drawback of CAD models is that the depth analysis is limited to the representation on the screen and may not include true perspective representation which may not be accurately be reflected in the model (Eggert, 2005; Ryder et al., 2002).

Model Usage in Engineering Design

Model construction is considered a fundamental tool of design and has been for many centuries (Gibson, Kvan, & Ming, 2002). Traditional techniques in model construction involve a variety of materials including wood, paper, foam, and clay. Models can serve as the bridge between ideas and the physical world. Complex ideas are often more easily communicated in models (Frampton & Kolbowski, 1981). The usage of these models is divided into two main purposes: investigation and demonstration (Alley, 1961).

Investigative models. Investigative models are primarily for feedback of form to

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the designer and architect and are an integral part of the creative process (Starkey, 2006) and in the engineering design process (Eggert, 2005). Models are usually called prototypes in the engineering design process. These models are used to define the basic design, spatial relations, proportion, and flow within the project. Architects, designers, and engineers have been using this process since the Renaissance and it has been suggested that the word "model" is derived from an Italian source that refers to something incorporating a design idea (Janke, 1968; Starkey, 2006). The construction of the investigative model is often minimal in detail with the focus on the visual concept of form and relative size. Models themselves can be a medium to think through and draw ideas from spaces. Spatial thinking as constructed in the modeling stages will result in a different form than the plan derived from floor plans (Kelley, 2001).

By disaggregating a project into components, the very process of model construction can be viewed as a means to analyze design concepts on complex problem, which may as a whole seem insurmountable (Janke, 1968).

Demonstrative models. Also known as presentation models, demonstrative models serve the purpose of displaying finished project ideas. These models are usually of higher quality and are used to display the final product. Presentation models convey information as to the appearance, use, and structure in ways graphic models cannot (Frampton & Kolbowski, 1981). The models allow architects, designers, and engineers to present ideas and complex building schemes that are difficult to interpret in two-dimensional drawings. This form of communication is highly valued when the presentation involves those who are not trained in the profession of design. In stressing

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the value of models in communication, the veteran studio head of IDEO, a leading design firm, Dennis Boyle stated "never go to a meeting without a prototype" (Kelley, 2001). This study will approach the creation of models and prototypes through rapid prototyping technology.

The usage of a model may reduce the distance in transfer for some students who are less familiar with graphical representation or of lower spatial ability. Reducing the transfer distance is a key element in learning success (Royer, Carlo, Dufresne, & Mestre, 1996). Piaget and Inhelder (1948) advocated that a combination of hands-on experiences in addition to visual stimulus were important in the development of spatial ability of children.

Model Usage to Improve Spatial Visualization

The usage of physical models as teaching aids is nothing new to drafting, graphics, and design courses. This practice goes back to graphics courses during the industrial arts era. As computers and three dimensional imaging technology developed, instructional models began to rely more on virtual than physical models. The exclusive use of three dimensional virtual models has shown to be beneficial to students who already posses high spatial ability, and detrimental to students with lower spatial ability due to a cognitive overload (Huk, 2006). One explanation is that the usage of physical models is more conducive to students who are better haptic learners (Silverman, 1989). Schribner and Anderson (2005) discovered that identified haptic learners scored significantly lower than visual learners on spatial visualization tests.

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Improving Spatial Ability through Exercises

There are many techniques for developing spatial ability in students. Isometric and orthographic sketching, pattern development, two and three coordinate drawings, rotations of objects, and cross sections of solids are examples of common exercises. Gerson, Sorby, Wysocki, and Baartmans (2001) at the Michigan Technological University documented a 6-year longitudinal study of the effects of these exercises on freshman engineering students. Students who undertook these exercises scored higher than a control group that did not undergo these exercises. The testing included five different tests of spatial ability, and qualitative measures of student confidence. Improvements were highly significant on all five tests. An important aspect in evaluating the validity of this study is that the research was conducted of students being self selected into the treatment and control groups. From a list of students who performed below a satisfactory level, all students wanting to be admitted to the program working on spatial ability were considered the treatment group and students who decided not to enroll in the program were considered the control group.

Individual Factors Affecting Spatial Ability

Outside of educational factors, several factors have been identified as correlated to spatial ability. These factors include gender, exposure to games and hobbies, and extracurricular involvement.

Gender. Gender differences in spatial ability have been clearly outlined in a variety of studies of spatial ability. A major meta-analysis of 286 studies addressing sex differences in spatial ability concluded that males are favored in tests of spatial ability

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with a mean effect size of *d* = 0.37 and considered to be a medium effect size (Voyer et al., 1995). A meta-analysis of studies from 1975 to 1992 showed a stable effect size of the differences over time (Masters & Sanders, 1993).

It is unclear of whether these differences are sex differences (genetic) or gender differences (experiences and cultural constructs). There are many studies theorizing evolutionary genetics varying as widely as explanations from the gender roles of a hunter-gatherer society (Ealsa & Silverman, 1994); competition for mating and survival (Ecuyer-Dab & Robert, 2004), and hormonal factors (Williams, Barnett, & Meck, 1990). Likewise, a variety of gender roles as an explanation are given. Many of these explanations focus on the toys, activities, and hobbies of children (Newcombe & Frick, 2010).

Some researchers have begun looking at ways of minimizing gender bias within the tests of spatial ability. Brandoff (2000) looked specifically at the Purdue Spatial Visualization Test of Rotations and theorized that adding x,y, and z coordinate axes reduced the gender bias to nonsignificant levels. The experiment also showed reliability when compared to the original Purdue Spatial Visualization Test of Rotations with a 0.83 correlation on a Kuder-Richardson 20 (KR-20) test. This study will utilize the modified Purdue Spatial Visualization Test of Rotations with the added x, y, and z coordinate axes.

Hobbies. Two hobbies have been identified in the literature as being correlated to spatial ability: model construction, and virtual games. An analysis of three studies show a significantly reduced or statistically nonsignificant effect in spatial ability when females are exposed to action video games (Feng et al., 2007). Another study found that 60% of

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students surveyed stated that their spatial ability improved through virtual games (Crown, 2001). Another study looked at the spatial cognitive abilities of student not playing video games, playing violent video games, and playing non-violent video games. The research concluded that students not playing video games had no significant change in cognitive ability, whereas students playing video games (either violent or nonviolent) improved their spatial ability. Additionally, students playing violent video games improved at a greater rate than those playing nonviolent video games (Barletta, Vowelsb, Shanteaub, Crowb, & Millerb, 2009).

Tests of Spatial Ability

The construct addressed in the study was the spatial ability of engineering graphics students. Spatial ability, spatial perception, spatial intelligence, and spatial visualization are terms used to describe the ability to visualize and manipulate three-dimensional objects within the mind (NCTM, 2000, p. 42). Measuring this construct is difficult. The construct has been divided into two main constructs: spatial orientation and spatial visualization. The object is not physically altered in spatial orientation; just the position of the object is manipulated. In spatial visualization, the object is physically altered (Bodner & Guay, 1997). Several tests have been developed with the intent of measuring spatial ability. The first was Piaget's water level test (Piaget & Inhelder, 1948). The most common spatial ability test looks at how someone mentally rotates objects (Shepard, 1978). Two other methods include tests of mentally cutting objects, or creating orthogonal projections (Németh, 2007). Both of these tests are not commonly

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used and difficult to evaluate and assess. This study conducted a pretest and a posttest using the modified Purdue Spatial Visualization Test: Rotations (PSVT:R) Test, which is a test of mentally rotating objects. This test is the most widely utilized spatial visualization test and has been used for over 30 years.

Summary

Distance education is one of the fastest growing trends in education at the start of the twenty-first century. Advantages of distance education include having the ability to reach a greater number of students who may have limited access to educational opportunities and minimizing overhead and facility costs to the university. One area which is slow to accept distance education is laboratory classes in STEM fields. The removal of the physical presence of the instructor from a laboratory can make many STEM educators apprehensive to implement distance classes.

One instance where a distance education course is possible with a STEM laboratory experience is engineering graphics. An important aspect of engineering graphics courses is the development of spatial ability, which is considered to be an important skill in engineering and prior researchers have found a correlation between spatial ability and academic achievement in a variety of STEM fields. As a result of interest in testing spatial ability, psychologists and educators have developed an array of spatial ability tests. These tests provide researchers an effective instrument which can be used to assess if the removal of the instructor from the classroom has any effect on the outcome of spatial ability in an engineering graphics course.

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Researchers have looked at a variety of factors impacting spatial ability and have identified noncurricular factors impacting spatial ability including: gender, hobby and leisure activities, prior graphics experience, prior experience with virtual software and games, and prior experience with object modeling. Identifying and statistically accounting for these noncurricular factors is important to accurately determine any effect the presence of an instructor has on spatial ability within a beginning engineering graphics course. The PSVT:R has been identified as a test which is appropriate to the engineering graphics course to be evaluated, is a widely accepted test of spatial ability, and has evidence of validity and reliability as a test instrument.

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CHAPTER III

METHODOLOGY

Study Purpose and Research Questions

The purpose of the study was to compare a face-to-face engineering graphics course with a distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. Additionally, the study looked at noncurricular factors and how any potential differences in spatial ability were impacted by these factors including interactive effects. The noncurricular factors include: age, gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling. The study looked specifically at the following research questions.

1. Is there a statistical measure of change in the spatial ability of students in a synchronous distance education engineering graphics course? This will be tested against the null hypothesis that there is no change in spatial ability in a synchronous distance education engineering graphics course.

2. Is there a statistical measure of change in the spatial ability of students in a face-to-face engineering graphics course? This will be tested against the null hypothesis that there is no change in spatial ability in a face-to-face engineering graphics course.

3. Is there a statistical difference between the change in the spatial ability of students in face-to-face and synchronous distance education engineering graphics course? This will be tested against the null hypothesis that there is no difference in change in

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spatial ability in a face-to-face engineering graphics course when compared to a synchronous distance education engineering graphics course.

4. Is there a statistical difference in the change in spatial ability for various student populations in both face-to-face and synchronous distance education courses when factoring in the noncurricular factors of: gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling? This will be tested against the null hypothesis that there is no difference in change in spatial ability in a face-to-face engineering graphics course when compared to a synchronous distance education engineering graphics course after performing a partial regression of noncurricular factors.

Research Design

This study utilized a quasi-experimental design from a convenience sample. In order to provide the data necessary for the study and research questions, four sections of an introductory engineering graphics course were selected for participation in the study. This convenient sample consisted of students from the engineering graphics course, MAE 1200, which is a required course in the department of Mechanical and Aerospace Engineering at Utah State University. All four sections were taught on campus in the engineering graphics computer lab at a set meeting time by the same instructor. Each section met for 2 hours twice a week for 15 weeks of instruction each semester. The data for the study were collected during the regular meeting time in each course. Two sections were taught through video conferencing with the instructor at a remote site and two were

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taught as face-to-face courses. Students who registered in the synchronous distance education class did not know they were registering for a distance education course as the course required students to be present on campus at a specific class time. This eliminates self-selection as a threat to internal validity in this study. All four sections utilized the same teacher's aide who was present on site for all four sections. The teacher's aide graded papers, collected assignments, and answered general questions for students. The instructor had taught this specific course for 2 years, and the teacher's aide has assisted him for both years. Additionally, the instructor had taught engineering graphics for over seven years. This experience should minimize threats to validity due to maturation effects. The two sections taught through video conferencing were taught during fall semester of 2010, and the two sections taught face-to-face were taught during spring semester of 2011. The instructor was physically present for the first two class periods in the distance education sections. The course utilizes SolidEdge, which is a three-dimensional parametric (virtual) software. The course material focuses on the creation and manipulation of three-dimensional virtual objects. Approximately 30 students enrolled in each course section, providing approximately 60 students in the synchronous distance education study population and 60 students in the face-to-face study population.

Instrumentation

Two instruments were used for data collection in the study. These instruments were the modified PSVT:R and the demographics survey constructed specific for this study.

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The PSVT:R is the most widely utilized spatial visualization instrument and has been used for over thirty years (see Appendix A). The test consists of thirty analogy test items where one must identify how an object will be rotated and viewed related to the rotations of another object. Isometric representations are used to depict all objects. This test is the most widely utilized spatial visualization test and has been used for over thirty years. Additionally, the mental rotation of objects fits into the engineering graphics curriculum and course goals. In order to justify the application of the PSVT:R the reliability and validity of the test will be explored.

Content validity is the extent to which the measured variable has adequately measured the conceptual variable (Stangor, 2004). Spatial ability extends beyond just mental rotations and several tests such as the mental cutting test, water level test, and orthogonal projections each measure separate facets of spatial ability. The mental rotation of objects as found in the PSVT:R fits into the course objectives of the engineering graphics course. In the case of the PSVT:R, content validity will be addressed in the correlation to other spatial ability tests. The PSVT:R was tested for correlation to five other tests of spatial ability. The test showed the highest correlation to Shepard-Metzler test ($r = 0.61$, $p = .001$), which was considered to be the best test of spatial ability, and least correlated to the Revised Minnesota Paper Form Board (MPFB) test ($r = 0.25$, $p = 0.01$), which was considered to be the weakest of the tests of spatial ability (Bodner & Guay, 1997). These designations of the strength of spatial ability tests come from an independent study by (Guay, McDaniel, & Angelo, 1978).

Criterion validity is the extent to which the results of an assessment instrument

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correlate with another related variable (Leedy & Ormrod, 2005). A test is said to have criterion-related validity when the test is demonstrated to be effective in predicting criterion or indicators of a construct. There are two types of criterion validity: concurrent and predictive validity. Concurrent validity is the extent to which a measurement actuality captures the state of the individual at that point in time. In the case of the spatial ability test, concurrent validity is how accurately the test score shows ones spatial ability at the time of the pre- and posttests. Concurrent validity is best established by a correlation to other presumed valid measurements of spatial ability similar to establishing content validity in the case of the PSVT:R (Cohen, 2008). Predictive validity is the extent to where a measurement can accurately predict future behaviors. One common example where predictive validity is crucial is in aptitude tests. The PSVT:R has been used as predictive test for academic success in the sciences and engineering. For example, Michigan Technical University uses the PSVT:R as a predictor of success in engineering. Students who score low on the test are advised into taking a workshop/course on improving spatial ability if they wish to continue studying engineering (Schribner & Anderson, 2005). The predictive validity of the PSVT:R is supported by a recent meta-analysis of 21 studies showing the correlation between PSVT:R scores and academic achievement in STEM areas (Smith, 2009).

One method for examining the reliability of a test is by the Kuder–Richardson statistical test. The test measures the homogeneity of test questions with dichotomous answers (right or wrong). The test ranges from 0 to 1 with scores closer to 1 indicating a higher level of internal consistency reliability (Cohen, 2008).

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Another statistical measure of reliability is the split-half reliability coefficient. This is done by separating the test into to halves and treated as if there were parallel forms. Like the Kuder–Richardson test, the split-half test ranges from 0 to 1 with scores closer to 1 indicating a higher level of internal consistency reliability (Cohen, 2008). Several studies have conducted these tests on the PSVT:R and have reported their results. This is reported in Table 1. These two tests statistically suggest that the PSVT:R shows both internal consistency reliability and test-retest reliability (Bodner & Guay, 1997).

The demographics survey focused specifically on the following demographic and noncurricular factors of: gender, age, major, previous graphics and drafting courses, current and past time spent with hobbies such as legos, connex, and other construction hobbies, and video games based in virtual reality. The survey incorporates a combination of precategorized demographic questions, and 4-point Likert scale questions (see Appendix B). The survey was created and published online through surveygizmo created by Widgix, LLC.

Table 1

Comparative Studies into Reliability Tests for the Purdue Spatial Visualization Test of Rotations

Students studied	*N*	Kuder-Richardson	Split-half
Ag/health science (McMillen, 1983)	757	0.80	0.83
Ag/health science (LaRussa, 1985)	850	0.78	0.80
Ag/health science (Pribyl, 1984)	127	--	0.84
Science/Engineering (McMillen, 1983)	1,273	0.80	0.85
Science/Engineering (Carter, 1984)	1,648	--	0.82
Biology/pre-med (Pribyl, 1984)	158	--	0.78

Note. Both the Kuder-Richardson and the Split Half Test are considered to have acceptable and reliable results with values greater than 0.70 (Cortina, 1993).

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Data Acquisition

A pretest and a posttest were conducted utilizing the modified PSVT:R. The pretest was administered during the first week of the course and the posttest was administered during the last week of the course. There were 15 weeks between the pre- and posttests of spatial ability. The pre- and posttests were conducted using the same form. The study used the same form to avoid issues with reliability of using different forms, and had a balanced design between the experimental and control groups so the same effects of testing validity should impact both groups equally. Using the same or similar test instruments as a pre- and posttest can challenge the testing validity of a study (Gall, Gall, & Borg, 2003). The time interval between the pre- and post test of the study is an important factor when assessing the validity of the study. If the time interval is too short, then students can remember individual test items and improve scores through retaking the test. If the time interval is too long, then the study may suffer from issues of history and maturation validity. The study had 15 weeks between the pre- and posttests. A separation of over 1 month can avoid some testing validity issues (Stangor, 2004). There was no evidence for a groupwise threat to validity due to history, and in keeping the separation of the pre- and posttest to fifteen weeks for both groups, there should be a minimal and balanced effect due to maturation between the two groups. Students were allotted forty minutes to complete the thirty question test. A similar study of college level engineering students found twenty minutes to be adequate time for a twenty question test of the PSVT:R (Smith, 2009). In addition to the spatial ability test, the posttest included the survey questions of demographic and noncurricular factors.

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Table 2 provides information about the factors to be used in the analysis of the study. The table provides information about the variable type, the range of scores possible, and values to be utilities in the analysis of the data. The table also provides information concerning the source where the data was collected in the study.

Protection of Students

This study was approved by the Institutional Review Board (IRB) at Utah State University and was given protocol number 2709. The confidentiality of the students was

Table 2

Data Collected and Analyzed in the Study

Factor	Source	Variable type	Score range
Spatial ability	PSVT:R	Continuous	0-30
Characterization of spatial ability	Pretest of PSVT:R	Ordinal	Low, medium, high (1-3)
Gender	Survey	Nominal	Male or female
Age	Survey	Ordinal	18, 19, 20, 21-22, 23-24, 25 and older
Previous drafting experience	Survey	Ordinal	0-6 courses
Experience with hobbies Subcategories: building/ assembly, model construction, robotics, Radio-controlled toys, video games, programming	Survey	Ordinal	Very little to none, some, moderate, considerable (1-4)
Experience with extracurricular activities Subcategories: FIRST Robotics, JETS, Future City, TechXplore, VEX Robotics, Think Quest, Lego Engineering, INSPIRE!, Botball, Odyssey of the Mind	Survey	Ordinal	Very little to none, some, moderate, considerable (1-4)

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and will be maintained by not releasing student responses on an individual basis, and not releasing student names associated with any data. The student names were coded to a corresponding number by the researchers, and that number was used in all data analysis, and student names and responses were held confidential. This information was explained to the students when the study was presented, and was provided to all students on the letter of information (see Appendix C). Prior to statistical analysis, the pretests, posttests, and surveys were coded to a student number and checked for completeness. Pre- and posttests had a separate sheet for student names stapled to the front of the answer sheet. Students were matched by name with the survey, pretest, and posttest. At that time, students were assigned a research number. The name of the student in the database was changed to the corresponding number and the number was assigned to the answer sheet of the pre- and posttests. The cover sheets of the pre- and posttests were removed leaving only the research number on the answer sheet. The cover sheets were then destroyed. After coding, it was no longer possible to match student names to any grading or statistical analysis.

Analysis of the Study

All statistical analysis for the study was conducted through Predictive Analysis SoftWare (PAWS, formerly known as SPSS) version 18.0. Missing data in individual subjects resulted in the removal of data from the study. Descriptive statistics were taken of the dependant variables of the pre- and posttests of spatial ability. These descriptive statistics included measures of central tendency, distribution, and outliers. Histograms

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and bar charts were used in the analysis of the descriptive statistics to test for a normal distribution of the data. The analysis of these statistics was looked at for suggestions for meeting the statistical assumption of being normally distributed and homogenecy of variance. Homogeneity of variance was check by a Levene's test for homogeneity of variance. Levene's test is an inferential statistic used to assess the equality of variance in different samples.

Statistical Power Estimates

A priori statistical power estimates were conducted for the study using G*Power 3.1.2 software created by the Psychology Department at the University at Düsseldorf. G*Power is designed for calculating statistical power and is tailored to the specific needs of research in the social sciences (Erdfelder, Faul, & Buchner, 1996). The first two research questions looked at paired sample *t* tests. For a two-tailed hypothesis test, given a power (1- β) of .80, and an acceptable α level of 0.05, 34 research subjects would be needed to identify a medium effect size ($d = 0.5$). There were an estimated 60 research subjects per group tested in the first and second research questions. The third research question looked at an independent sample *t* test. For a two-tailed hypothesis test, given a power (1- β) of .80, and an acceptable α level of 0.05, 64 research subjects per group would be needed to identify a medium effect size ($d = 0.5$). Research question four was analyzed through an analysis of covariance. Statistical power will be estimated through the maximum possible number of covariates (9) in the model. Given a power (1- β) of .80, and an acceptable α level of 0.05, 128 research subjects would be needed to identify

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a medium effect size (f = 0.25).

Analysis of Research Questions One, Two, and Three

Research questions one, two, and three were a comparison of sample means. To answer research questions one and two, paired-sample *t* tests were utilized because the samples were not independent (student A in the pretest was the same as student A in the posttest). For research question three, an independent sample *t* test was conducted because of the simplicity of the research design (one repeated measure of pre- and post-tests, and one factor level). In all analysis, a difference of means was considered significant at a level of p = .05. In order to do this, an additional factor was created of the difference between post- and pretest. This factor was tested against the treatment factor of instructional delivery. An additional subgroup analysis was conducted in all three research questions after grouping the students into low, medium, and high spatial ability based on their pretest scores of spatial ability. This was done to look for effects of the various student abilities. Students were placed into these subgroups with students being in the lower third of spatial ability scores considered lower spatial ability, within the middle third being medium spatial ability, and in the highest third as being higher spatial ability.

Analysis of Research Question Four

Research question four was answered using an analysis of linear regression. This analysis was possible because all factors are either continuous or ordinal in nature with

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the exception of gender, which is a dichotomous factor (Cohen, 2008, p. 584). The linear regression consisted of several models. The first was creating a linear model predicting change in student scores. This model answers what effect each factor has on the change in spatial ability within a course. This was conducted with factors being placed and removed from the model using a stepwise method. The main effects were reported. A second model was run looking for interactive effects of factors with the curriculum delivery methods. The final model employed the usage of partial correlation to identify the unique effects of the presence of an instructor on spatial ability. The study reported significant factors, and interaction effects along with mean changes, standard deviations, and effect sizes.

Summary

The purpose of the study was to compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. The study looked specifically at the following research questions.

1. Is there a statistical measure of change in the spatial ability of students in a synchronous distance education engineering graphics course?
2. Is there a statistical measure of change in the spatial ability of students in a face-to-face engineering graphics course?
3. Is there a statistical difference between the change in the spatial ability of students in face-to-face and synchronous distance education engineering graphics course?

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4. Is there a statistical difference in the change in spatial ability for various student populations in both face-to-face and synchronous distance education courses when factoring in the noncurricular factors of: gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling?

Students from four sections of a mechanical and aerospace engineering graphics course were studied. Two of the sections were taught through a synchronous distance education (video conferencing) format, and two sections were taught face-to-face. Students took a pre- and a posttest of spatial ability using the modified PSVT:R, along with survey consisting of demographics, prior graphics experience, and involvement in hobbies and extracurricular activities. The data was coded then analyzed for meeting statistical assumptions of normal distribution and heterogeneity. The study utilized independent sample *t* tests to analyze the first three research questions, and partial correlation in answering the fourth research question. These procedures produced the results that were reported and analyzed in the following chapters.

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CHAPTER IV

ANALYSIS OF DATA

Introduction

The purpose of the study was to measure and compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. Each individual factor measured in the study will be separately analyzed. The analysis of the data will be reported in three steps. These steps are as follows.

1. The demographic statistics describing the student population.
2. The descriptive statistics of the data. This will include the pre- and posttests of spatial ability and the survey questions of demographic and noncurricular data. This will include tests for meeting statistical assumptions such as heterogeneity of variance, and a normal distribution for independent variables.
3. A simple correlation between predictive variables and the independent variable will also be reported.

Following the analysis of the data, the specific research questions will be addressed. The study looked specifically at four research questions. The first question was if there was there a statistical measure of change in the spatial ability of students in a synchronous distance education engineering graphics course? The second question was similar and looked at if there was there a statistical measure of change in the spatial ability of students in a face-to-face engineering graphics course? The third research

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question compared the two delivery methods and asked if there was a statistical difference between the change in the spatial ability of students in face-to-face and synchronous distance education engineering graphics course? The fourth research questioned asked if there was a statistical difference in the change in spatial ability for various student populations in both face-to-face and synchronous distance education courses when factoring in the noncurricular factors of: gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling?

Demographic Data for the Study

The study consisted of 122 students completing both pre- and posttests of the PSVT:R. Of the 122 participants, 65 students were from the two face-to-face sections of the course, and 57 students were in the distance education sections. Eleven students completed the pretest of the PSVT:R but not the posttest. Four students took the posttest of the PSVT:R which did not take the pretest. The students who did not take complete both the pre- and posttests could have done so for various reasons. As the pretest was conducted during the second class period, students who dropped the course would have taken the pretest and not the posttest. Likewise, students who added the class late would have taken the posttest and not the pretest, and it would be expected that several students would be absent for various reasons. No students known to the instructor or the researchers chose to opt out of the study.

The majority of the students were between 18 and 24 years old. Student ages at

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Utah State University are typically older than most colleges and universities in the United States. It is common for the male students of the predominant religion of the area to serve a two year mission. This is most often done between the ages of 19 and 21. This is an explanation for few students being 20 years old in the study and a large number of students older than 21 in a (Peterson, 2009). The ages of student participants in the study are given in Table 3.

The majority of the students in the study were male. Of the 122 students, only seven females were represented in the study accounting for 5.7% of the research subjects. Nationally, the enrollment of females in mechanical and aerospace engineering is low with only 11.4% of bachelor's degrees being awarded to females in mechanical engineering (Gibbons, 2009).

The study consisted of students taking a Mechanical and Aerospace Engineering Graphics course. Two other engineering graphic courses are taught at Utah State University and are recommended for students pursuing other engineering and technology disciplines. Only one student in the study reported not studying mechanical and

Table 3

Student Age in the Study

Age range	*N*	%
18	29	23.4
19	22	18.2
20	3	2.6
21-22	43	35.1
23-24	16	13.0
25 and older	9	7.8

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aerospace engineering. That student was studying mechanical engineering and has since changed major to exercise science.

Independent Variables

Purdue Spatial Visualization Test of Rotations

The PSVT:R is the independent variable of the study. Participants in the study took this test twice, in the first week of the course as a pretest and in the last week of the course as a posttest. The researchers categorized the students' beginning spatial ability into low, medium, or high spatial ability from scores on the pretest. Students were placed into these coding levels with students being in the lower third of scores considered lower spatial ability, the middle third being medium spatial ability, and in the highest third as being higher spatial ability. The change in spatial ability was calculated for each student. This was done by subtracting the pretest score from the posttest score of the PSVT:R. The change in spatial ability was the independent variable for the research questions in the study.

Pretest of PSVT:R

The pretest of the PSVT:R was conducted in the first week of the course in all four sections of the course studied. Descriptive statistics of the data are given in Table 4.

Statistics of the pretest of the PSVT:R show the data to be left or negatively skewed. This can be seen in the histogram (see Figure 1), and in the descriptive statistics with the median (27.00) being 0.93 points greater than the mean (26.07). This skewness

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Table 4

Descriptive Statistics for the Pretest, Posttest, and Change in Score of the PSVT:R

	Pretest of the PSVT:R		Posttest of the PSVT:R		Change in score of the PSVT:R	
Descriptive statistic	Statistic	Std. Error	Statistic	Std. Error	Statistic	Std. Error
N	133		126		122	
Mean	26.07	.304	26.94	.239	.88	.226
Median	27.00		28.00		.00	
SD	3.359		2.642		2.495	
Minimum	16		17		-4	
Maximum	30		30		12	
Skewness	-1.283	.219	-1.339	.219	1.103	.219

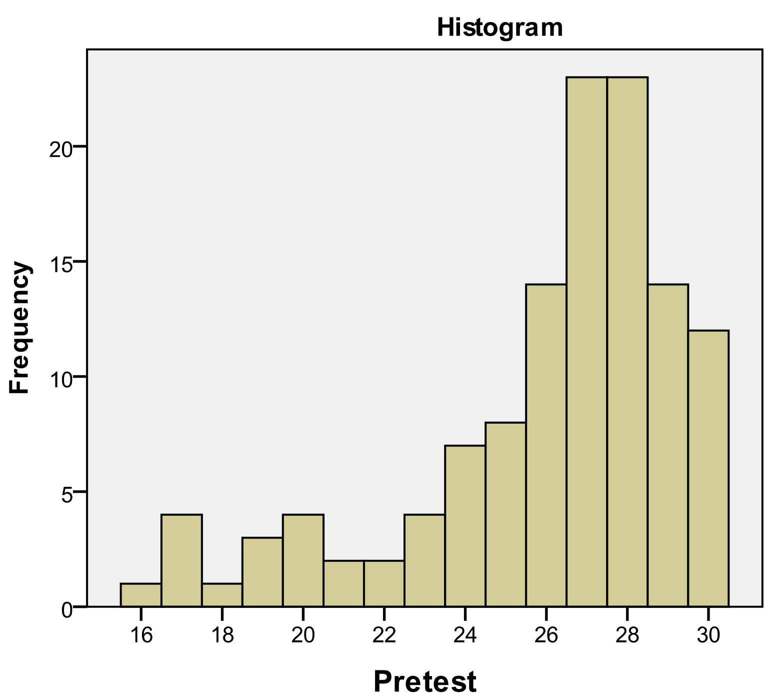

Figure 1. Histogram of the pretest of the PSVT:R.

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can be explained by having many students score near the upper limit of the PSVT:R, and with the test having a maximum of 30 questions. Skewness in the pretest of the PSVT:R is not an issue in the study as the variable is not used as an independent variable in answering the research questions in the study. This shows the possibility of a ceiling effect, which will be discussed in Chapter V.

Posttest of PSVT:R

The posttest of the PSVT:R was conducted in the last week of the course in all four sections of the course studied. Descriptive statistics of the data are given in table 5 above. Statistics of the posttest of the PSVT:R show the data to be left skewed. This can be seen in the histogram (see Figure 2), and in the descriptive statistics with the median (28.00) being 1.06 points greater than the mean (26.94). As with the pretest of the

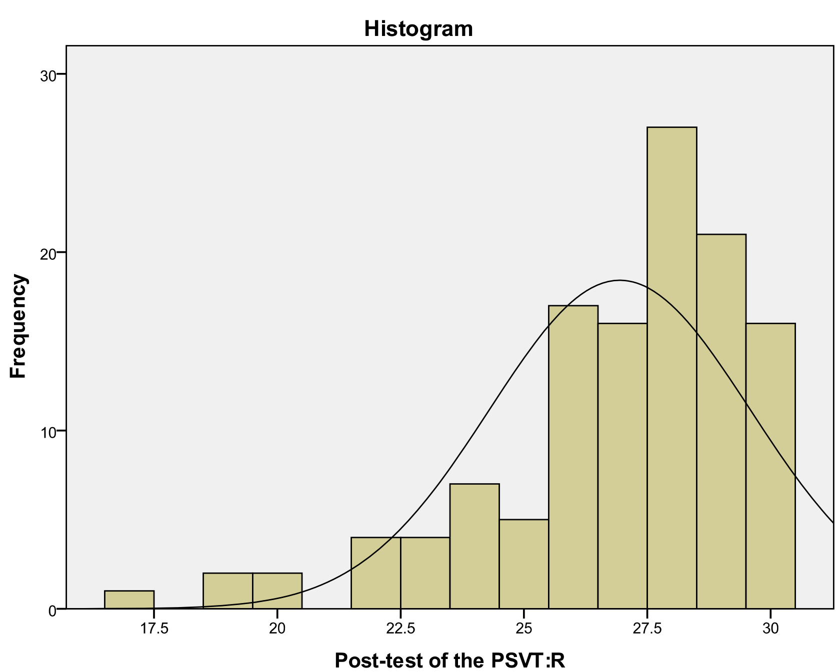

Figure 2. Histogram of the posttest of the PSVT:R.

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PSVT:R, this skewness can be explained by having many students score near the upper limit of the PSVT:R, and with the test having a maximum of 30 questions. Skewness in the posttest of the PSVT:R is not an issue in the study as the variable is not used as an independent variable in answering the research questions in the study. This shows the possibility of a ceiling effect, which will be discussed in Chapter V.

Change in Spatial Ability

The change in spatial ability was calculated by subtracting the pretest score from the posttest score of the PSVT:R. A student who scored better on the pretest than on the posttest was represented by a negative value on the change in spatial ability. The mean change in spatial ability was an improvement of answering 0.88 questions more correctly on the posttest over the pretest. Descriptive statistics for the change in spatial ability were given in Table 4. Most students scored relatively high on the pretest (mean = 26.06, median = 27), giving little room for improvement for many students. The change in spatial ability will be the independent variable for most analyses in the study making normalcy of the data essential. The histogram of the change in spatial ability show normally distributed data with two possible outliers and are shown in Figure 3. The normal Q-Q plot of the data against the expected values shows a deviance from those expected values for the same two variables identified as outliers in the histogram. Both outliers were male students with the two lowest scores on the pretest of the PSVT:R (16 and 17 out of 30 questions). The student who improved by 12 points was identified by the box-plot as an outlier and was then removed from the study. This student was in the face-to-face section of the engineering graphics course. The student who improved by 9

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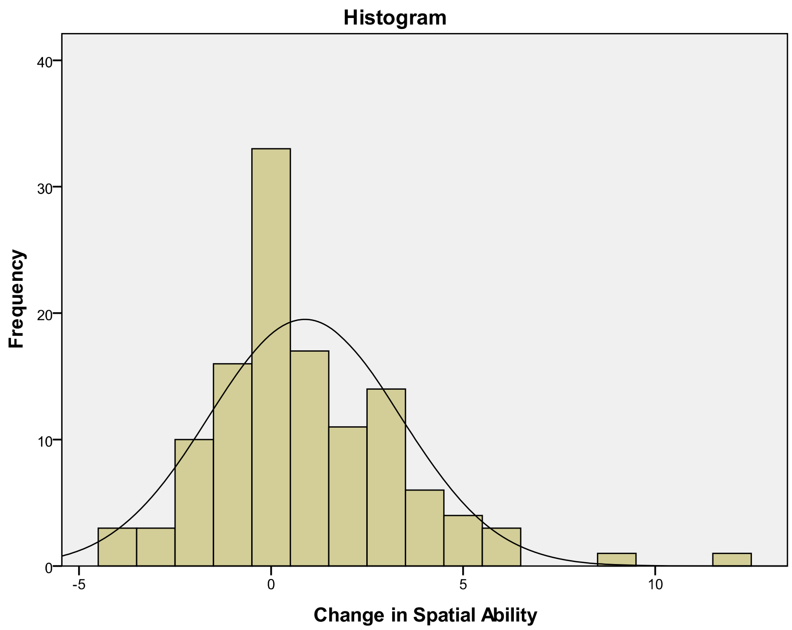

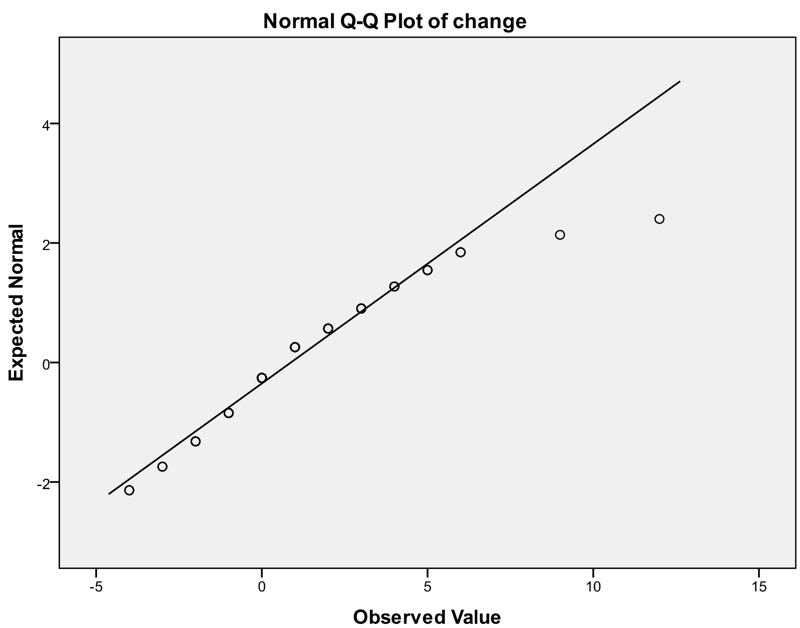

Figure 3. Histogram and normal Q-Q plot of the change in scores from the pretest to the posttest of the PSVT:R. Both graphs show two possible outliers in the data.

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points was identified by the box-plot as a potential outlier. This student was in the distance education section of the engineering graphics course. Additional data associated with this student was outside of the normal score range on several survey items. This student reported having nine previous drafting and graphics courses. No other student in the study reported having more than three drafting and graphics courses. The reliability of this data was suspect, and the student's data was removed from the study. After the removal of these outliers, the data appears more normally distributed. This is shown in the histogram and Q-Q plot of the data in Figure 4.

Student's Beginning Spatial Ability

The factor of student's beginning spatial ability is a predictive variable in this study. This factor was created by rank ordering the students by pretest scores, then dividing the students into group sizes as equally as possible. This division was created to see if the instructional strategies had an impact on students by subgroups of beginning spatial ability. Table 5 shows how the groups were subdivided in the study. The difference in change in spatial ability of students between students group according to

Table 5

Subdivision of Students by Beginning Spatial Ability and Descriptive Statistics for Change in Spatial Ability Within Groups

Group of spatial ability	*N*	Pretest score range	Mean change in spatial ability	*SD*	SEM
Low	34	16-25	2.38*	2.336	.401
Middle	37	26-27	.86*	1.751	.288
High	49	28-30	-.55*	1.415	.202

* $p = .001$.

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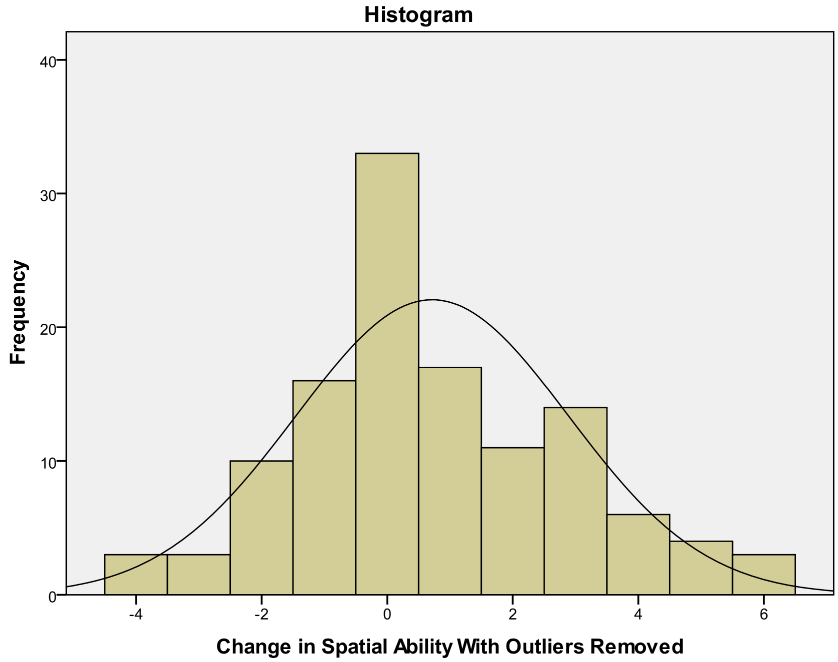

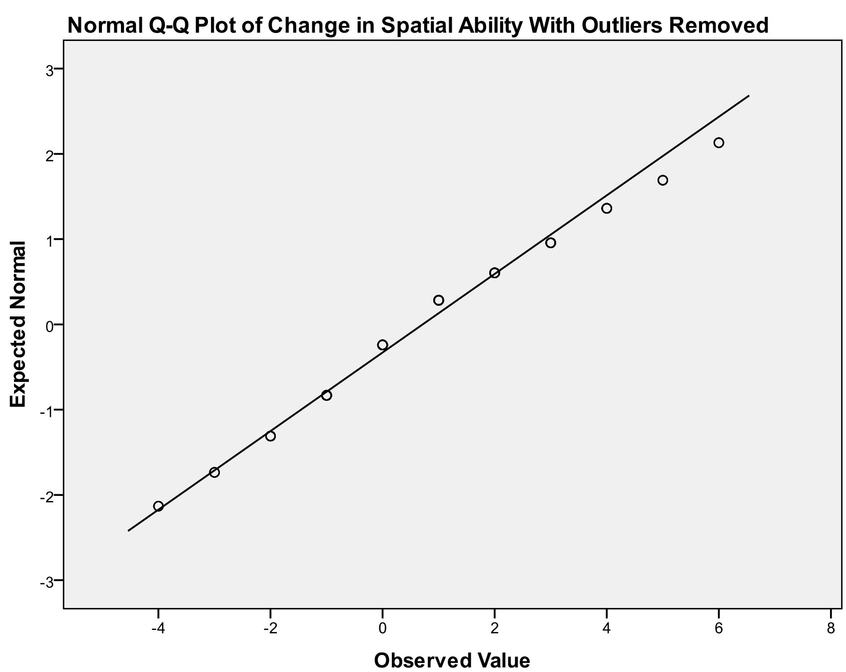

Figure 4. Histogram and normal Q-Q plot of the change in scores from the pretest to the posttest of the PSVT:R with no outliers. The histogram shows normally distributed data with no outliers and the normal Q-Q plot shows normalcy as the observed values are near the count of the expected values for normally distributed data.

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beginning spatial ability is significant (p = .001) in an analysis of variance (ANOVA) test between all three groups using a least significant difference (LSD) post-hoc test.

Correlations of the Independent Variable to Student Demographics

Two measurements of student demographics were tested for a correlation to the independent variable of change in spatial ability. There was no significant correlation using a Pearson correlation between age and change in spatial ability (p = .475) and between age and the pretest score of spatial ability (p = .212). There was a significant difference in an independent samples t test (p = .002) in the mean scores of female and male students on the pretest, even with very few female participants. Although there was a statistically significant difference between male and female students on the pretest of the PSVT:R, there are too few female participants in the study to draw conclusions. The difference is reported in Table 6.

The majority of the students had at least one prior graphics or drafting course. The percentages of students and their prior experience with graphics courses are shown in Table 7.

With improving spatial ability being an objective of drafting and graphics courses,

Table 6

Difference in Pretest of Spatial Ability by Gender

Gender	*N*	Mean of pretest score	*SD*	SEM
Female	7	22.29*	3.817	1.443
Male	115	26.30*	3.206	.299

* p = .002.

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Table 7

Count and Percentages of Students with Prior Graphics and Drafting Courses

Graphics/drafting courses	0 prior graphics/ drafting courses		1 prior graphics/ drafting courses		2 prior graphics/ drafting courses		3 or more prior drafting courses	
	n	%	*n*	%	*n*	%	*n*	%
High School	103	84.5	8	6.9	8	6.9	2	1.7
College	53	43.5	63	52.2	3	2.9	2	1.7
Other (trade school)	118	98.1	2	1.9	0	6.9	0	5.6
Total	43	35.2	64	52.1	8	6.9	7	5.6

it was expected that having prior drafting and graphics experience would correlate to a higher beginning spatial ability. A significant correlation was not found between the number of drafting classes and beginning spatial ability (r = .167, p = .166); however, a significant difference in beginning spatial ability was found in an independent samples *t* test when students had at least one graphics or drafting course. This is reported in Table 8.

Hobbies

Hobbies have been identified in the literature as being correlated with spatial ability. The study looked at several factors which may have correlated to spatial ability. Students were asked how much prior experience they have with a variety of hobbies and had the ability to answer: very little to none, some—I play (or have played) around with it a little, but average less than a few hours a month, moderate—I play (or have played) with it for several hours a month on average, or considerable—I play (or have played)

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Table 8

Difference in Pretest of Spatial Ability by Having Students Who Have Had a Previous Graphics or Drafting Course

Prior drafting or graphics courses	*N*	Mean of pretest score	*SD*	SEM
One or more prior drafting or graphics course	46	26.30*	2.980	.439
No prior courses	58	24.72*	3.835	.767

* $p = .038$.

with it for several hours a week on average. Student responses and any correlations to spatial ability are reported in the following sections.

Experience with Modeling

Students were asked how much prior experience they have with model construction (rockets, airplanes, cars, trains, etc.). The majority of students had either some or moderate experience with model construction. The percentages of students and their model experience are reported in Table 9.

No significant differences in an ANOVA test were found in the difference in means of beginning spatial ability by model construction experience (p = .822), or the difference in means of change in spatial ability by model construction experience (p = .216).

Programming

Students were asked how much prior experience they have with programming.

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Table 9

Count and Percentages of Students with Prior Model Construction Experience

Model construction experience	*n*	%
Very little to none	22	19.2
Some experience	50	43.6
Moderate experience	31	26.9
Considerable experience	12	10.3

The majority of students had very little to none or some experience with programming. No students reported having considerable experience with programming. The percentage of students and their programming experience is reported in Table 10.

No significant differences were found in an ANOVA test for the difference in means of beginning spatial ability by programming experience (p = .277), or in the difference in means of a change in spatial ability and programming experience (p = .467).

Robotics

Students were asked how much prior experience they have with robotics as a hobby. The majority of students had very little to none or some experience with robotics. Only one student reported having considerable experience with robotics. The percentage of students and their robotics experience is reported in Table 11.

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Table 10

Percentages of Students with Prior Programming Experience

Programming experience	*n*	%
Very little to none	65	58.4
Some experience	35	31.2
Moderate experience	12	10.4
Considerable experience	0	0

Table 11

Percentages of Students with Prior Robotics Experience

Robotics experience	*n*	%
Very little to none	53	47.4
Some experience	45	41.0
Moderate experience	12	10.7
Considerable experience	1	.8

With only one student reporting considerable experience with robotics, an ANOVA test is not possible for that level. A significant difference was found in the difference in means of beginning spatial ability by robotics experience (p = .026), but not in the difference in means of change in spatial ability by robotics experience (p = .658). This is reported in Table 12.

The difference in means of beginning spatial ability by robotics experience was in the direction different from what was expected by the researchers. The literature yields several articles linking higher spatial ability with success in robotics (Lathan & Tracey, 2002; Wong, 2009), and no articles were found linking robotics experience with a

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Table 12

Mean Differences of Robotics Experience and Beginning Spatial Ability

Robotics experience	Mean beginning spatial ability	*SD*	SEM
Very little to none	26.62*	2.82	.464
Some experience	25.22*	3.62	.644
Moderate experience	23.33*	4.66	1.54

* $p = .002$.

decrease in spatial ability. Post-hoc tests (least significant difference) show that the difference is only found between students with very little to none and those with moderate robotics experience. With very few students having either moderate or considerable experience in robotics (11 students), it may be that this significant difference is more representative of a type I error (false positive) than evidence that robotics decreases spatial ability.

Radio Controlled Toys

Students were asked how much prior experience they have with radio controlled toys. The majority of students had some or moderate experience with radio controlled toys. The percentage of students and their experience with radio controlled toys is reported in Table 13.

No significant differences were found in the difference in means of beginning spatial ability by experience with radio controlled toys on an ANOVA test ($p = .218$), or in the difference in means of a change in spatial ability and experience with radio controlled toys ($p = .534$).

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Table 13

Count and Percentages of Students with Prior Experience with Radio-Controlled Toys

Experience with radio controlled toys	*n*	%
Very little to none	21	18.0
Some experience	51	44.2
Moderate experience	42	36.4
Considerable experience	7	6.5

Video Games

Students were asked how much prior experience they have with playing both first person shooter (you see what the character sees) and flight simulator, race car, and driving video games. The majority of students had at least moderate experience with at least one of the types of video games. The percentage of students and their video game experience is reported in Table 14.

No significant differences were found in the difference in means of beginning spatial ability by video game experience for either first person shooter type games (p = .992), or with flight simulator, race car, or driving video games (p = .691) on an ANOVA test. Additionally, no significant differences were found in the difference in means of change in spatial ability by video game experience for either first person shooter type games (p = .687), or with flight simulator, race car, or driving video games (p = .794).

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Table 14

Count and Percentages of Students with Video Game Experience

Video game type	*n*	%
First person shooter		
Very little to none	13	11.5
Some experience	28	24.4
Moderate experience	25	21.8
Considerable experience	49	42.3
Flight simulator, race car and driving		
Very little to none	10	9.0
Some experience	29	25.6
Moderate experience	41	35.9
Considerable experience	34	29.5

Extracurricular Involvement

The study looked at several extracurricular factors that may have correlated to spatial ability. Students were asked how much prior experience they have with a variety of engineering related extracurricular programs and had the ability to answer: very little to none, some—I play (or have played) around with it a little, but average less than a few hours a month, moderate—I play (or have played) with it for several hours a month on average, or considerable—I play (or have played) with it for several hours a week on average.

Most students were not involved with most extracurricular programs. Percentages of students involved in extracurricular programs are reported in Table 15.

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Table 15

Percentages of Students Involved in Extracurricular Programs

	Very little to none		Some experience		Moderate experience		Considerable experience	
Program	*n*	%	*n*	%	*n*	%	*n*	%
FIRST robotics	110	93.5	2	1.6	2	1.6	4	3.2
JETS	103	90.9	9	7.8	2	1.6	0	0
Future city	111	97.3	2	1.6	2	1.6	0	0
TechXplore	114	98.7	0	0	1	.8	0	0
VEX robotics	107	94.8	2	1.6	3	2.5	2	1.6
Think quest	111	97.3	0	0	3	2.5	0	0
Lego engineering	75	65.4	15	12.8	21	17.9	4	3.2
INSPIRE!	110	96.1	2	1.6	3	2.5	0	0
Botball	114	98.7	0	0	1	.8	0	0
Odyssey of the mind	114	98.7	1	.8	0	0	0	0
Highest level of extracurricular involvement	68	59.0	19	16.7	22	19.2	10	8.8

All factors, with the exception of Lego Engineering and the highest level of extracurricular involvement, had too few students who had participated to conduct statistical tests. No significant differences were found in the difference in means of beginning spatial ability by student involvement in Lego Engineering ($p = .224$), or in the difference in means of a change in spatial ability and student involvement in Lego Engineering ($p = .729$) on ANOVA tests. Likewise, no significant differences were found in the difference in means of beginning spatial ability by student involvement in engineering related extracurricular activities ($p = .592$), or in the difference in means of a change in spatial ability and student involvement in engineering related extracurricular activities ($p = .317$).

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Answering Research Questions One, Two, and Three

The comparison of distance education to face-to-face instructional methods was the key comparison of the study. Descriptive statistics comparing the two methods are provided in Table 16. The difference in change in spatial ability was marginally nonsignificant at $p = .078$ on an independent sample t test when comparing the two methods against each other.

The first research question was: is there a statistical measure of change in the spatial ability of students in a synchronous distance education engineering graphics course? There was little change in spatial ability (0.33 more questions answered correctly) found in the synchronous distance education class. When tested against the null hypothesis that there is no significant change in spatial ability for engineering graphics students in a synchronous distance education course, the results lead one to fail to reject the null hypothesis. This test showed a small effect size ($d = .18$), and given a power of 0.80 or greater, the smallest measurable effect size for this study was a medium effect size ($d = 0.35$). The results of the paired sample t test are given in Table 17.

Table 16

Mean Differences of Instructional Method and Change in Spatial Ability

Instructional method	*N*	Mean change in spatial ability	*SD*	SEM
Synchronous distance education	63	0.33	1.82	.233
Face-to-face	56	1.14	2.40	.320

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Table 17

Paired Sample t *Test for Change in Spatial Ability in Synchronous Distance Education Engineering Graphics Course*

Instructional method	*N*	Mean change in spatial ability	*SD*	SEM	*t*	*p*
Synchronous distance education	63	0.33	1.88	.236	1.41	.16

The second research question was: is there a statistical measure of change in the spatial ability of students in a face-to-face engineering graphics course? There was a change in spatial ability (1.14 more questions answered correctly) found in the face-to-face class. When tested against the null hypothesis that there is no significant change in spatial ability for engineering graphics students in a face-to-face course, the results lead one to reject the null hypothesis. This test showed a medium to large effect size (d = .48), and given a power of 0.80 or greater, the smallest measurable effect size for this study was a medium effect size (d = 0.38). The results of the paired sample *t* test are given in Table 18.

The third research question was: is there a statistical difference between the change in the spatial ability of students in face-to-face and synchronous distance education engineering graphics course? There was a statistically nonsignificant (p = 0.078) difference found when comparing the means of the distance education course to the face-to-face course with a mean difference of 0.70. Although this statistic was nonsignificant, the difference in means shows a medium effect size (d = .32). A post-hoc power analysis of the study shows the calculated power to be 0.95. With the effect size being as great as it was, and the *p*-value being marginally nonsignificant, this suggests

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Table 18

Paired Sample t *Test for Change in Spatial Ability in a Face-to-face Engineering Graphics Course*

Instructional method	*N*	Mean change in spatial ability	*SD*	SEM	*t*	*p*
Face-to-face	56	1.14	2.40	.32	3.58	.001

further exploration will be needed to determine if there is no significant difference between the synchronous distance education course and the face-to-face course.

Factoring in the initial spatial ability of the students into the comparison between the change in spatial ability for synchronous distance education and a face-to-face course provides an additional level of analysis for the comparison. The mean change in spatial ability when comparing the synchronous distance education sections to the face-to-face sections shows very little difference in students of medium and high beginning spatial ability, but a significant difference in the change in spatial ability for students with low beginning spatial ability when comparing the synchronous distance education sections to the face-to-face sections. The mean change in spatial ability for the two instructional methods by beginning spatial ability is given in Table 19 along with the test statistics of the general linear model in Table 20.

Answering Research Question Four

The fourth research question was: is there a statistical difference in the change in spatial ability for various student populations in both face-to-face and synchronous

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Table 19

Mean Differences in Change in Spatial Ability by Beginning Spatial Ability

Beginning spatial ability	Instructional method	*N*	Mean	*SD*	SEM
Low	Synchronous distance education	18	1.39	2.25	0.41
	Face-to-face	16	3.50	1.93	0.44
Medium	Synchronous distance education	17	0.88	1.87	0.42
	Face-to-face	20	0.85	1.69	0.39
High	Synchronous distance education	29	-0.52	1.24	0.33
	Face-to-face	20	-0.60	1.67	0.39
Mean		120	0.72	2.17	0.23

Table 20

Tests of Between-Subject Effects for the General Linear Model Measuring Mean Differences in Change in Spatial Ability by Beginning Spatial Ability

Source	Type III sum of squares	*df*	Mean square	*F*	Sig.	Partial Eta squared
Corrected model	211.733[a]	5	42.347	13.847	.000	.378
Intercept	97.295	1	97.295	31.815	.000	.218
Beginning spatial ability	178.858	2	89.429	29.242	.000	.339
Instructional method	12.795	1	12.795	4.184	.043	.035
Beginning spatial ability * instructional method	28.494	2	14.247	4.659	.011	.076
Error	348.634	114	3.058			
Total	622.000	120				
Corrected total	560.367	119				

[a] *R* Squared = .378 (Adjusted *R* Squared = .351).

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distance education courses when factoring in the noncurricular factors of: gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling? Partial correlation was used to answer this research question. Since many of the predictor variables showed very weak correlations and statistically nonsignificant relationships to the independent variable of change in spatial ability, a regression model was computed to find appropriate variables to include in the model. The variables of pretest of the PSVT:R (beginning spatial ability), gender, instructional method (synchronous distance education or face-to-face), total drafting courses, highest level of experience in extracurricular involvement, experience programming, experience in model construction, experience in robotics, experience with radio-controlled toys, experience with first person video games, and experience with flight simulator, race car, or driving video games were included in the model. The variables were entered into the model through a stepwise method were the variables were entered into the model with the probability of the f-statistic in the model being less than $p = 0.100$ and removed from the model with the probability of the *f*-statistic being greater than $p = 0.200$. The model stopped finding variables in the model that met the criteria after two steps. The final model included the variables of the pretest of the PSVT:R (beginning spatial ability), gender, and instructional method (synchronous distance education or face-to-face).

A partial correlation of the most prominent factors identified in the regression model was used in order to answer the research question. This model was adapted by the model presented by Cohen (2008, p. 584) and is equivalent to:

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$$r_{Y1.23} = (r_{Y1} - (r_{23} * r_{Y123})) / (\sqrt{(1 - r^2_{Y23})} * \sqrt{(1 - r^2_{23})})$$

This is explained as r being the correlation of 1 on Y in the partial correlation model. Y is the independent variable of change in spatial ability, and 1 is instructional method (synchronous distance education or face-to-face), which is the variable correlated to the independent variable. Variables 2 and 3 are the variables partialed out of the model representing the variables of the pretest of the PSVT:R (beginning spatial ability), and gender. This model showed a statistically nonsignificant correlation ($r = 0.125$; $p = 0.177$) between the instructional method (synchronous distance education or face-to-face) and the change in spatial ability with the effects of the beginning spatial ability (pretest of PSVT:R) and gender being partialed out of the model.

Summary

The independent variables were analyzed for meeting the statistical assumptions of normality and homogeneity of variance. Two outliers were removed from the change in spatial ability factor, and a more normal distribution for the data was created. The dependant factors were analyzed and descriptive statistics and correlations to independent factors were reported. When compared to the pretest of spatial ability, a significant difference was found with gender, having at least one drafting or graphics course, and experience with robotics. The difference found with the pretest of spatial ability and experience with robotics was in a direction not expected by the researchers or within the literature. Further explorations should be conducted before any conclusions on the correlation should be drawn. No significant differences were found when comparing any

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of the noncurricular factors to the change in spatial ability. A statistical differences was found when the mean change in spatial ability was compared with the instructional method (synchronous distance education or face-to-face) along with factoring in a student's beginning spatial ability. The difference was found in the student's with the lowest beginning spatial ability with students improving at a greater rate in the face-to-face courses than in the distance education courses. A partial correlation showed no significant correlation between the instructional method (synchronous distance education or face-to-face) after partialing out the effects of the beginning spatial ability (pretest of the PSVT:R), and gender.

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CHAPTER V

DISCUSSION AND RECOMENDATIONS

Introduction

The purpose of the study was to measure and compare a face-to-face engineering graphics course with a synchronous distance education engineering graphics course by identifying the impact of the teacher's physical presence on students' spatial ability. Additionally, the study looked at noncurricular factors and how any potential differences in spatial ability were impacted by these factors (including interactive effects). The noncurricular factors included: age, gender, prior graphics experience, prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling. The study looked specifically at four research questions. The first question was if there was there a statistical measure of change in the spatial ability of students in a synchronous distance education engineering graphics course? The second question was similar and looked at if there was there a statistical measure of change in the spatial ability of students in a face-to-face engineering graphics course? The third research question compared the two delivery methods and asked if there was a statistical difference between the change in the spatial ability of students in face-to-face and synchronous distance education engineering graphics course? The fourth research questioned asked if there was a statistical difference in the change in spatial ability for various student populations in both face-to-face and synchronous distance education courses when factoring in the noncurricular factors of: gender, prior graphics experience,

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prior experience with virtual software and games, hobby and leisure activities, and prior experience with object modeling?

The study employed several different statistical techniques to answer these questions. Each statistical analysis provided a different insight into answering the research questions. The conclusions of the study focused on the particular interpretation of each method and noteworthy observations and patterns that appeared in the analysis of the study. Following the conclusions of the study, recommendations of how this study may apply to engineering graphics and drafting practitioners, and additional recommendations for further inquiry that emerged as a result of the study was reported.

Several conclusions were drawn from this study. Each conclusion will be explored with more depth in the Discussion section following this introduction. When comparing all students taking a synchronous distance education to students taking a face-to-face course there was no statistically significant (p = 0.078) differences found in the two populations. A difference was found in the change of spatial ability between students taking an engineering graphics course by means of synchronous distance education and face-to-face courses in students with a low beginning spatial ability. Students with a low beginning spatial ability showed greater improvement in spatial ability in the face-to-face courses than in the synchronous distance education courses. The study did not have a large enough female population to draw conclusions from the available data, however, the limited data was consistent with research studies in the literature which may suggest a stronger difference in change in spatial ability between female students in a synchronous distance education engineering graphics course when compared to the same face-to-face

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course than was found within the male student population. The study recommends more exploration into this possibility. The study also found with this population, the PSVT:R may have had a possible ceiling effect and may not have allowed the researchers the ability to accurately measure the change in spatial ability for students with higher scores on the pretest.

Discussion

There were a few noteworthy results in analyzing the data collected in the study. The focus of the study was on the impacts of curriculum delivery (specifically synchronous distance education, and face-to-face) on spatial ability in an engineering graphics course. In analyzing each curriculum delivery method independently with a paired samples *t* test against a null hypothesis that there is no change in spatial ability of students over the period of the course, one instructional method (face-to-face) rejected the null hypothesis while the other instructional method (synchronous distance education) failed to reject the null hypothesis that there is no change in spatial ability over the period of an engineering graphics course. The data statistically showed that the face-to-face course had a medium to large effect size ($d = .48$) on the change in spatial ability over the duration of the course. Likewise, the data showed that the synchronous distance education course had a nonsignificant small effect size ($d = .18$) on the change in spatial ability over the duration of the course. There was a statistically nonsignificant ($p = 0.078$) difference found when comparing the means of the distance education course to the face-to-face course with a mean difference of 0.70. Although this statistic was nonsignificant,

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the difference in means shows a medium effect size (d = .32).With the same effect size and variation in data, a sample size of 245 subjects would be required to give the study enough power ($1 - \beta = 0.80$) to avoid making a type II error in the study. This considerable difference in effect sizes suggests that one would reject the null hypothesis that there are no differences in change in spatial ability when comparing classes taught through a synchronous distance education format and a face-to-face format.

A greater sample size would be needed to better assure that one was not making either a type I or type II error in the study. A type I error could be made by assuming the inference of comparing the two methods of instructional delivery as measured in a paired sample *t* test for a statistical change in spatial ability over the engineering graphics course as sufficient evidence to reject the null hypothesis that there is no statistically significant impact on spatial ability over an engineering graphics course taught in a synchronous distance education format and a face-to-face format. A type II error could occur if the study fails to reject the same null hypothesis given the probability ($p = 0.078$) is greater than the predetermined α level of the study ($\alpha = 0.05$). It is the recommendation of this study that more data be collected to reduce the chances of making either a type I or a type II error in concluding whether there is not a difference in change in spatial ability over the engineering graphics course between courses taught through synchronous distance education and face-to-face means. Although the data suggests that with a greater sample size, a statistically significant difference would be found when comparing the change in spatial ability between students in a synchronous distance education course and a face-to-face course as a whole, a statistically significant difference was found when looking at

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specific subgroups. These subgroups will be explored followed by possible explanations for the difference.

Students with Low Beginning Spatial Ability

The most notable measurement for comparing the impacts of instructional formats on the spatial ability of students was when the beginning spatial ability of the students was a factor of the analysis. The mean change in spatial ability when comparing the synchronous distance education sections to the face-to-face sections shows very little difference in students of medium and high beginning spatial ability (mean differences of 0.03 and 0.08, respectively), but a significant difference in the change in spatial ability for students with low beginning spatial ability (a mean difference of 2.11) when comparing the synchronous distance education sections to the face-to-face sections. The statistics associated with this test were reported in Table 19 in Chapter IV. This analysis gives insight into any differences in the change in spatial ability of engineering graphics students between synchronous distance education and face-to-face instructional formats. The findings showed that students with a lower beginning spatial ability tended to improve their spatial ability and at a much greater rate in a face-to-face format than the students with the synchronous distance education format. Many factors which have provided explanations for variations between distance education and face-to-face hands on courses were held constant in this study. For example, Ma and Nickerson (2006), found that instructors who advocate hands-on instruction focused on design aspects in their courses while instructors who advocated remote laboratories focused on conceptual principles in their courses. This study used the same instructor and curriculum for all four

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class sections. The students were in the same classroom for all sections, used the same computers and software, and all had the same teacher's aide. The distance education course was taught synchronously, so a delay in feedback should not have been an issue as one would conclude from an asynchronous course. It is reasonable to conclude that the outstanding factor was the physical presence of the teacher which raises the question of why would the physical presence of an instructor have a greater impact on the improvement of spatial ability for the students with the lowest beginning spatial ability? Garrison, Anderson, and Archer (1999) provided a framework of how we may look at the teacher's presence in the education experience of students. According to the framework, the educational experience is composed of the main elements of cognitive presence, social presence, and teaching presence with learning occurring through the interaction of those elements. This is shown graphically in Figure 5. Within the teaching presence element of the framework is the interpersonal element of building understanding between the teacher and the student which may be difficult in distance education formats. Similarly other studies in distance education have found students may feel alienated in distance education courses, which has had a negative impact on student performance (Lazarevic, 2010). Using the framework provided by Garrison, Anderson, and Archer, it would be reasonable to believe that any changes in the teaching presence would result in changes in the interactions with the social and cognitive presence thus affecting the educational experience.

The purpose of this study was to identify if a difference in change in spatial ability existed when comparing a synchronous distance education course to a face-to-face

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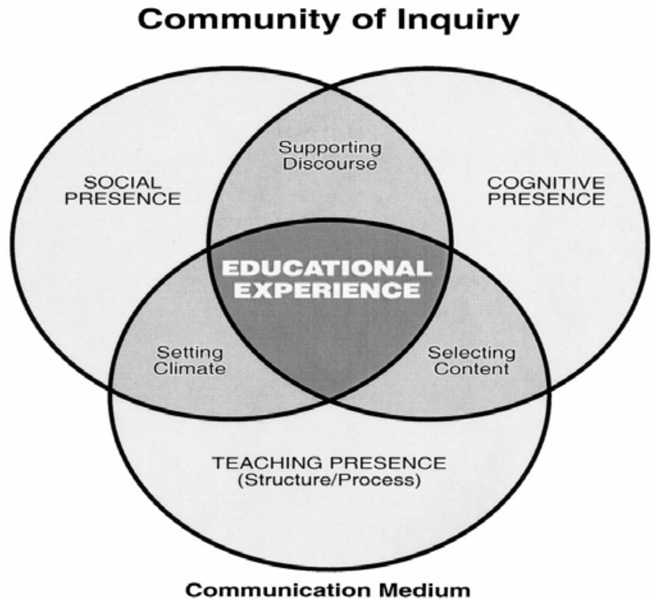

Figure 5. Graphical representation of the elements of educational experience framework showing teaching presence as a key element of the educational experience (Garrison et al., 1999).

course. Additional inquiry into why there was a difference is required to explain the differences. This inquiry would require a research methodology designed to answer that question which may consist of qualitative and mixed methods research.

Female Students

Students represented in the lower beginning spatial ability group showed a disproportionately large ratio of females. In this study, five of the seven females (out of 122 total students) were in the lower third of beginning spatial ability. Although the number of female students in the study was too few draw conclusions about the beginning spatial ability of female students compared to male students, the differences, however, between male and female students in spatial ability has been well documented

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with female students consistently scoring lower on spatial ability tests than their male counterparts in over 238 studies (Voyer et al., 1995). The number of female students in this study was too few to provide any conclusions that a face-to-face instructional format was more conducive to improving spatial ability for female students in an engineering graphics course. However, with female students being more strongly represented in the lower beginning spatial ability group than other groups, and students from the lower beginning spatial ability group showing the strongest gains in a face-to-face course, it may be reasonable to infer that decisions on instructional methods in an engineering graphics course could have a greater impact on female students who are disproportionately represented in the low beginning spatial ability group at the beginning of the semester. This inference is of particular note as recruitment and retention of female students is considered to be highly important for improving engineering programs and all fields of engineering (NAE, 2004).

Noncurricular Factors

Although the literature showed many factors correlated to improved spatial ability, nearly all of the noncurricular factors measured in the demographics survey showed an extremely weak correlation. The survey showed that very few students had experience in engineering related extracurricular activities. The majority of students (59%) had no experience with any engineering related extracurricular activities listed on the survey. Likewise, experience with robotics was the only hobby that had any correlation to beginning spatial ability, and that correlation was in the direction not expected (the more exposure one had to robotics, the lower the beginning spatial ability

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was predicted) by the researchers or within the literature (Lathan & Tracey, 2002; Wong, 2009). One explanation for low correlations is that the way the factors correlate may be complex in nature (Davis, 2006). Each factor may have several aspects such as duration of time spent on the hobby, length of time since the student was active in the hobby, age of the student while participating in the hobby, and what facets of the hobby interested the students. Further research may be needed to identify how each hobby may correlate to spatial ability with special attention to the many aspects of the hobby. This may require a mixed methods approach to identify the various aspects of each hobby. As a result of the low correlation of hobbies and extracurricular activities to change in spatial ability over the engineering graphics course, very few factors were available to provide a partial correlation with enough strength to show what the effects of instructional delivery methods were after partialling out the effects of hobbies and extracurricular activities.

Study Limitations

The study had three limitations to providing conclusive inferences. The first was that the convenience sample did not provide enough female students to provide a great enough sample size for conclusions about gender differences. This was anticipated as few female students choose to take mechanical engineering courses. With only an average of 11% enrollment of females in mechanical engineering, the researchers were unable to find a mechanical engineering course with enough female students to provide the statistical power necessary for conclusions about the effects of gender as one examines synchronous distance education and face-to-face courses. To utilize the multiple courses

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necessary for a strong enough female sample size, the study would have had to sacrifice the internal controls of having the same instructor, teacher's aide, classroom, software, and curriculum. The second limitation was in the high scores shown by many of the mechanical engineering students in the PSVT:R. With the scores of students being higher on the pretest than recorded in studies of other disciples, a possible ceiling effect may have occurred where medium and high beginning spatial ability students did improve their spatial ability skills more than was shown in the study, but the instrument was unable to accurately show that change. With students in the 21st century having greater access to activities that develop spatial ability such as video games, three-dimensional computer modeling software, and hobbies such as robotics which improve spatial ability, students may have higher spatial ability in 2010 than comparable students did at the creation of the test in 1979. With this possible change in students' spatial ability, the PSVT:R may no longer be an adequate measurement of spatial ability due to a ceiling effect of the test. The third limitation was that the study was not designed to answer why the physical presence of an instructor in the face-to-face course correlated to a greater improvement in spatial ability for students in the beginning spatial ability group.

Recommendations for Future Inquiry

Having previously taken a drafting or a graphics course had a significant impact on the spatial ability of the students as they began the engineering graphics course with students who have previously taken a drafting or graphics course showing a mean difference of 1.58 more questions being answered correctly. Additionally, the beginning

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spatial ability of students was the strongest predictor of the change in spatial ability with students who scored low on the pretest of spatial ability showing the most gain between the pretest and the posttest of spatial ability. There was no statistically significant effect shown when the change in spatial ability was analyzed for an interactive effect between having previously taken a graphics course and the beginning spatial ability of the students ($f = .135$; $p = 0.87$) in a general linear model. The statistics from the model are reported in Table 21.

This suggests that regardless of having previously taken a graphics or drafting course, students should continue to improve their spatial ability at the same rate as other students with comparable beginning spatial ability. This study was not designed to answer the question of what effect does previous engineering graphics and drafting

Table 21

Tests of Between-Subject Effects for the General Linear Model Measuring Mean Differences in Change in Spatial Ability by Beginning Spatial Ability and Prior Graphics Courses

Source	Type III sum of squares	*df*	Mean square	*F*	Sig.
Corrected model	113.264	11	10.297	2.927	.004
Intercept	26.316	1	26.316	7.482	.008
Beginning spatial ability	31.494	2	15.747	4.477	.016
Prior graphics courses	6.176	3	2.059	.585	.627
Beginning spatial ability * prior graphics courses	13.930	6	2.322	.660	.682
Error	204.007	58	3.517		
Total	367.000	70			
Corrected total	560.367	119			

R Squared = .357 (Adjusted R Squared = .235)

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courses have on the development of spatial ability of students currently taking an engineering graphics course, but the data suggests that previous graphics courses have little effect on the development of spatial ability for students enrolled in a mechanical engineering graphics course.

Other Fields and Beginning Spatial Ability

This study focused on mechanical and aerospace engineering students. Many STEM and design fields require engineering graphics and drafting course. Likewise, higher spatial ability has been correlated to success in many of those fields. This study found that a face-to-face course was at the greatest advantage for students of lower spatial ability. This study had a mean beginning spatial ability of 26.07 questions answered correctly out of 30. Another study given to university engineering students in the United States, Germany, and Poland showed students had a mean score of 23.12 on the same test (Gorska, Sorby, & Cornelie, 1998). This study would suggest that over half of the students would have statistically significant greater improvements in spatial ability for more than have of the students in a course consisting of students with similar spatial ability to that of the students in the Gorska and colleagues study. Further inquiry is needed to better understand how a course structure may impact the variations in spatial ability upon entering a course that would be representative of the various STEM and design fields. It is recommended that this is explored in other fields such as industrial technology and other engineering fields that have different beginning spatial ability skills and also fields such as interior design which would have a greater number of female students. It is also recommended that this study be replicated with another test of spatial

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ability which may measure an additional factor of spatial ability and may have more room for improvement for students with higher spatial ability. The mental cutting test is a recommended test for a follow-up study.

Female Students

The results of this study suggest that female students are disproportionately found in the low spatial ability group on the PSVT:R at the beginning of the course which was the group with the greatest difference in change in spatial ability when comparing the synchronous distance education students to the face-to-face students. This study had too few females to make generalizations about the differences in spatial ability by gender for students who scored low on the pretest of the PSVT:R, but suggests that as part of the group which showed the greatest improvements with a face-to-face instructional strategy, female students may be impacted most by curricular decisions regarding how courses are offered. Recruitment and retention of female students is a priority of many engineering programs and the National Academy of Engineering. With a strong correlation between spatial ability and academic achievement in STEM fields (Smith, 2009, p. 29), the improvement and development of spatial ability of female students is an important aspect in promoting success for female students in engineering.

Other Factors and Distance Education Methods

This study focused on one method of how an engineering graphics course could be delivered through distance education. There are many factors when comparing a distance education to a face-to-face course. This study looked at the impacts of removing

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the instructor physically from the course. The curriculum remained unchanged, as well as the physical settings. There students were present in the same classroom for the synchronous distance education course, and the same teacher's aide was present. This setting is not representative of all distance education courses. Many courses are taught asynchronously, students may utilize different tools (in this case computers and software), and may not have interactions peers or a teacher's aide. Further inquiry is needed to identify how these varying factors could impact spatial ability in an engineering graphics course.

Recommendations for Curriculum Developers

This study was needed to identify the impact of the physical presence of an instructor versus a distance education course on the spatial ability of students in an engineering graphics course. This study was designed to be useful in identifying if remedial measures are needed to improve the spatial ability for students or specific student populations in both distance education and face-to-face classrooms. The findings of the study showed that for students of medium and high beginning spatial ability levels, there were no statistically significant differences in improving spatial ability when comparing a synchronized distance education course to a face-to-face course. If educators and curriculum developers wish to explore a synchronized distance education course that may improve access to more students than might have the ability to attend a face-to-face course, then a synchronized distance education course provides a comparable educational experience to a face-to-face course when looking at improving spatial ability for students

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who begin with a medium to high spatial ability. For students beginning with a lower spatial ability, it is recommended that those students are placed in face-to-face course. Spatial ability has been correlated to success in many STEM fields, and it is recommended that curriculum developers and educators account for this ability when making curricular decisions.

Summary

The differences found in the change of spatial ability between students taking an engineering graphics course by means of synchronous distance education and face-to-face courses were found in students with a low beginning spatial ability. Students with a low beginning spatial ability showed greater improvement in spatial ability in the face-to-face courses ($m = 3.50$, $SD = 1.93$), than in the synchronous distance education courses ($m = 1.39$, $SD = 2.25$). There was a high proportion of females in this group, and this was expected in the literature suggesting that female students may be impacted more than male students by a course with synchronous distance education. Further inquiry is suggested to look into how synchronous distance education impacts students from various fields with varying abilities in spatial ability upon entering courses. Likewise, further inquiry is suggested to look at how various methods of delivery in distance education impact spatial ability in engineering graphics courses.

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APPENDICES

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Appendix A

Modified Purdue Spatial Visualization Test: Rotations Test

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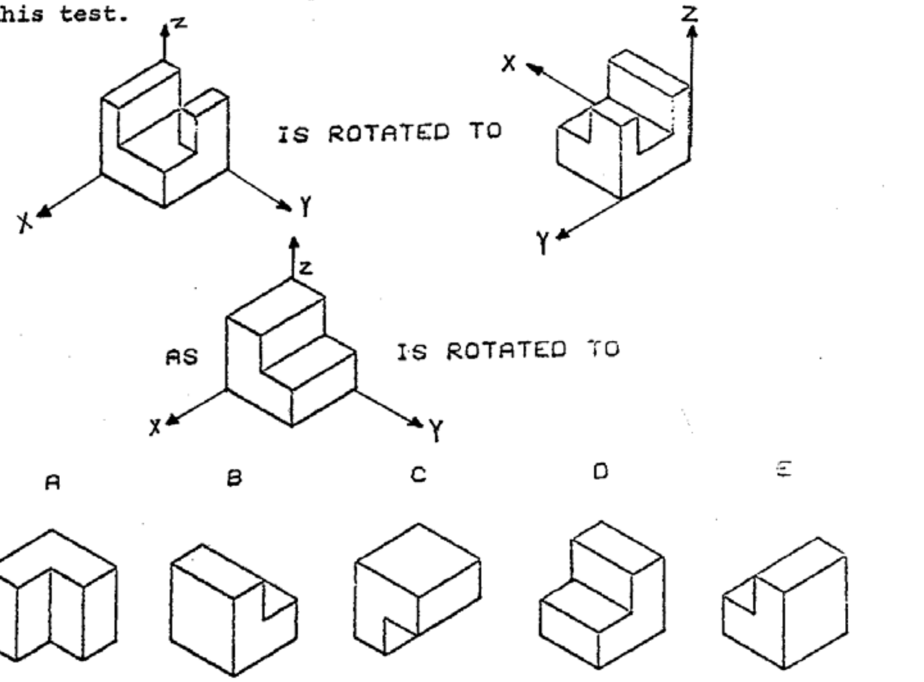
Do NOT make any marks in this booklet.
Mark your answers on the separate answer card.

DIRECTIONS

This test consists of 30 questions designed to see how well you can visualize the rotation of three-dimensional objects. Shown below is an example of the type of question included in this test.



You are 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;
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.

What is the correct answer to the example shown above?

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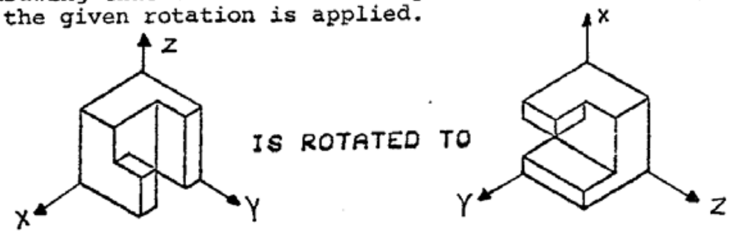
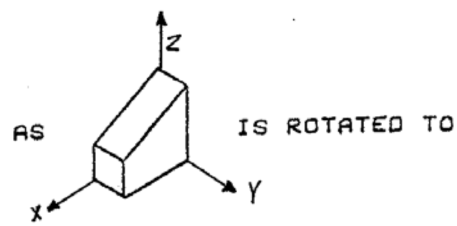
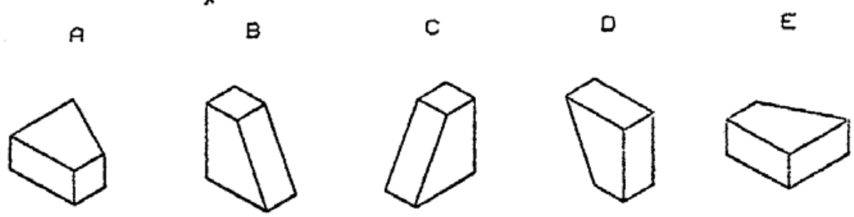
Answers A, B, C, and E are wrong. Only drawing D looks like the object rotated according to the given rotation. In this test each question has only one correct answer.

Now look at the next example shown below and try to select the drawing that looks like the object in the correct position when the given rotation is applied.







Notice that the given rotation in this example is more complex. The correct answer for this example is B. Remember in this test only one answer is correct for each question.

During the test you are to show your choices on the answer card by making a heavy black mark in the space with the same letter as the correct answer you choose.

> Do NOT make any marks in this booklet.
> Mark your answers on the separate answer card.
> You will be told when to begin.

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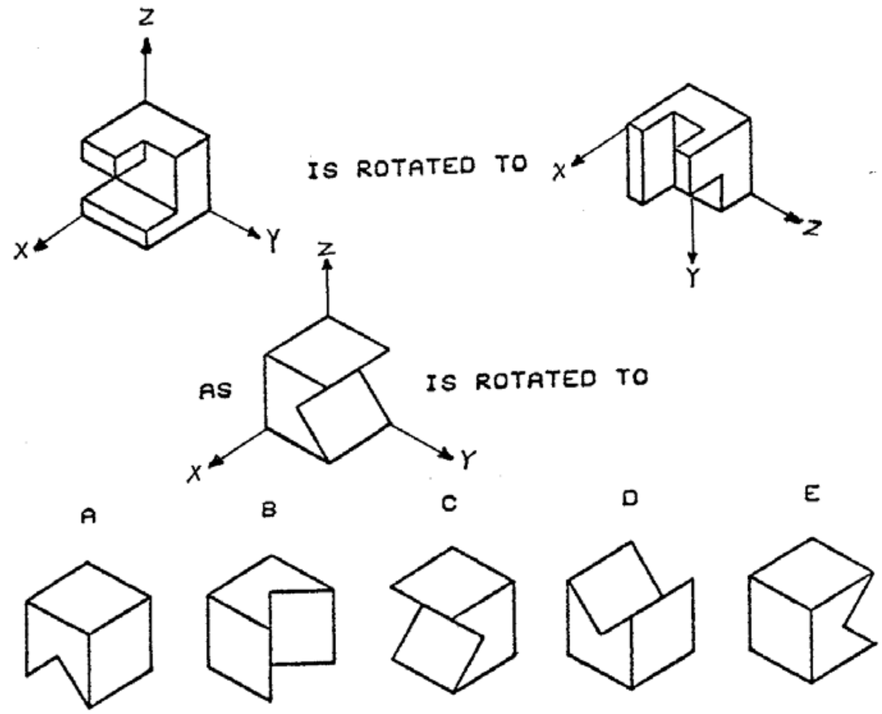

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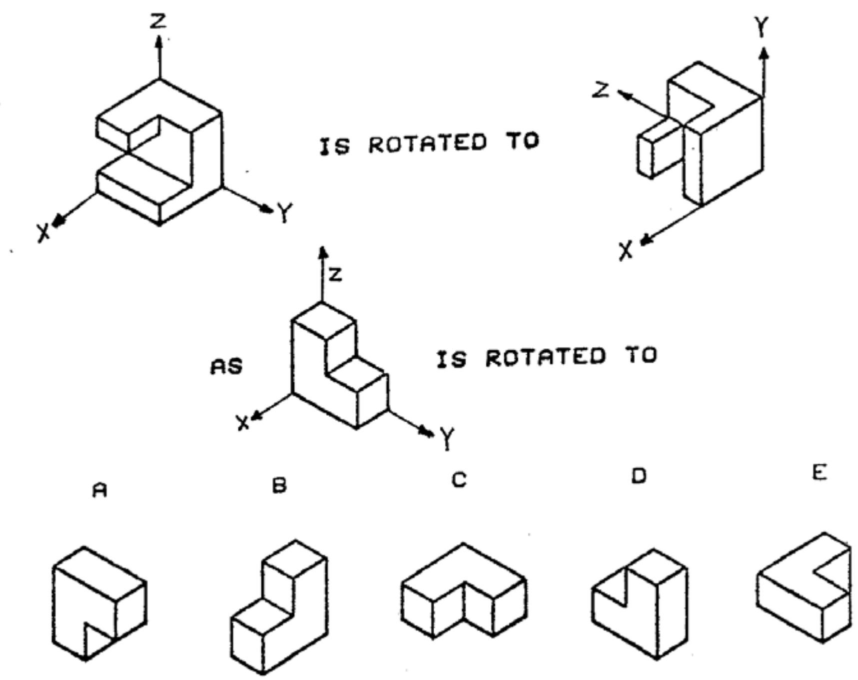

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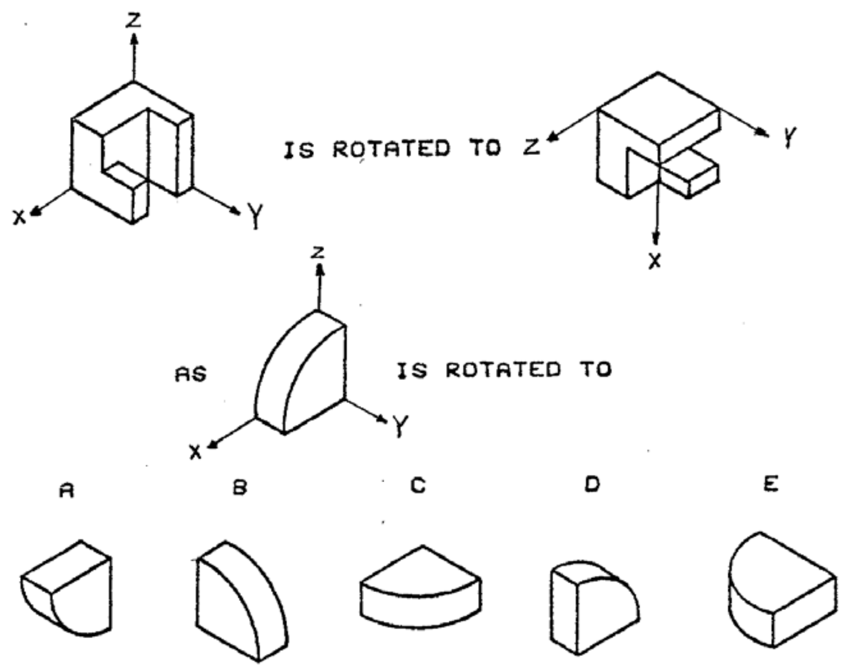

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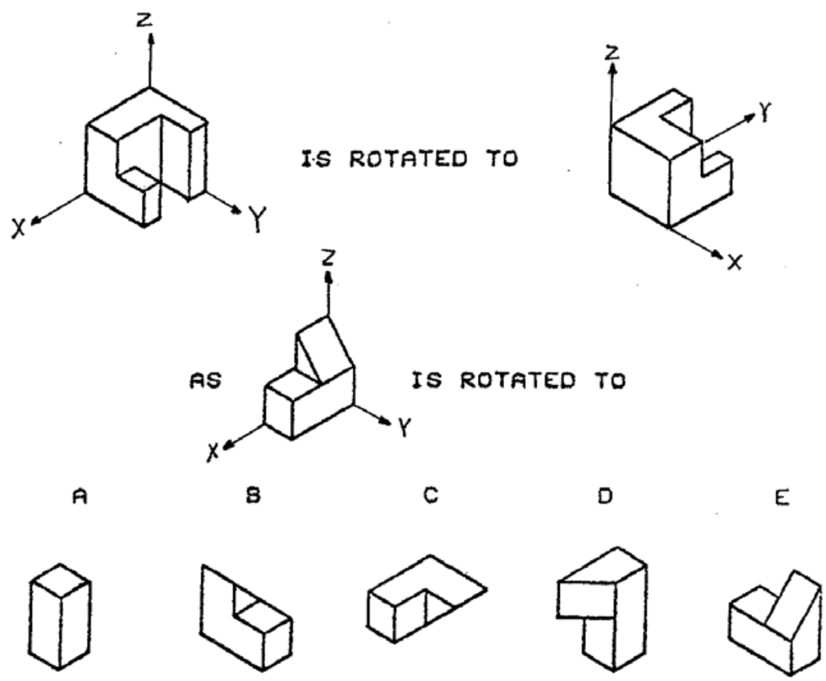

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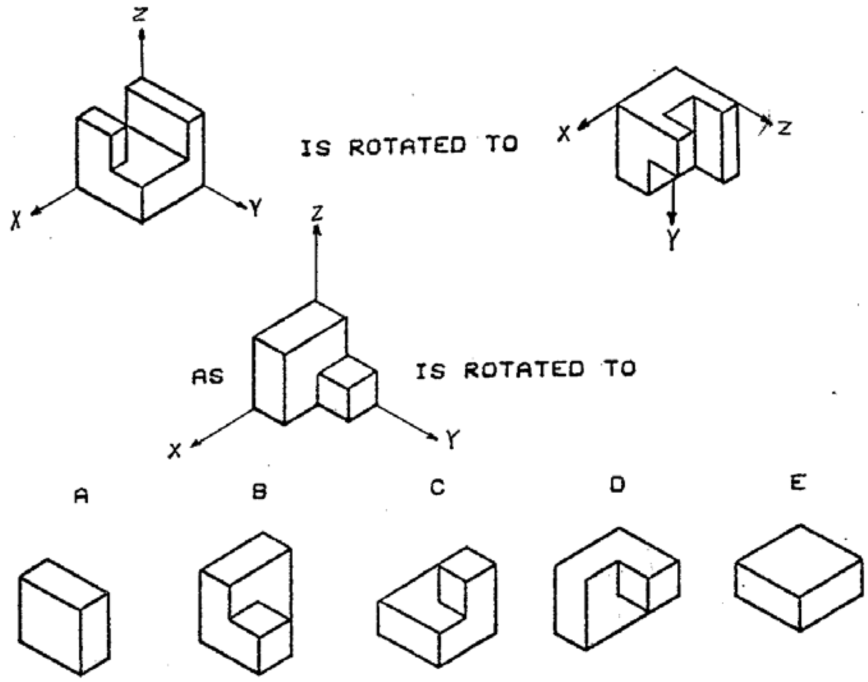

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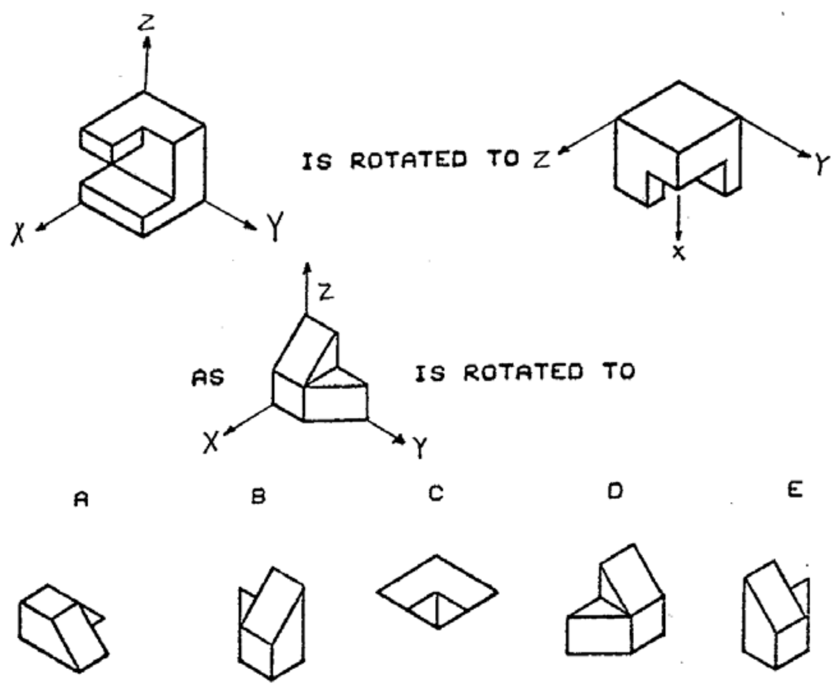

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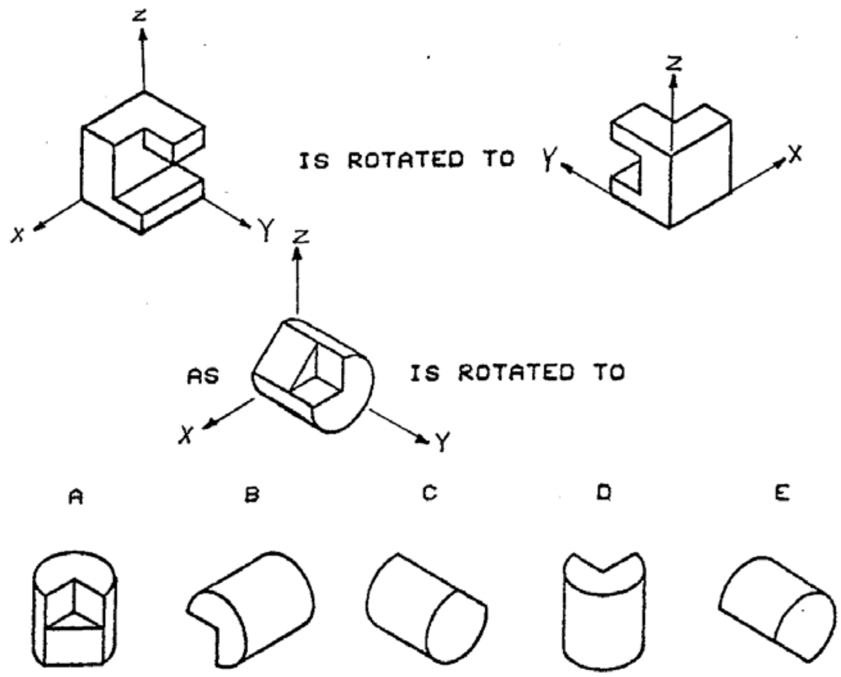

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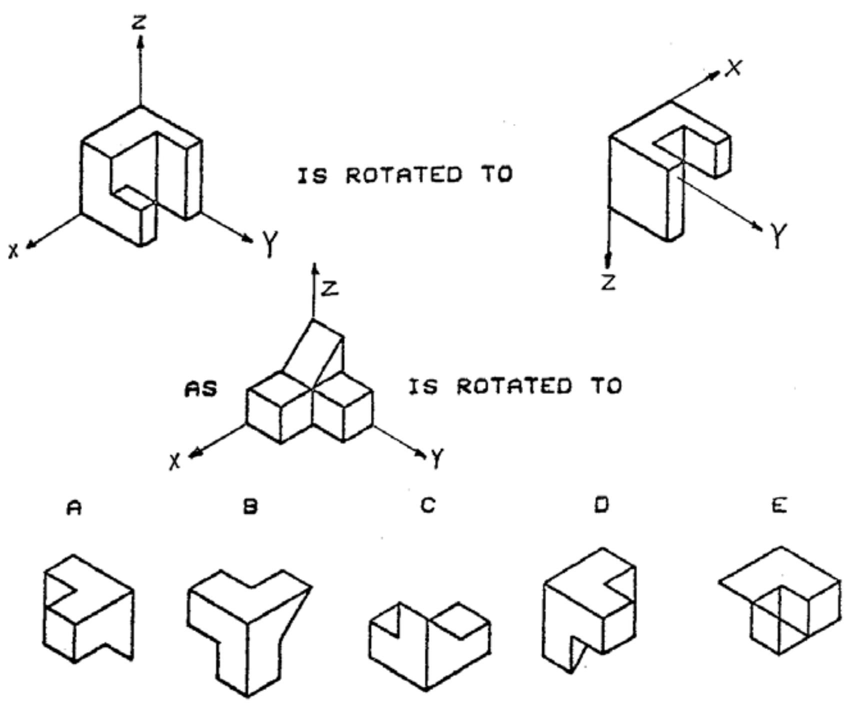

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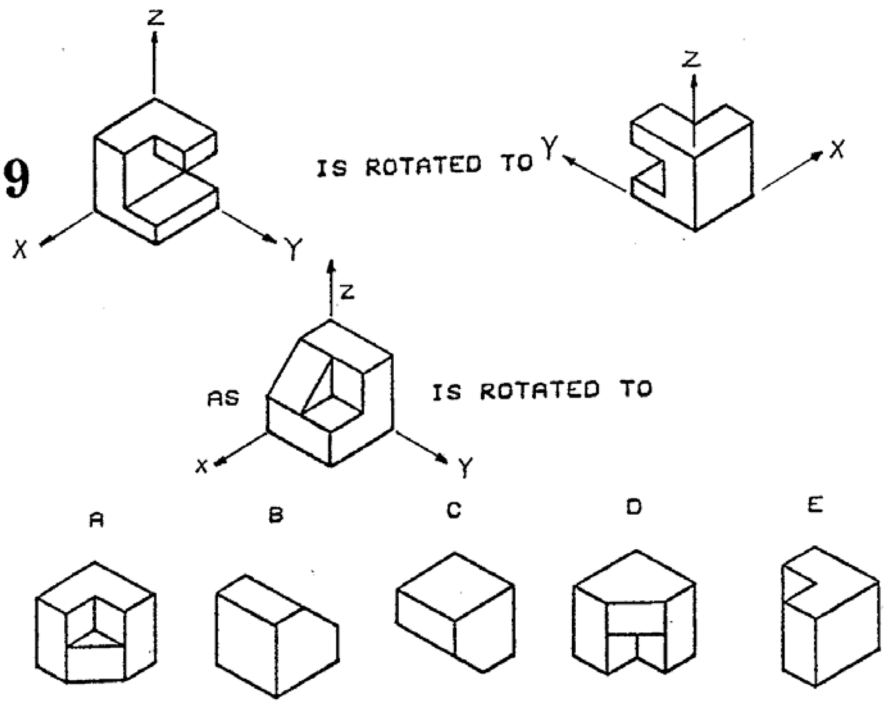

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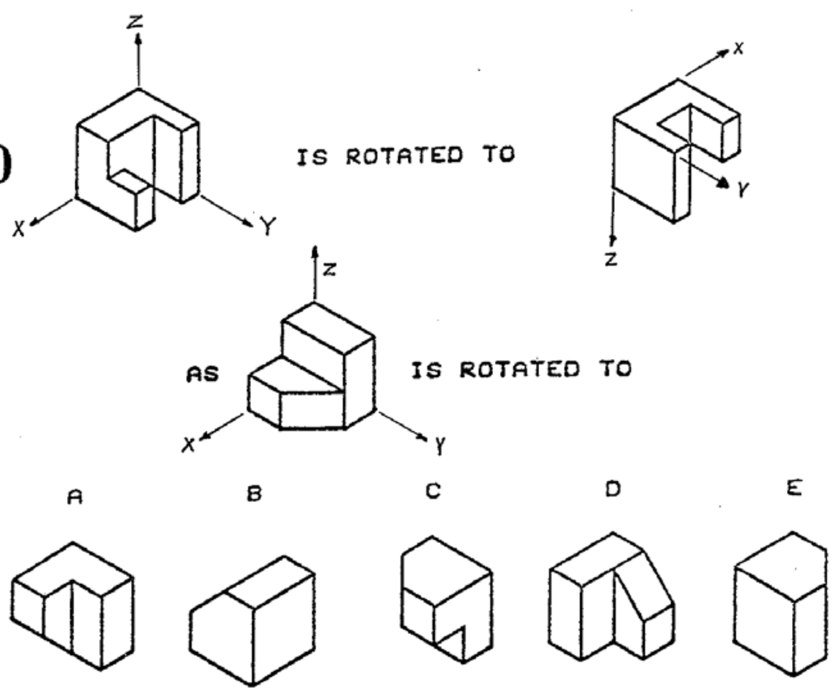

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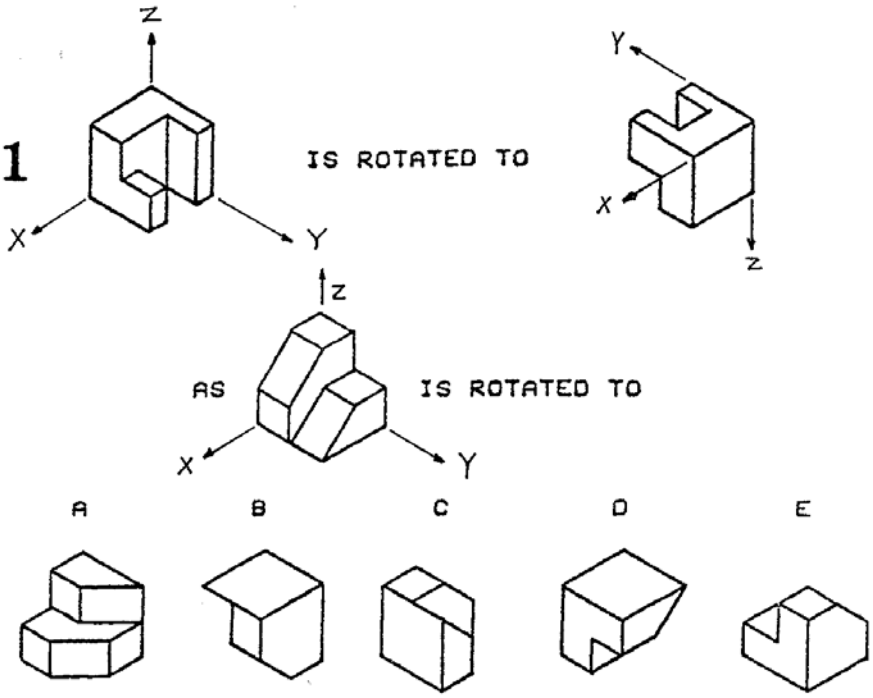

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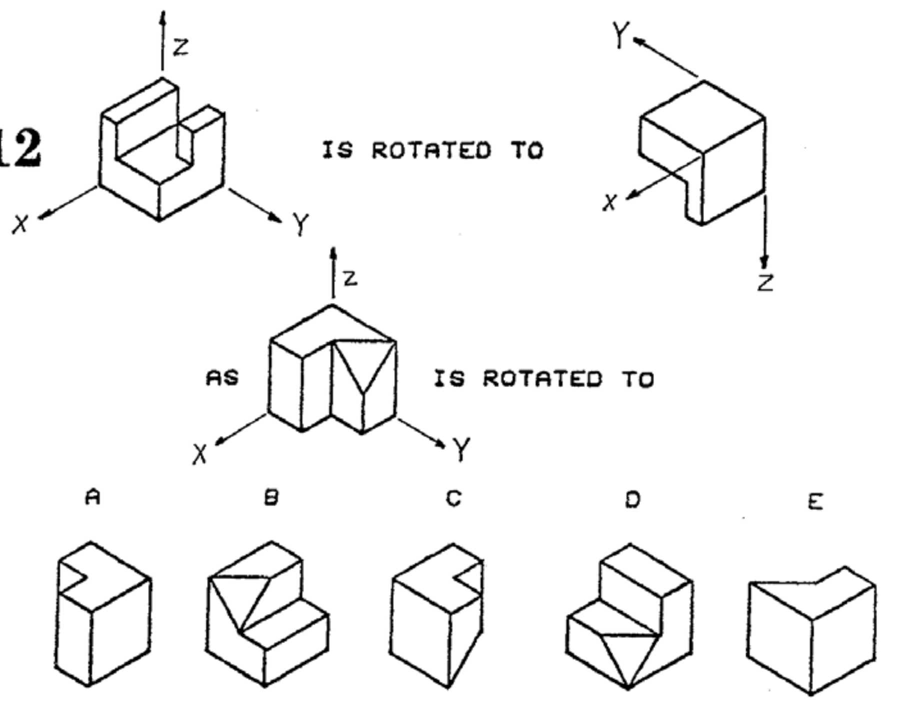

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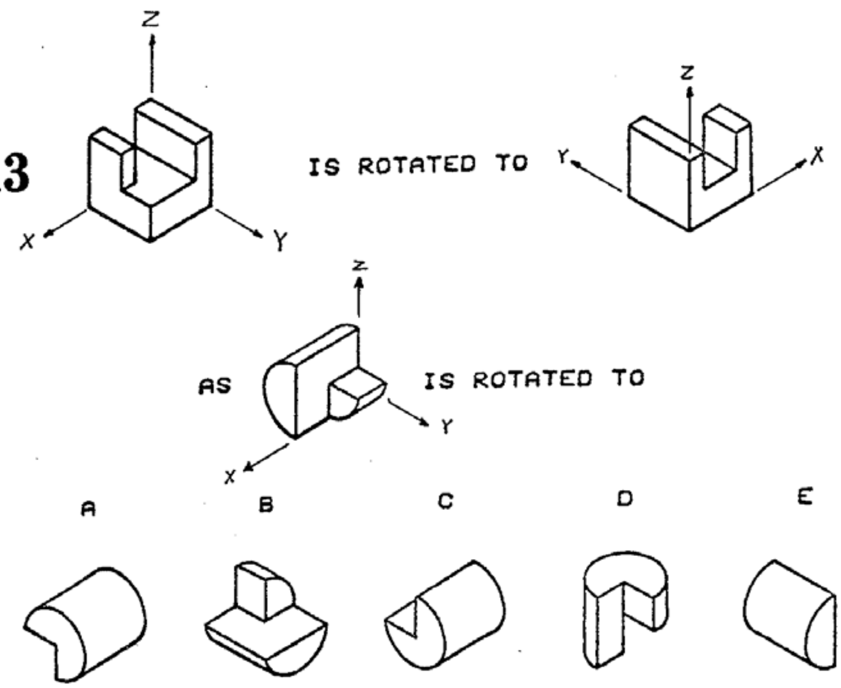

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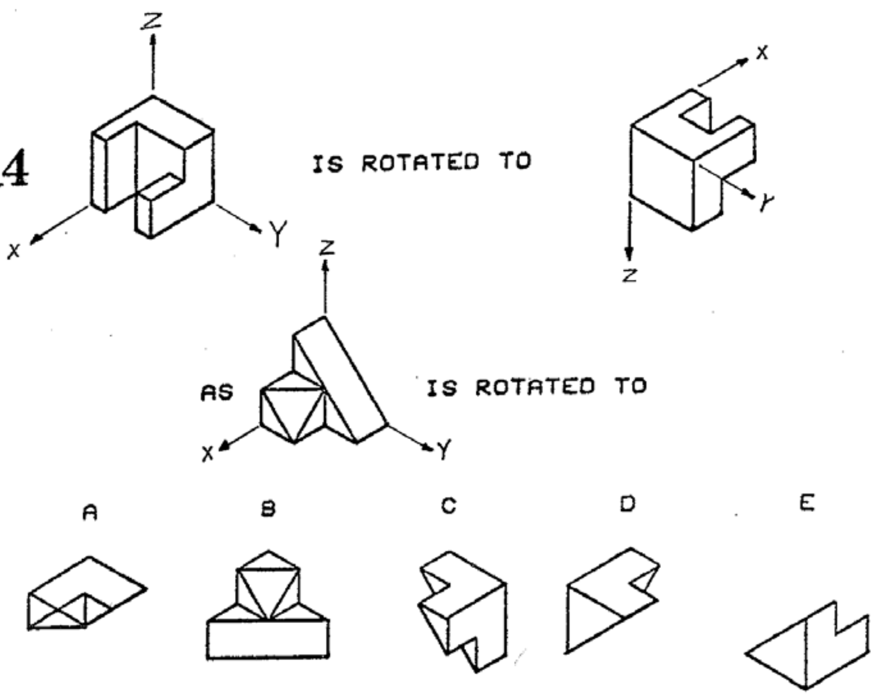

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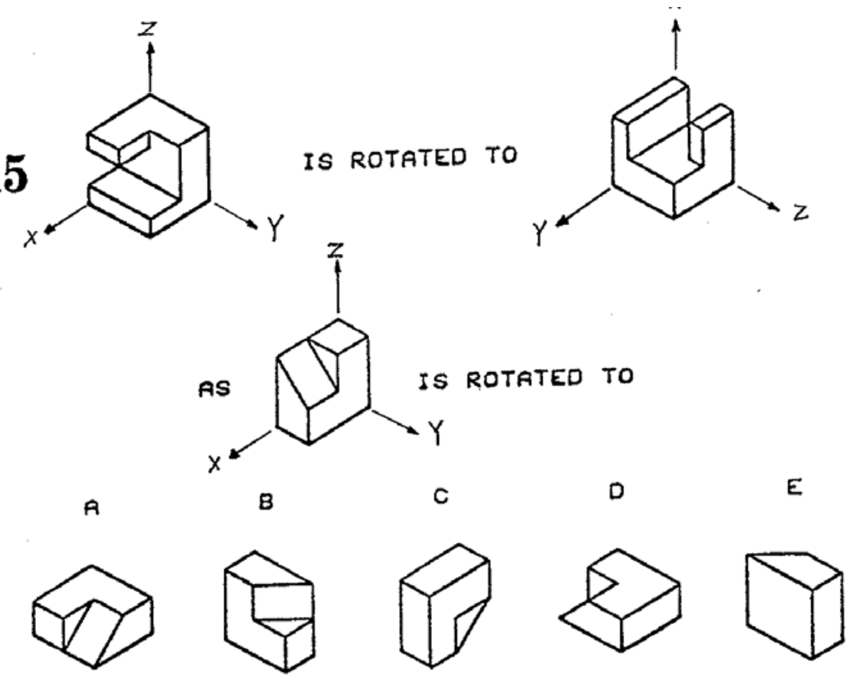

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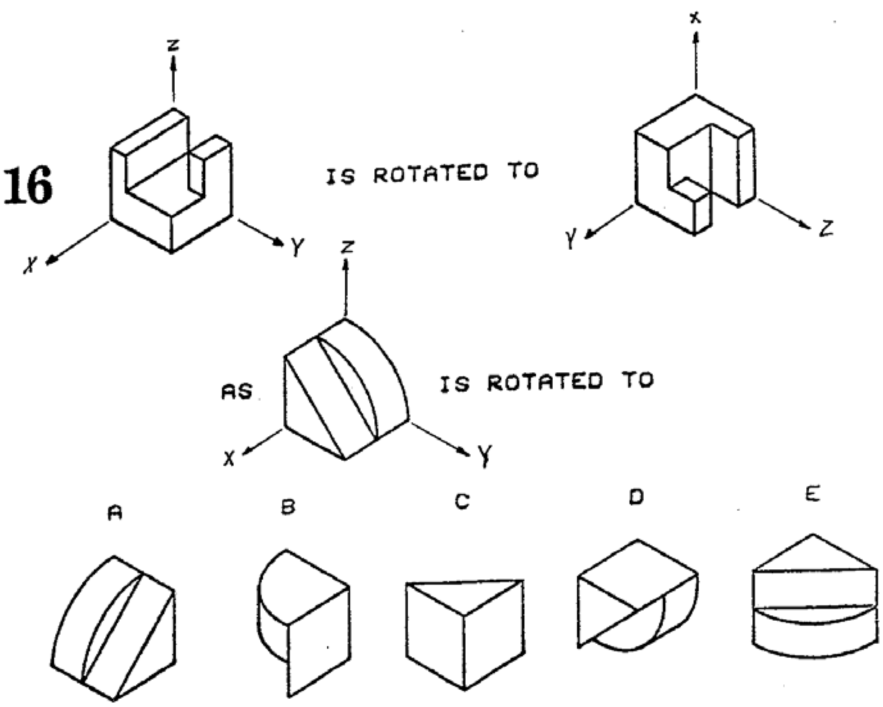

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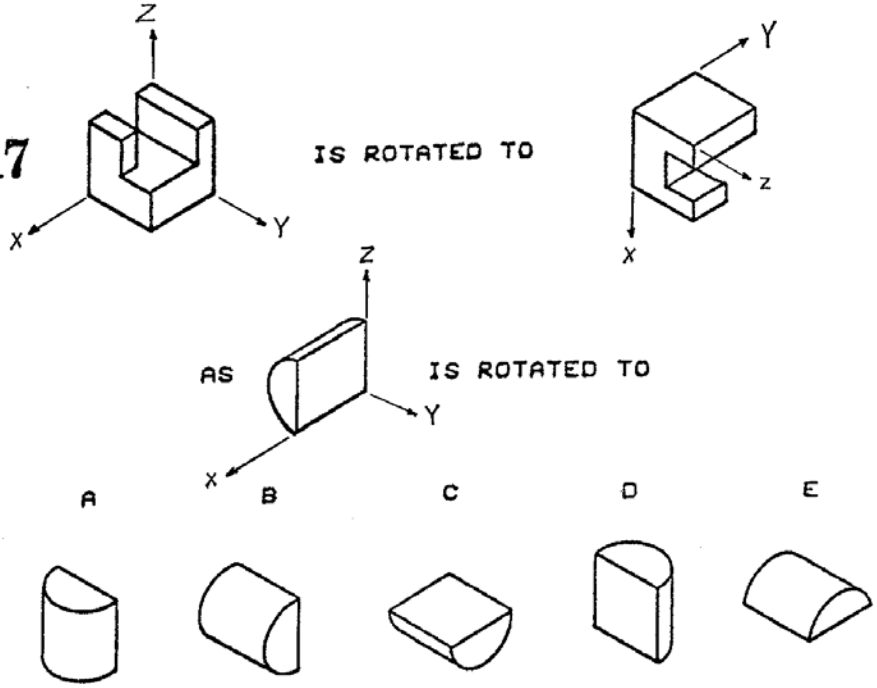

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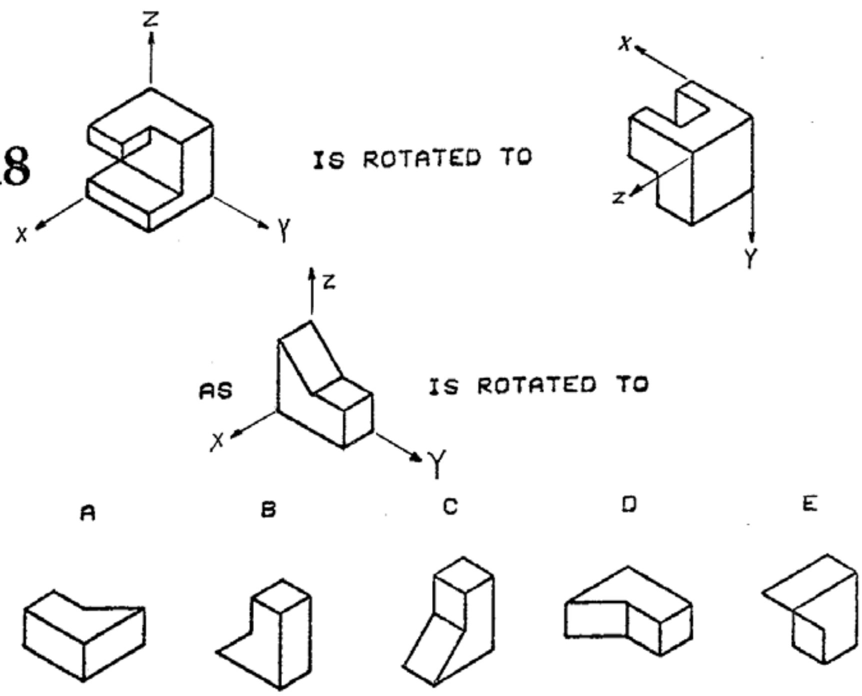

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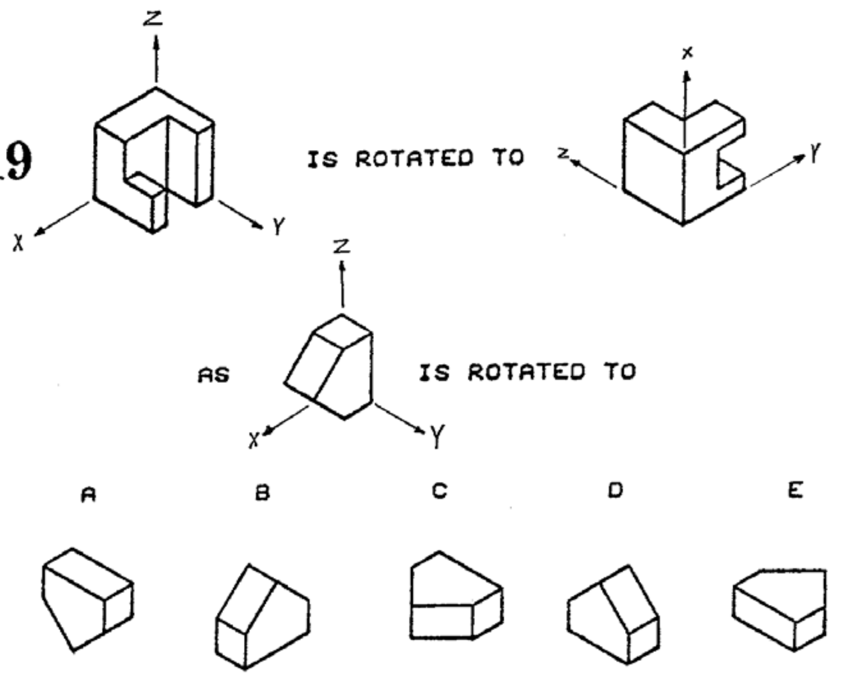

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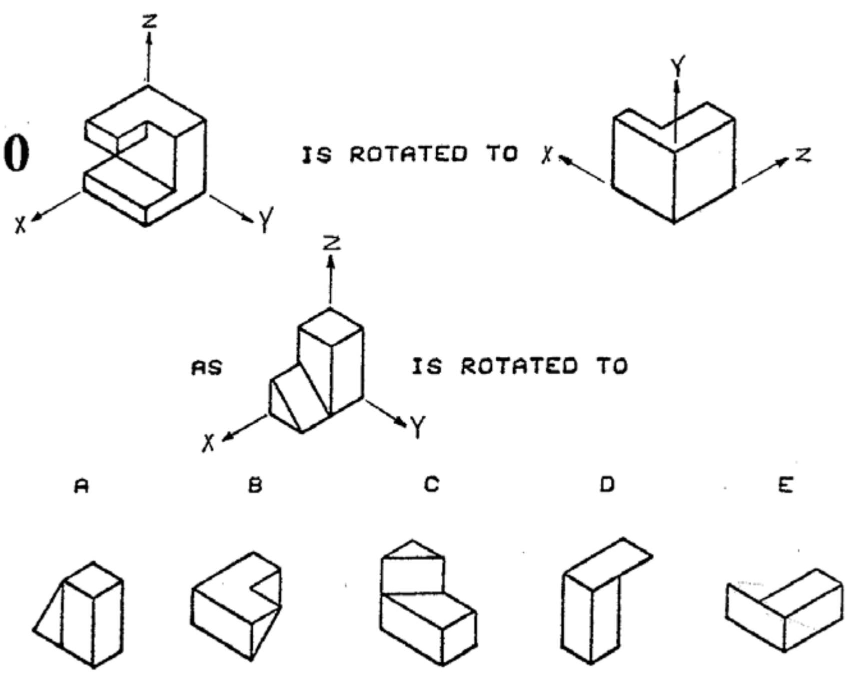

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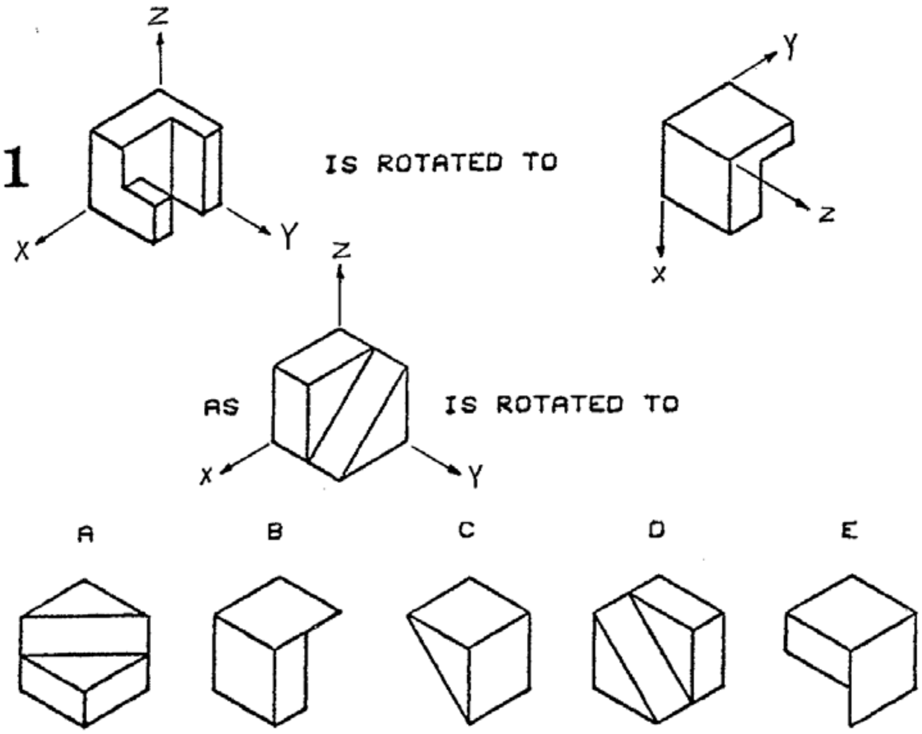

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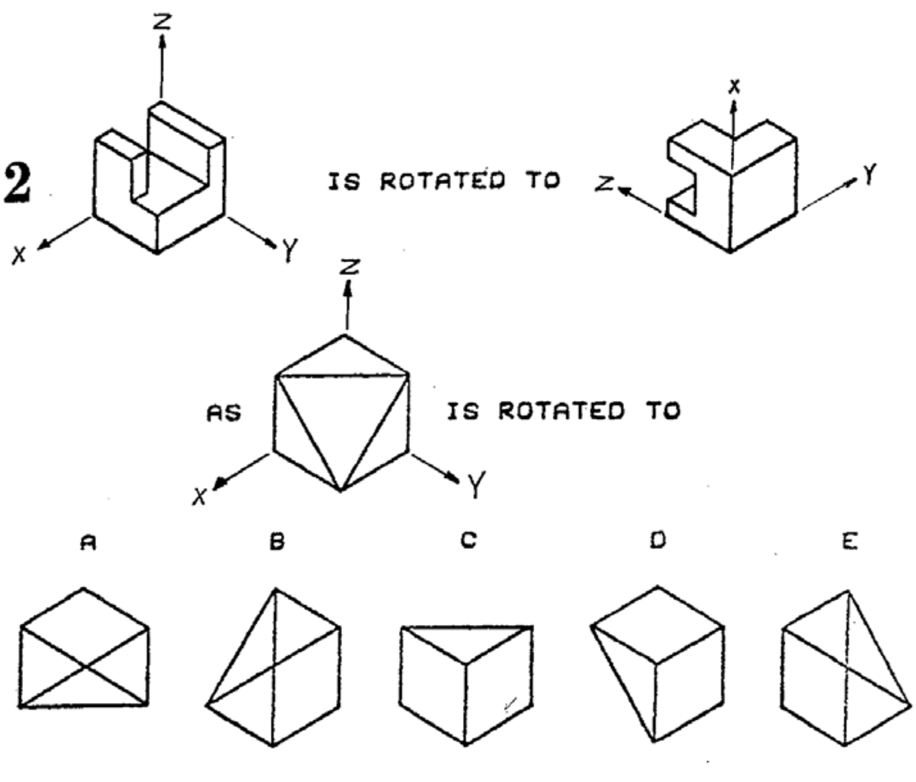

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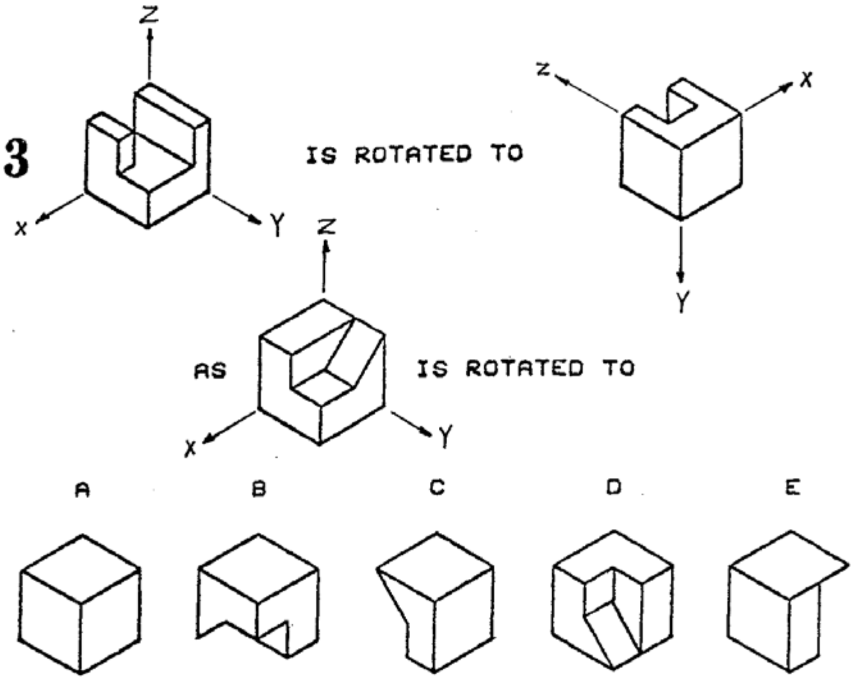

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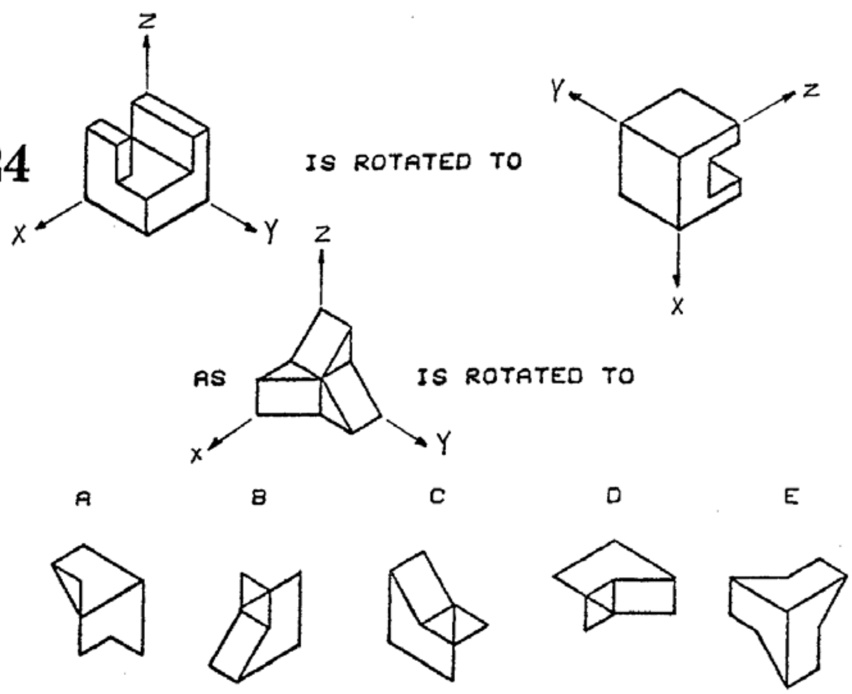

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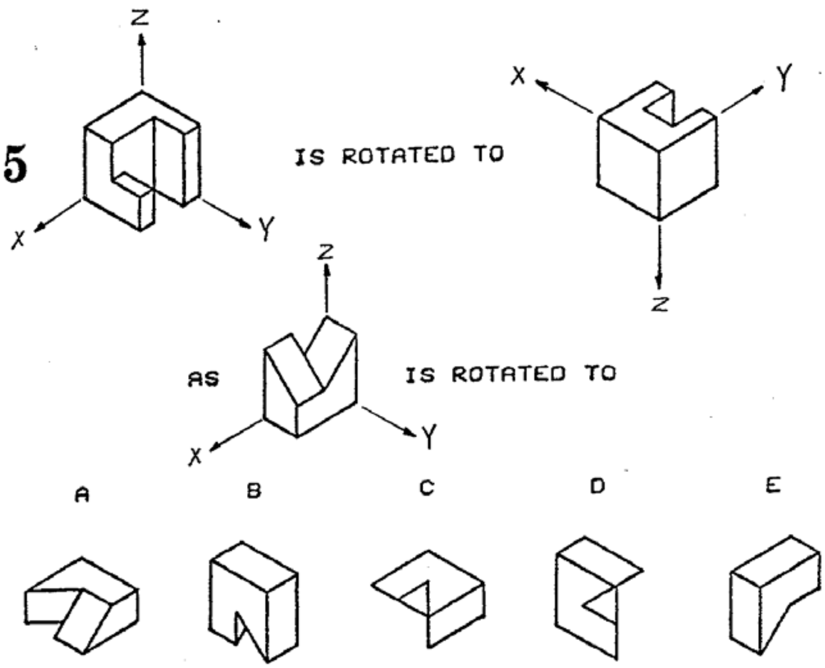

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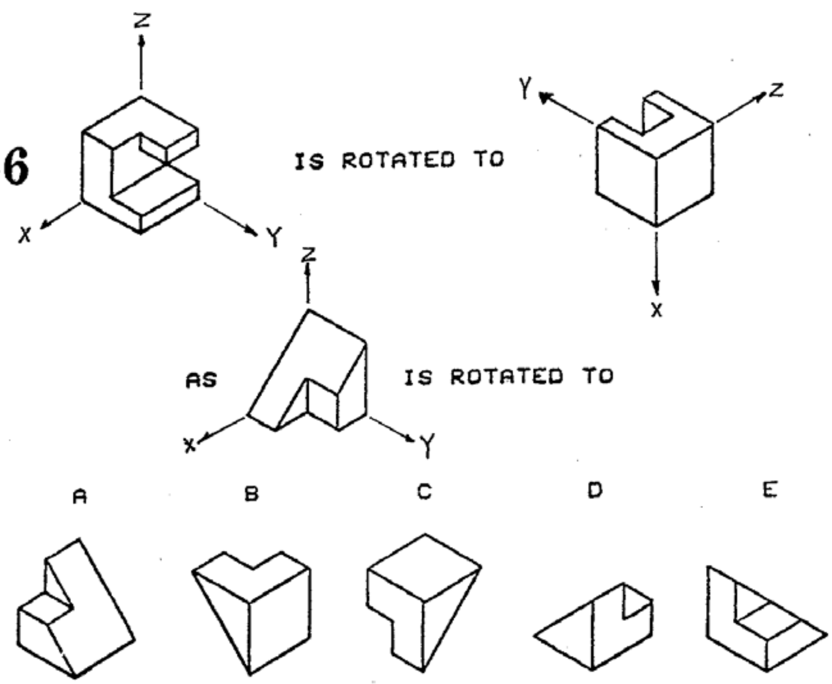

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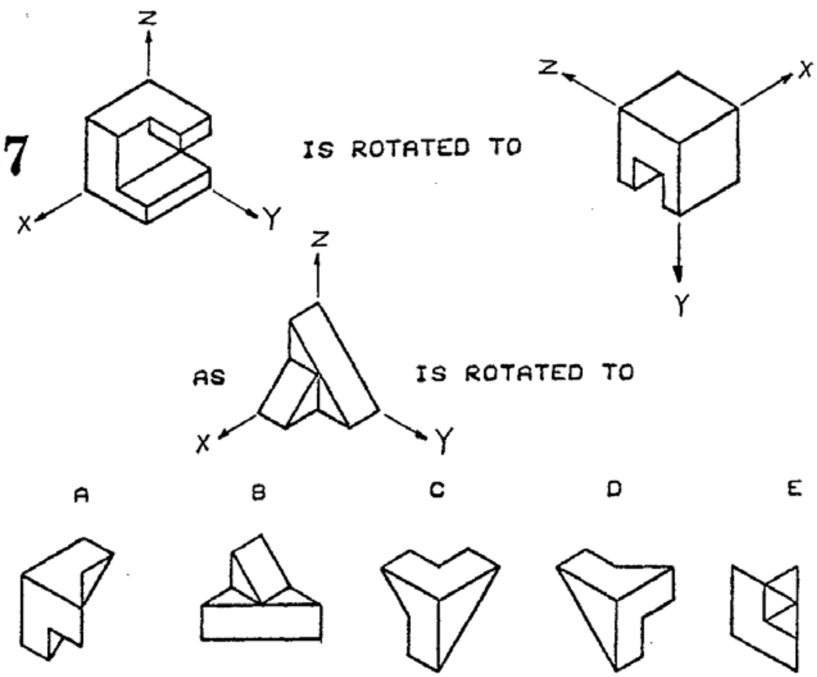

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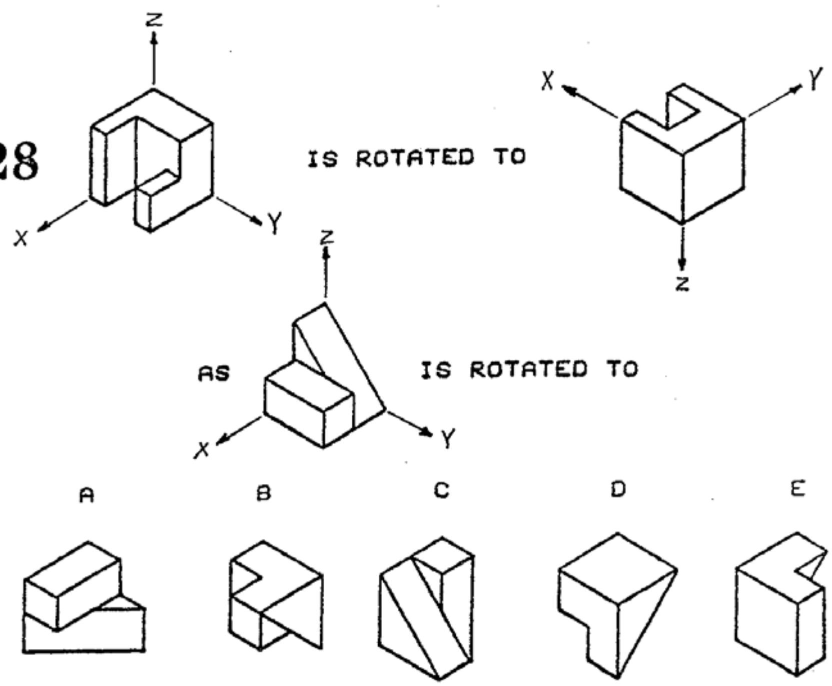

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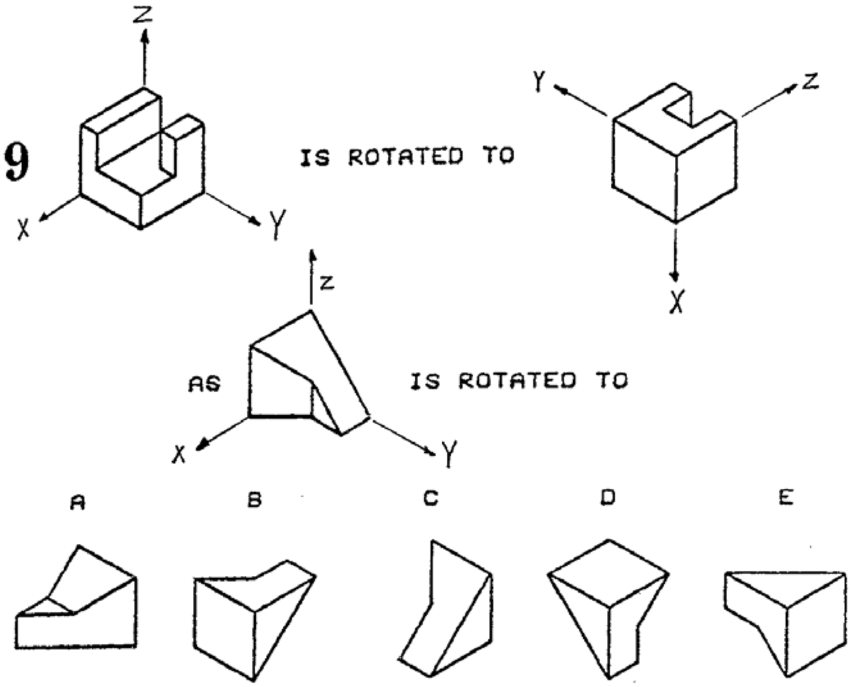

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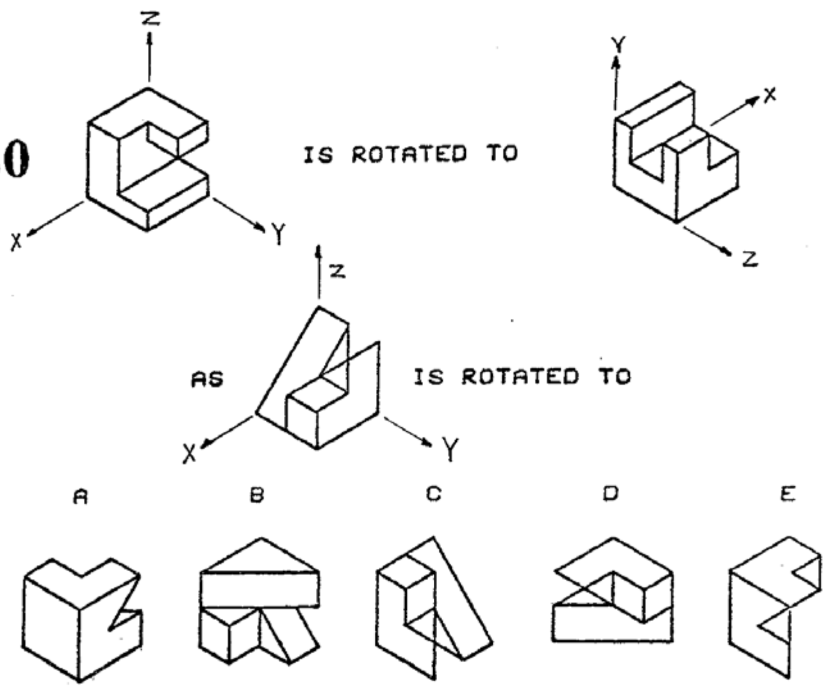

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Appendix B

Survey

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Engineering graphics Survey: Name:

Your participation in this study will only be for the semester you are enrolled in engineering graphics. If you choose not to participate, you will not be penalized. If you begin the study and decide that you want to withdraw, all data pertaining to you will be removed from the research study. Your name will not be published or used in the analysis, and the survey will be destroyed after the study.

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Page One

1.) What is your name (this will only be used temporarily to link your name to a coding number, your name will be erased from the data base once you are assigned a number and will not be used in any analysis. This will happen within ten days)

____

2.) What is your major?

() Biological Engineering

() Civil Engineering

() Electrical Engineering

() Engineering and Technology Education

() Environmental Engineering

() Mechanical Engineering

() Other

3.) If you selected other, please specify. Otherwise please skip this question.

____

4.) What is your gender?

() Female

() Male

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5.) What is your age?

() Under 18

() 18

() 19

() 20

() 21-22

() 23-24

() 25 or older

6.) How many drafting courses have you had in

	0	**1**	**2**	**more than 2**
High School	()	()	()	()
College	()	()	()	()
Technical or Trade School	()	()	()	()
Other	()	()	()	()

7.) If you selected other, please specify. Otherwise please leave this question blank.

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8.) How much prior experience do you have with the following hobbies?

	Very little to none	**Some- I play (or have played) around with it a little, but average less than a few hours a month**	**Moderate- I play (or have played) with it for several hours a month on average**	**Considerable- I play (or have played) with it for several hours a week on average**
Building/ assembly (lego, connex, erector set, ect.)	()	()	()	()
Model construction (rockets, airplanes, cars, trains, ect.)	()	()	()	()
Robotics	()	()	()	()
Radio-controlled toys	()	()	()	()
Video Games- first person shooter (you see what the character sees)	()	()	()	()
Video Games - flight simulator, race car, driving, ect.	()	()	()	()
Video Games - Other	()	()	()	()
Programming	()	()	()	()

9.) If you selected other, please specify. Otherwise please leave this question blank.

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10.) How much experience do you have with the following extracurricular activities?

	Very little to none	**Some- I play (or have played) around with it a little, but average less than a few hours a month**	**Moderate- I play (or have played) with it for several hours a month on average**	**Considerable- I play (or have played) with it for several hours a week on average**
FIRST Robotics	()	()	()	()
JETS	()	()	()	()
Future City	()	()	()	()
TechXplore	()	()	()	()
VEX Robotics	()	()	()	()
Think Quest	()	()	()	()
Lego Engineering	()	()	()	()
INSPIRE!	()	()	()	()
Botball	()	()	()	()
Odyssey of the Mind	()	()	()	()
Other	()	()	()	()

11.) If you selected other, please specify. Otherwise please leave this question blank.

Thank You!

Thank you for taking our survey. Your response is very important to us.

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Appendix C

Letter of Information

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v7 8/27/2009

Utah State University
Department of Engineering and Technology Education
6000 Old Main Hill
Logan UT 84322-6000
Telephone: (435) 797-1795

Page 1 of 1
USU IRB Approved 08/13/2010
Approval Terminates: 08/12/2011
Protocol Number 2709
IRB Password Protected per IRB Coordinator

Letter of Information

Improving Spatial Ability in Engineering

Professor Gary Stewardson and Scott Greenhalgh in the Department of Engineering and Technology Education at Utah State University are conducting a research study to find out more about the spatial ability of engineering students. Your engineering graphics class has been asked to take part in the study. There will be approximately 30 participants at this site and there will be approximately 180 total participants in this research study.

Participating in this research involves no greater risk than that encountered in daily life or normal classroom activities and your participation is voluntary. Participation in the study will require you to take a short (20 question) test of spatial ability at the beginning and at the end of the semester and complete a brief questionnaire consisting of demographics, past coursework and interests and hobbies. Your participation in this study will only be for the semester you are enrolled in engineering graphics. If you choose not to participate, you will not be penalized. If you begin the study and decide that you want to withdraw, all data pertaining to you will be removed from the research study.

While there is no direct benefit or compensation for you in participating, the results from this study may improve student success for other engineering students at Utah State. If you have any other questions or research related problems, you may reach Gary Stewardson at (435) 797-1802 or Scott Greenhalgh at (435) 797-1796.

To protect your privacy, you will be assigned a code number for use in all analyses and reporting of the data. Your name will not appear on any study documents. Research records will be kept confidential, consistent with federal and state regulations. Gary Stewardson and Scott Greenhalgh will be the only researchers who have access to the data collected and it will be kept in a locked file cabinet. The list that links your code number with your name will be destroyed at the end of the semester after you complete the test of spatial ability and questionnaire.

The Institutional Review Board (IRB) for the protection of human participants at USU has reviewed and approved this research study. If you have any pertinent questions or concerns about your rights or think the research may have harmed you, you may contact the IRB Administrator at (435) 797-0567 or email irb@usu.edu. If you have a concern or complaint about the research and you would like to contact someone other than the research team, you may contact the IRB Administrator to obtain information or to offer input.

I certify that the research study has been explained to the individual, by me or my research staff, including the nature and purpose, the possible risks and benefits associated with taking part in this research study. Any questions that have been raised have been answered.

Gary Stewardson, PhD
Principal Investigator
(435) 797-1802
gary.stewardson@usu.edu

Scott Greenhalgh
Student Researcher
(435 797-1796
scott.greenhalgh@aggiemail.usu.edu

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CURRICULUM VITAE

SCOTT GREENHALGH

EDUCATION:

Ph.D Curriculum and Instruction December 2011
Utah State University
Engineering and Technology Education Emphasis

M.S. Engineering and Technology Education February 2009
Utah State University

B.A. Engineering Technology May 2006
Southern Utah University

B.A. Technology Education May 2006
Southern Utah University

Certificate of Civil Design May 2000
Southern Utah University

EMPLOYMENT EXPERIENCE:

Graduate Instructor 2006 - Present
Utah State University

- Taught two courses per semester in the Engineering and Technology Education Department

Courses Taught:

- Computer Aided Drafting and Design
- Construction Systems and Estimating
- Computer Engineering Drafting
- Architecture and Construction Systems
- Woods-based Manufacturing Systems

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Architectural Designer and Owner 2003 - 2009
Stone Owl Architectural Design and Drafting

- Ran and operated an architectural drafting business specializing in residential architecture
- Designed over 100 homes

Required tasks:

- Identifying client needs and wants
- Conceptualizing appropriate designs
- Creating construction documents
- Synthesizing local building requirements, engineering requirements, and builders' requirements

Architectural Designer/ Structural Detailer 2005
Insite Engineering

-
- Prepared construction documents in a civil engineering firm

Architectural Drafter 2000
American TimberCraft

- Prepared construction documents for modular log cabins

AWARDS, EXTRA- CURRICULAR, AND COMMUNITY INVOLVMENT:

2011 Robins Award Finalist for Graduate Teaching Assistant of the Year at Utah State University

2011 Graduate Teaching Assistant of the Year for the Engineering and Technology Education Department

Head Instructor 2003, 2004, 2006
Red Cliff Ascent

- Red Cliff Ascent is a wilderness therapy program for troubled and at-risk teens

Responsibilities as a head instructor included:

- Working with diverse students. Student backgrounds include a variety of cultures, backgrounds and requires sensitivity to issues such as drug abuse, violence, gang activity and depression.
- Ensuring the safety and well- being of students
- Teaching wilderness skills
- Working with psychologists and therapists to provide appropriate help for students
- Mentoring and being a positive role model

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Full-Time Volunteer Representative Jan. 2001 – Dec. 2002
Church of Jesus Christ of Latter-Day Saints

- Representative in Berlin and Mecklenburg-Vorpommen, Germany
- Fluent in German
- Responsibilities included:
- Community service
- Working with local media, schools, and community organization
- Giving informative presentations

PUBLICATIONS AND PRESENTATIONS:

Lammi, M., Greenhalgh, S. (2010). *3D projectile STEM design challenges*. Paper presented at the International Technology and Engineering Education Association Conference, Charlotte, NC.

Schreuders, P. Greenhalgh, S.; Mansfield, S. (2009). *An examination of rapid prototyping in design education*. Paper presented at the American Society for Engineering Educators National Conference, Austin, TX.

Submitted and in Preparation:

Greenhalgh, S. Olsen, D.; Tibbits, S.; Schreuders, P. (2011). *Instructors' Expectations on Rapid Prototyping in Interior Design Education*. Paper submitted for presentation at the Interior Design Educators Conference, Denver, CO.

Greenhalgh, S. Schreuders, P. (2011). An examination of rapid prototyping in design education. In preperation for submission.

Lammi, M., Greenhalgh, S. (2011*). Having Fun With a 3D Projectile*. The Technology and Engineering Teacher, Manuscript accepted for publication.

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