The effects of 3-dimensional CADD modeling software on the development of the spatial ability of ninth grade technology discovery students

K. Lynn Basham

Louisiana State University and Agricultural and Mechanical College, lynn.basham@doe.virginia.gov

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THE EFFECTS OF 3-DIMENSIONAL CADD MODELING SOFTWARE
ON THE DEVELOPMENT OF SPATIAL ABILITY OF NINTH GRADE
TECHNOLOGY DISCOVERY STUDENTS

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
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Doctor of Philosophy

in

The School of Human Resource Education and Workforce Development

by

K. Lynn Basham
B.S., University of Southern Mississippi, 1977
M.S., University of Southern Mississippi, 1985
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ABSTRACT

The purpose of this quantitative study was to determine if there is a difference in the development of spatial abilities of ninth grade Technology Discovery students in Mississippi as measured by the Purdue Visualization of Rotations Test. Students experienced one of three differing instructional methods utilizing Pro/Desktop® 3-D CADD solid modeling software. Participants were students in Mississippi schools operating on a 4 x 4 block schedule during either fall or spring semesters during the 2005-2006 school year, and a control group of students whose schools did not offer CADD. Instructional material designed by the researcher was used for two instructional treatment methods, with existing instructional materials available for the software were used in the third instructional method.

Demographic information was collected for students from 14 schools in the study. The primary research question asked if differences existed by instructional treatment method when spatial ability pretest scores, gender, ethnicity, co-registration in art, and co-registration in geometry were controlled. Analysis of Covariance was conducted to analyze the data for this research question, using the pretest as the covariate and instructional method as the fixed factor. The dependent variable was the posttest score. The other independent variables of gender, ethnicity, and co-enrollment in art and/or geometry were included in analysis. No affects concerning these additional variables was found.

A statistically significant difference existed concerning the method used to instruct students on the use of 3-D CADD modeling software. The instructional consisting of method of teacher-lead instruction using the software in a design lesson, followed by student-directed modular instruction, was found to be effective. These lessons included 3-D physical models manipulated by the teacher and students. The group of students taught using this method had
higher mean posttest scores than students instructed with other methods. The other instructional methods did not significantly affect student achievement on the test of spatial ability.
CHAPTER 1: INTRODUCTION

Spatial abilities are fundamental to human functioning in the physical world. Spatial reasoning allows people to use concepts of shape, features, and relationships in both concrete and abstract ways, to make and use things in the world, to navigate, and to communicate (Cohen, Hegarty, Keehner, & Montello, 2003; Newcombe & Huttenlocher, 2000; Turos & Ervin, 2000). Spatial concepts are used to visualize the physical world and the relationships of tangible objects. Visualizing intangible boundaries such as state and national borders helps organize, orient, and compartmentalize knowledge of the world. In a similar way, this ability is used to envision new things, and establish relationships of concepts in the mind (Jones & Bills, 1998).

One source estimates that 80% of jobs primarily depend on spatial ability, not on verbal ability (Bannatyne, 2003). A broad spectrum of career clusters requires spatial ability. Surgeons, pilots, architects, engineers, mechanics, builders, farmers, trades people, and computer programmers all rely on spatial intelligence in their workday lives (Bannatyne, 2003). Fields such as inventory control and office support positions that are considered less technical in nature also require spatial abilities.

People have been heard to say that they have no spatial ability, meaning they are not good at interpreting graphic representations, have difficulty with directions and location of things, or are poor at estimating size or visualizing things and their relationships to one another (Newcomer, Raudebaugh, McKell, & Kelley, 1999). A common statement is “I can’t draw a straight line without a ruler.” Yet, these people successfully function in the world around them, because they have more spatial ability than they realize. Research findings indicate that spatial ability can be improved in both children and adults (Potter & van der Merwe, 2001; Strong & Smith, 2001). A potential benefit of improving spatial abilities is the improvement of academic
achievement in areas of mathematics and science (Keller, Wasburn-Moses, & Hart, 2002; Mohler, 2001; Olkun, 2003; Robichaux, 2003; Shea, Lubinski, & Benbow, 1992).

Mathematical concepts are intangible things with relationships, and are often difficult to teach. A relationship has been shown between spatial and mathematical ability, and some indicators suggest spatial ability is also important for achievement in science and problem solving (Grandin, Peterson, & Shaw, 1998; Keller et al., 2002). Yet there is little emphasis in the current educational system toward development of spatial abilities. Perhaps that is because such abilities are taken for granted, or believed to be innate.

The National Council of Teachers of Mathematics (NCTM) produced *Principles and Standards for School Mathematics* (2000). This document maintains that 2-D and 3-D spatial visualization and reasoning are core skills that all students should develop (Keller et al., 2002). The *Geometry and Spatial Sense* strand is described as content that extends beyond the identification of shapes into the ability to transform and combine those shapes. The strand also includes the expression of reasoning within both formal and informal settings. Proportional thinking and estimation of measurements are other important spatial connections for students. According to Ritz (2004) two of the five *National Assessment of Educational Progress* (NAEP) strands for mathematics are *Measurement*, and *Geometry and Spatial Sense*. Data indicates that although overall average performance in each strand has increased between 1990 and 2000, geometry and measurement are the bottom strands each year, with eighth-grade student achievement lowest in geometry and spatial sense (Ritz, 2004). Ritz states that since NAEP data indicated that students in grade 8 need most assistance with measurement, geometry, and spatial sense, technology education instructors need to highlight these concepts in the contextual activities that are a key feature of this field.
Quality teaching practices have been shown to increase the degree to which students transfer their learning to new situations and events (Alagic, 2003). The NCTM included computer technology in their principles of quality mathematics education. Research implies that computer technology is helpful in supporting learning, and is especially useful in developing higher order skills of analysis, critical thinking, and scientific inquiry. Of course, some computer applications have been shown to be more successful than others. Because the external world is interpreted according to one’s own experiences, knowledge, and beliefs, each person visualizes the external world at least slightly differently. Various factors influence how well even the most promising computer applications are implemented (Roschelle, Pea, Hoadley, Gordin, & Means, 2001). According to Guidera (2002) the increased use of 3-D parametric modeling programs is bringing about a fundamental shift in the use and instruction of computer aided drafting and design (CADD) to a model-centric paradigm that may ultimately have a tremendous impact on learning. The availability of computers and CADD software in schools has the potential to increase student transfer of learning.

Another widely publicized aspect of spatial ability is the apparent difference between genders. Generally, it is said that boys have better spatial ability than girls. Findings from previous studies indicate a possible relationship between gender and spatial visualization ability (Alias, Black, & Gray, 2002). However, there is evidence that males perform better on spatial rotation tests, but not necessarily on other aspects of spatial ability (Grandin et al., 1998; Santacreu, 2004). Other findings of interest are disparities by race/ethnicity, and socioeconomic factors. The strand with the largest disparity between African Americans and white students in grade eight is measurement. The gap increased from 40 points in 1990 to 58 points in 2000. A similar gap exists when comparing whites and Latinos (Ritz, 2004). The wide-spread use of
multimedia and video games may be impacting these differences, and the differences may also affect how students react to instructional strategies.

If spatial abilities are important for improving academic success and can be improved through various ways, then identifying techniques that aid in development of these abilities will benefit students. One means that may affect development of spatial ability is the study of Computer Aided Design and Drafting (CADD) (Guidera, 2002; Potter & van der Merwe, 2001).

The impact of high performance rendering and animation software, solid modeling packages, virtual reality, and online testing opens a number of doors for spatial visualization research and measurement (Strong & Smith, 2001). One might ask why use 3-D imagery software instead of video or photographs to depict real events. Three-dimensional CADD modeling software is a way of representing certain aspects of the sensory world that can be difficult to comprehend in other ways.

A description of how an object moves through space can be complicated to visualize. It can be explained that a planet moves around the sun in an elliptical orbit. Assuming that students understand the terms *planet, space, ellipse*, and *orbit*, they might be able to imagine the relationships. Planets and orbits can even be physically modeled. Even so, the words used to form the mental image might be quite different in meaning to different students. It is possible to painstakingly describe difficult concepts in verbal terms using a sequential approach. By the time one gets to the end of the explanation, an important aspect may be forgotten or be misunderstood. Much ambiguity can be overcome by viewing and producing 3-D animation using computer software. Such software delivers all this information simultaneously, and also has the potential to activate alternative knowledge structures specific to 3-dimensions; those that deal with visual-spatial orientation and kinesthetics (Steed, 2001).
Background and Significance

Most Mississippi students in grade nine take a modular technology education course named Technology Discovery. One of the instructional modules in this course is computer-aided design and drafting (CADD). With the release in 2001 of the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association, 2000), comparison of course activities to standards revealed a weakness in the area of teaching about design. In addition, computer and software developments changed greatly over the years since the initial implementation of the course. During the 2002 revision of the Technology Discovery curriculum, a decision was made to adjust the curriculum to include specific time to study design, and to specify that 3-dimensional CADD should be implemented. A major characteristic of 3-D CADD modeling is manipulation of geometric shapes using spatial ability.

In order to implement 3-dimensional software in programs statewide, the researcher undertook exploration of available 3-dimensional software. A program called *Pro/Desktop*® (2003) was made available through the *Design and Technology in Schools Program* sponsored by the Parametric Technology Corporation (PTC). This made 3-dimensional parametric CADD software and instructional materials available free to Mississippi teachers upon completion of a 12-hour training session. During October 2003, approximately 300 teachers successfully completed training for the software. Many reported implementing it immediately. When asked by the researcher, teachers using the software often stated that students loved the program, as opposed to previous CADD programs. Some teachers did not implement the change as a module, usually because their existing 2-dimensional CADD programs were still functioning. Some teachers utilized both 2-and 3-dimensional programs. Teachers have been encouraged to use the software as an enhancement for other instructional modules utilized in the course.
The primary method for delivery of CADD instruction was student pairs using a student-directed modular learning environment. Teacher-focused instructional methods were also utilized in some aspects of the course. Observation of how the software was being utilized in classrooms resulted in the conclusion that an instructional module was needed to assist Mississippi students and teachers in effective use of the software.

This study investigated whether use of Pro/Desktop® software had an effect on the development of spatial ability of ninth grade students, comparing three instructional methods and a control group. If the study indicated that use of 3-D CADD modeling software increased student achievement on a spatial ability test, further use of the software might be made in other aspects of curriculum.

Limitations of the Study

This study was carried out under unusual circumstances. Hurricane Katrina disrupted and damaged or destroyed schools from the Mississippi Gulf Coast to at least 150 miles inland in late August, 2005. The schedules of schools in approximately half of the state were disrupted due to power outages, trees blocking roadways, and facilities being used as shelters for evacuees. Materials mailed to the initial 15 teachers in the study were reported received as late as two months after they were mailed. Teachers who joined the study after classes resumed were, in many cases, unable to conclude the number of CADD rotations needed for the study. These unusual circumstances affected the researcher, students, and teachers. Contemporary history must be taken into consideration in determining the value of data collected. Replication of this study during a school year not interrupted by traumatic events might result in further useful knowledge regarding the effect of instructional methods used for all three treatment groups.
The study did not include students enrolled for a full school year of Technology Discovery, only students who completed the full course during a semester. Therefore, the time spent on CADD instruction incorporated fewer days than if students spent a full year on the course. Only ninth grade students were included, limiting the ability to generalize to other grades.

Much research about spatial abilities pertains to the growing fields of artificial intelligence and geo-spatial information technology. These areas were not included in the research. Technology Discovery students do study spatial information technology (SIT), so activity plans were included to address that factor.

Statement of the Problem

The purpose of this study was to determine if there was a difference in the development of the spatial abilities of ninth grade Technology Discovery students by whether they were taught using 3-dimensional CADD software. The study also determined if there is a difference in the development of spatial abilities of ninth grade Technology Discovery students by the instructional methods used.

Research Questions

The following research questions were answered:

1. What are the demographic characteristics of students enrolled in Technology Discovery classes? The demographic and personal variables included in this research question are gender, ethnicity, co-registration in art, co-registration in geometry, and economic status of the school.
2. Do differences exist in spatial ability test scores of technology discovery students as measured by the Purdue Visualization of Rotations Test, when the pretest scores are controlled, and students are instructed using the following instructional treatments? (See Table 1)

   a. Teacher and Module Treatment Group: Teacher-directed instruction utilizing researcher-developed lesson plans that incorporate the use of 3-D models and 3-D CADD software, followed by researcher-developed modular student-directed learning utilizing 3-D models and 3-D CADD software.

   b. Module Only Treatment Group: Instruction utilizing researcher-developed curriculum materials that incorporate the use of modular student-directed learning utilizing 3-D models and 3-D CADD software.

   c. Existing Material Group: Instruction utilizing existing modular student-directed learning curriculum materials using 3-D CADD software.

   d. No CADD Instruction Treatment Group: No instruction about CADD.

Table 1. Instructional Treatment Components for the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Instructional Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3D CADD</td>
</tr>
<tr>
<td>1. Teacher with Module</td>
<td>X</td>
</tr>
<tr>
<td>2. Module Alone</td>
<td>X</td>
</tr>
<tr>
<td>3. Existing Materials</td>
<td>X</td>
</tr>
<tr>
<td>4. No CADD Instruction</td>
<td>X</td>
</tr>
</tbody>
</table>

Note. These treatments are described in more detail in Chapter 3.

3. Do differences exist by instructional treatment group in spatial ability of Technology Discovery students as measured using the Purdue Visualization of Rotations Test scores when spatial ability pretest scores, gender, ethnicity, co-registration in art, co-registration in geometry, and economic status of the school are controlled?
Definitions of Terms

The following terms are defined to assist the reader:

**CADD**--- computer aided design and drafting

**CAM**--- computer aided manufacturing

**Mental imagery**--- mental invention or recreation of an experience that resembles the actual experience of perceiving an object or event, either with or without direct sensory stimulation (Barkowsky, 2001).

**Modular Instructional Method**--- student-directed learning guided by such things as activity manuals and computer-aided instruction. Instructional material is usually designed for students to work in pairs. Modules include all supplies and equipment needed for activities in a focused workstation.

**MDE**--- Mississippi Department of Education.

**Spatial**--- of, relating to, involving, or having the nature of space (Isaac & Marks, 1994).

**Spatial Ability**--- cognitive functions that make it possible for people to deal effectively with spatial relations, visual spatial tasks, and orientation of objects in space (Sjölinder, 1998).

**Spatial Cognition**--- cognition in which input references space.

**Spatial Intelligence**--- ability to form a mental model of a spatial world and to be able to maneuver and operate using that model (Gardner, 1993).

**Spatial Perception**--- ability to determine spatial relations despite distracting information (Hubona & Shirah, 2004).

**Spatial Reasoning**--- methods and tools that represent or process spatial information to derive, make explicit, or predict new spatial knowledge.
**Spatial-temporal reasoning**---the ability to create, maintain, transform, and relate complex mental images even in the absence of external sensory input and feedback (Grandin, 1998).

**Spatial Visualization**---ability to manipulate an object in an imaginary 3-D space and create a representation of the object from a new viewpoint (Strong & Smith, 2001).

**Technology Discovery**---Mississippi ninth grade technology education course.

**Visualization**---act or process of interpreting in visual terms or of putting into visual form, also the formation of visual images.
CHAPTER 2: REVIEW OF LITERATURE

Introduction

The word *Spatial* means *of, relating to, involving, or having the nature of space* (Isaac & Marks, 1994). For humans, spatial ability is the intellectual ability primarily used to function and operate in 2- or 3-dimensional spaces (Bannatyne, 2003). Familiar terms are used to describe both spatial relationships and features. Spatial relationships are described by terms such as over, under, beside, on, inside, outside, between, left, right, up, down, attached, and apart. Terms like flat, slanted, straight, crooked, curved, round, tall, short, height, width, depth, side, top, and bottom describe spatial features (Newcombe & Huttenlocher, 2000).

People have a physical presence in space, and sensors in the form of eyes, ears, noses, etc. collect information about space and one’s presence in it. “Thus space is a fundamental category of thought, one that plays a deep role in many aspects of human cognition” (Epstein & Marefat, 1997, Introduction ¶1). For instance, actions or responses are often required of people due to consequences of movement of external objects. The ability to predict the consequences of the motion of objects and perspective change is thus essential for everyday reasoning, and probably confers adaptive fitness that allows people to function in the world (Zacks, Mires, Tversky, & Hazeltine, 2000).

After WWII, the value of differentiating between types of intelligences became widely appreciated with the rapid growth of science, engineering, and technology, all of which have spatial ability as their primary basis (Bannatyne, 2003). Over time, spatial reasoning has developed as a significant target subject in the study of both human and machine intelligence. Spatial reasoning has been studied and applied in such areas as computer graphics, robotics, CAD/CAM, spatial databases such as Geographic Information Systems (GIS), computer vision,
image processing, linguistics, neuroscience, and expert systems (Epstein & Marefat, 1997). Recent vast changes in computer technology have drawn attention to spatial visualization (Strong & Smith, 2001). Computer scientists and cognitive scientists approach the analysis of spatial representation and cognition in very different ways resulting in quite separate issues and vocabulary in the two fields (Epstein & Marefat, 1997). This review of literature will focus on spatial issues as they relate to human cognition.

**Importance of Spatial Ability**

In order to interpret, understand, and appreciate our inherently geometric world, spatial understanding is necessary (Lowrie, 1994). According to Newcombe and Huttenlocher (2000), as the use of tools and making of artifacts became part of the human repertoire, the ability to imagine and construct useful implements and materials likely increased reproductive advantage. In the current world, spatial competence is still basic to daily activity. It is also basic to higher-level activities such as sophisticated mathematical thinking, and the use of information presented in such representations as maps, graphs, diagrams, and other spatial layouts. It is even basic to the understanding of verbal descriptions of spatial material such as following directions and instructions for hooking up electronic equipment.

According to Olkun (2003) spatial thinking is used to represent and manipulate information in learning and problem solving. These skills are required in many intellectual endeavors such as solving problems in engineering, design, physics, and mathematics. It is also relevant to problem solving that is not dependent on spatial strategies. In cases where non-spatial strategies are required, spatial ability influences the degree to which a problem solver is able to develop and evaluate these strategies (Alias et al., 2002). Problem solving commonly uses perceptual representations to partially encode the problem elements involved, which is
helpful in supporting inferences. Hypotheses and ideas are often reflected in diagrams and other such graphical representations (Chandrasekaran, 1997). Many have noted that good spatial conceptualization is not an asset but a necessity for engineering as well as other math and science disciplines (Kinsey, 2003). Zacks et al. (2000) state that the ability to imagine and reason about changes of objects and their spatial layout is important, both for everyday cognition and for reasoning in technical domains. Proficiency in spatial ability has also long been associated with success in cognitively demanding educational tracks and occupations such as architecture, chemistry, and medical surgery, as well as in trades and certain industrial positions (Shea et al., 2001).

Additional studies collected from diverse journals including astronomy, music, and geology support this view (Mohler, 2001). A 2003 study examined the effects of spatial ability in promoting logical thinking abilities of students with regard to programming language (Tai, Yu, Lai, & Lin, 2003). Kaufmann, Steinbügel', Dünser', & Glück (2003) indicated that training of spatial abilities using Virtual Reality is of strong interest in application areas such as surgery, navigation, and way finding, as well as for rehabilitation of patients and for pretest space flight training. In fields such as biology, specimens are often presented as 2-D slices. These diagnostic imaging representations are also used in anatomy, histology, and botany (LeClair, 2003). A description of the Johns Hopkins Spatial Test Battery describes spatial ability as important in visualizing the structure of complex molecules in chemistry (Johns-Hopkins University, 2005). The need for technological and scientific literacy in day-to-day actions and in the workforce includes the need for spatial ability skills. These skills will enable students to think spatially and utilize technologies as simple as a bar graph and as complex as GPS, CADD, and
virtual reality systems. It is critical that students be equipped with these skills (National Research Council of the National Academies, 2006).

Effect of Spatial Abilities on Academic Achievement

Educators have debated whether increased spatial aptitude improves performance in science, as well as other subjects (LeClair, 2003). Very little academic training in science focuses on spatial thinking and most instructors assume the existence of necessary spatial skills (Schultz, Huebner, Main, & Porhownik, 2003). It is also suspected that spatial ability contributes additional validity to mathematical and verbal reasoning abilities. Spatial ability aids students in the choice of educational pursuits and, hence, aspects of their subsequent career development. Shea et al (2001) state that Gardner suggests one’s skill in spatial ability determines how far one will progress in the sciences. “Wide agreement exists that spatial ability distinguishes group membership and performance in certain artistic, engineering, and scientific disciplines” (Shea et al., 2001, p. 604).

Assessments of spatial abilities have seemingly been neglected in working with intellectually talented students. This may stem from false beliefs that spatial ability is more relevant to vocational trades and less relevant to academic or professional endeavors as the latter tend to place a heavy emphasis on verbal competence. Another possibility, however, is that evidence of the differential and incremental validity of multiple abilities has been lacking. Tests of spatial ability display limited usefulness for predicting traditional academic criteria, partly because academic accomplishment assessment is saturated with content specifically indicative of reasoning with numbers and words (Shea et al., 2001).

While educators have not agreed upon a common definition of spatial ability, most agree that such skills or abilities are important in the complete education of a child. Until recently,
“simple merchant” math was enough for most people. Today, individuals are increasingly called
upon to use mathematical skills not only to calculate basic needs, but also to reason about
uncertainty, change, trends in data, and spatial relations (Roschelle et al., 2001).

According to Keller et al. (2002) numerous correlation studies have shown that spatial
ability is positively related to mathematics achievement. Developing spatial sense, as well as
number sense, is a fundamental goal of mathematics instruction that develops skills in problem
solving in particular and doing mathematics in general. Strong spatial sense permits students to
formulate image-based solutions to mathematics problems. Having a mental image of a
parallelogram or circle is fundamental in geometry. Without spatial sense, students may act
mechanically with shapes and symbols, having little understanding of their meaning and
relevance (Reynolds & Wheatley, 1999).

As indicated, spatial visualization is an important factor in student success in a variety of
spatial domains including geometry and other higher forms of math, chemistry, and physics
(Smith, 2001). Some proponents say that spatial ability and geometry are dependent, and
improvement in one leads to improvement in the other. Lowrie (1994) advocates that the process
of visual reasoning be given the equal status and attention as the algebraic reasoning process.

Enhancing spatial abilities of students is one of the roles of geometric activities (Smith,
proven to be a powerful means of improving spatial abilities; therefore geometry must be
vitalized in ways that avoid destroying pupil’s interests (as cited in Kaufman et al. 2003).
Kaufman recommends that the teaching of geometry should promote student use of visualization,
spatial reasoning, and geometric modeling to solve problems Geometry is more than shapes; it is
also spatial orientation and location. Communication in learning geometry makes vocabulary
important, but vocabulary is sometimes taught as rote, which is not the purpose of studying
generalom. Children need to describe shapes in terms of their feature attributes, analyze the role
of attributes and make logical arguments to justify conclusions about geometric relationships
(Kaufman et al., 2003). For example, the Geometry Standard (National Council of Teachers of
Mathematics, 2000) states the need to put shapes together and take them apart. Neglecting this
aspect deprives students of a foundation to understand everyday applications such as visualizing
2-D and 3-D objects, giving and receiving directions, using maps, using geometric models for
numerical and algebraic relationships, working with coordinates, and graphing.

Jones and Bills (1998) comment that a visual image not only organizes the data at hand in
meaningful structures, but is also an important factor in guiding the analytical development of a
solution. Recognizing the complex nature of visualization and imagery, especially its role in the
development of geometrical reasoning, there is definite value in emphasizing visual
representations in all aspects of the math classroom.

Current educational theories such as constructivism propose that to truly understand new
ideas, students must personally construct meaning using their own knowledge and reasoning.
Traditional elementary and middle school geometry focus on learning lists of definitions and
properties of shapes. True understanding of math arises as students progress through phases of
manipulation, abstraction, and reflection. Cycling through these phases time and again lets
students construct increasingly sophisticated mental models of concepts. Learning lists of
properties is not as important as being involved in developing and using property-based concepts
such as angles, angle measurement, features, length, parallelism and congruence in order to
describe and analyze spatial relationships (Battista, 2002).
The current shift away from memorization of formulas toward conceptualization and creativity encourages the capacity to develop mental imagery and transform these images in mathematical thinking. These are important skills in numerical and geometric learning (Reynolds & Wheatley, 1999). Differentiating between different processes is needed in mathematics curriculum. Curriculum that is more balanced, placing increasing importance on spatial and visual development, will allow children to remain motivated and stimulated in the classroom. Some children can be overlooked if too much emphasis is placed on analyzing and not enough on building a synthesis of ideas. This is perhaps more the case in spatial ability than any other area (Lowrie, 1994).

**Intelligence and Spatial Ability**

Spatial ability is an important, distinct aspect of human intelligence, separate from behavioral, computational, and neurological cognitive activities (Newcombe & Huttenlocher, 2000). According to the Columbia Encyclopedia, Sixth Edition (2005, ¶1), intelligence can be described as the general mental ability involved in calculating, perceiving, forming relationships and analogies, classifying, learning quickly, storing and retrieving information, using language fluently, generalizing, reasoning, and adjusting to new situations. Various investigations by psychologists theorize from one to 150 mental abilities involved in intelligence. Howard Gardner (1993) proposed eight separate intelligences, including spatial intelligence, one of the expressions of which is being accurate and using memory in spatial tasks. In the Columbia Encyclopedia (2005) intelligence is defined by Alfred Binet as the totality of mental processes involved in adapting to the environment. This definition seems to encompass all abilities well.

In writings by Sjolinder (1998) she agrees with Cattell that general intelligence can be divided into fluid and crystallized intelligence. Crystallized intelligence represents the sum of
acquired knowledge and experience, or what a person knows. It is usually measured with tests of verbal knowledge and general information. Fluid intelligence represents the ability to reason and apply information in new situations, and is usually assessed with tests of general reasoning ability and also with math and spatial ability measures. Spatial knowledge involves crystallized intelligence, while spatial ability predominately involves fluid intelligence. Spatial abilities are cognitive functions that make it possible for people to deal effectively with spatial relations, visual spatial tasks, and orientation of objects in space (Sjölinder, 1998). Spatial ability is more than mental pictorial representations; it includes analysis of structural relationships so that operational thought can take place. Spatial visualization involves comprehending and carrying out imagined movements of objects in 2- and 3-dimensional space (Keller et al., 2002). Spatial thinking occurs when visualization and rational thought are applied together (Lowrie, 1994).

There is nothing to distinguish the actual process of spatial reasoning from any other form of reasoning. Brain research indicates some key features used in spatial-temporal reasoning are the transformation and relating of mental images in space and time, symmetries of the innate cortical firing patterns used to compare physical and mental images, and the natural temporal sequences of those innate cortical patterns. Grandin et al. (1998) assert that spatial-temporal reasoning is the ability to create, maintain, transform, and relate complex mental images even in the absence of external sensory input and feedback.

Zacks et al. (2000) state that the two classes of mental transformation particularly important to human cognition are object-based and egocentric perspective. Object-based spatial transformations happen when a person imagines rotations or translations of how an object would look when moved in relation to an environment. Object-based transformations allow us to anticipate how objects will look if their position changes. This is critical for grasping, catching,
avoiding, and manipulating things. Egocentric perspective transformations happen when a person rotates or translates their point of view relative to the reference frame of the object, envisioning how the environment will look if the person is in a different location. Egocentric perspective transformations allow us to anticipate different points of view of the environment. This is critical for interacting and navigating in environments, and for describing them.

Categories of Spatial Abilities

Although there is no definite consensus as to the number of distinct spatial abilities that exist, there are several categories. The two most commonly agreed upon categories are mental rotation and visualization. A third category is usually perception, although some sources name orientation as the third category (Hegarty & Waller, 2004; Kaufmann et al., 2003). Bodner and Guay (1997) portray orientation and visualization as the two major categories as the result of factor analysis of various tests used to measure spatial ability.

Mental Rotation is sometimes referred to as spatial relations. This is the ability to mentally rotate a single stimuli object in the mind in order to envision it from different angles. Tests of this ability are generally timed. This is a less complex ability than visualization (Kaufmann et al., 2003).

Although accepted as a valid psychological construct and measurable by a number of standardized tests, spatial visualization remains elusive to unambiguous definition because it is a non-verbal ability. Smith (2001) defines spatial visualization as the ability to solve multi-step problems involving configurations of shapes, primarily using mental imagery which clearly preserves the topological and geometric relations of the problem, while possibly involving additional logical, verbal, and symbolic reasoning. Potter & van der Merwe (2001) explain that spatial visualization refers to the ability to mentally rotate in space 2-and 3-dimensional objects.
with one or more moveable parts. This is a complex task involving mental manipulation and integration of stimuli with multiple moveable parts. Spatial visualization tests rely on the power of the individual to accomplish the task, not on speed (Olkun, 2003).

The term *imagery* is also associated with visualization. Two kinds of imagery are kinetic and transformational. Kinetic imagery is based on one’s experience of an object’s movement. This allows one to judge whether an approaching object is likely to hit its target. Such imagery allows people to decide if the trajectory of a basketball is likely to drop the ball through a hoop. Transformational imagery allows the mental view of an object as it changes shape or form. This requires mental manipulation of a visual image from a different perspective, such as imagining the shape change of an object which has moved (Potter & van der Merwe, 2001).

The spatial perception category of spatial ability is described as a sensation in the brain occurring in the immediate presence of stimuli. An individual perceives an object or presence, consciously or unconsciously. An example of perception is the actions taken while driving a car. There are objects that immediately stimulate the brain and cause action on the part of the driver. Perception does not include memory, reflection, or conscious reasoning.

The spatial orientation category of spatial ability is the capacity to orient oneself in space in relation to objects and events; and the awareness of where one is located. Because of this, it may be that spatial abilities were even more crucial for survival in prehistoric times than today. Because of specific needs of hunting cultures, members tested exhibit good visual discrimination and spatial skills as shown by embedded figures tests. Groups for whom hunting is important for survival better perform the tasks on such tests. But contemporary human spatial abilities are not necessarily inferior to that of hunting cultures. Urban survival requires different, more verbally based, cognitive abilities. Current abilities may have evolved due to new living and cultural
conditions. Right brain specialization for spatial ability can be correlated with language acquisition and evolution (Sjölinder, 1998).

Categories of spatial abilities include mental rotation, visualization, perception, orientation, and concepts such as imagery. Various sources define these abilities differently, but most agree these are the major classifications of abilities. Critical to spatial abilities is the ability to visualize.

Spatial Strategies

One approach to thinking about spatial reasoning is by analyzing the processes people actually use to solve spatial tasks. All tasks can be solved in different ways, and people not only use different strategies, they may shift strategies during a task. The more complex a task, the more different strategies can be used to solve it. Two basic strategies are holistic and analytic. These categories should not be viewed as mutually exclusive (Kaufmann et al., 2003). A study of strategies used to solve spatial visualization tasks concluded the analytic approach uses feature comparison to identify key features in figures to locate change. Holistic, or spatial manipulation strategy, involves mental movements of the object, such as rotation.

Holistic strategies involve mentally representing and manipulating spatial information, using information about the relationships between elements in the mental representation. Subjects who reported the use of spatial manipulation spent significantly longer mean times in studying target figures than those who reported using analytical strategies (Burin, Delgado, & Prieto, 2000). Examples of holistic strategies are imagining how a figure is rotated, or how a 2-dimensional shape can be folded into 3-dimensions.

Analytic strategies reduce spatial information to non-spatial format. For instance, a route can be represented as an ordered list of landmarks. When deciding if a rotated figure is the same
as one previously viewed, a comparison of features is an analytic approach. Analytic strategies usually take less mental effort than holistic strategies (Kaufmann et al., 2003).

Studies have also indicated that some form of relationship exists between spatial aptitude and spatial visualization ability. Aptitude has been shown to affect choice of strategy, and choice of strategy has been shown to affect performance on spatial tests (Alias et al., 2002). There is a relationship between time and spatial visualization. Without time pressure, people often use non-spatial strategies to solve spatial problems. The amount of time elapsed as well as success in solving the task gives a more accurate measure of spatial ability (Smith, 2001).

Relationships between spatial aptitude and spatial visualization affect the strategies used to solve spatial problems. Although an individual may favor analytical or holistic strategies, both are used, sometimes in combination, during spatial reasoning to solve spatial tasks.

Acquiring Spatial Information

An important factor in how spatial information is processed depends on the method of acquiring the information. According to Chandrasekaran (1999), people acquire such information through mental imagery, visual, auditory, kinesthetic, and haptic means. Vision provides perception of an object and its relationship to other things. Auditory senses may provide similar information by indicating that a bird (object) is located in a particular tree (relationship), or that when a plate was dropped, the crash heard originated in the kitchen. Kinesthetic methods include both experience and feeling an object. An example in one experiment told the researcher that people playing a game being tested reported the experience of navigation was easy to process but that the control buttons felt hard to reach (physical experience). Gaining information through the haptic method involves personal experience, such as working in a room or following a route. Someone who has previously followed a route will process the experience and follow
the route more easily a second time than someone without the experience. Another method of acquiring spatial information is mental imagery, in which people mentally recreate or invent an image that resembles the actual activity or object. For instance, as a story is read, one mentally imagines the spaces, objects, and relationships based on verbal descriptions (Chandrasekaran, 1999). In each instance, the spatial information was acquired through a different means, and automatically processed using spatial abilities.

Isaac and Marks (1994) view spatial ability from the perspective of relations, entities and structure. Relations refer to images assembled in the mind from haptic or pictorial experience. An entity refers to a moveable object such as a ball or a map, while landmarks are things that should not be moveable. Structure refers to types of spaces. Haptic spaces are defined by bodily interaction or touching, pictorial spaces are understood through visual experience, and transceptual spaces refer to those learned through inference during way-finding.

Development of Spatial Ability

Cognitive factors of spatial abilities are developed when humans interact with the world around them. They gain procedural knowledge from interacting with objects; in other words, using and manipulating the things around them. Configurational knowledge is gained through observation and interaction. Declarative knowledge is the factual information gained and used to communicate. For instance, the knowledge that a sphere is round, and that inside the box refers to objects located in a particular space defined and understood to be a box are both declarative knowledge (Isaac & Marks, 1994).

Potter and van der Merwe (2001) report that Piaget and Inhelder suggested that perception, mental imagery, and language develop over the entire life-span of the individual, as separate processes which are used in thought. Spatial abilities first develop as babies interact
with their surroundings (Newcombe & Huttenlocher, 2000). As they get older, their spatial understanding develops but the expression of this understanding via intelligence or symbolic code remains difficult. Children may find their way around, and what they are looking for, but they often will lack the capacity to provide a map, a sketch, or an overall verbal account of the relationship among several places (Lowrie, 1994). “Some developmental evidence suggests that encoding and retrieval of landmark knowledge may precede other sorts of spatial knowledge” (Sjölinder, 1998, p.53). Coding an object’s location with respect to an external frame of reference involves noting its relations to other objects. Stable landmarks provide the basis for short-term spatial coding that occurs during common activity such as the search for a misplaced item. The only functionally vital characteristic of a landmark is that it should be unlikely to move (Alias et al., 2002).

Acquisition of spatial knowledge can be divided between primary and secondary spatial learning. Primary learning refers to spatial memories based on direct experience. Three main types of spatial knowledge gained from primary spatial learning are landmarks (reference points), route knowledge, and configurational knowledge. Secondary learning refers to knowledge that is symbolically acquired, such as from studying maps and diagrams. The memory obtained from experience is different from memory obtained from representations (Sjölinder, 1998).

Cognitive science researchers explain differences among spatial abilities of individuals by both biological and environmental variables. Bunch (2005) describes such theories as Hunter-Gatherer and “Bent Twig”. The latter is based on the idea that people who have many experiences involving solving spatial problems will learn spatial strategies and enhance their natural abilities. Hunter-Gatherer refers to the theory that biologically, males evolved as hunters,
while females evolved as gatherers. These roles imply inherent spatial abilities suited to the activities.

Differences in spatial visualization ability and in its acquisition have been ascribed to a number of variables, including cognitive development, aptitude, spatial experience, and gender. Regularly engaging in tasks that require spatial problem solving such as gymnastics, clothing design, etc., together with specific spatial task practice and training are strongly associated with better spatial performance. Spatial experiences acquired through life experiences or formal education have been suggested to contribute to differences in spatial visualization ability (Alias et al., 2002; Schultz et al. 2003). In developing visualization skills, there appears to be a relationship between acquisition of skill and hands-on interaction. A combination of touching and different viewpoints seems to be effective. Scaffolding for learning mental image-based transformations such as mental rotation, particular to the system of shapes, can be provided through hands-on activity. The additional sense information of integrated visual and tactile processes, along with the motor processes associated with hand-eye coordination assists in interactively solving spatial problems (Smith, 2001).

Multiple studies found that individuals having active participation in musical activities such as singing or playing an instrument had stronger spatial visualization skills than their counterparts who did not engage in such activities. The finding that musical experience influences development of visualization supports prior research that the ability to recognize, execute, or create a melodic pattern is a spatial ability similar to mental rotation. Robichaux (2003) states that studies of the impact of the cultural aspects of one’s environment on development of spatial visualization ability indicate that children who grow up in environments that promote involvement in spatial activities in school or at play, or whose parents have an
occupation involving spatial ability, had higher spatial visualization than children who did not have these influences. The more a subject participated in spatial activities such as playing with blocks, participating in certain sports, drawing in 3-dimensions, and others, the higher his/her spatial test scores (Robichaux, 2003).

The development of spatial ability occurs as people interact with the world around them, beginning in infancy. They develop knowledge and abilities throughout their lives through primary learning involving direct experience. Secondary learning is gained through symbols such as descriptions and maps. There are multiple theories about the effects that both biological and environmental factors have on the development of spatial abilities.

Gender and Spatial Ability

Many researchers have cited evidence for the existence of sex differences in spatial skills while others have noted weaknesses in these studies. It can be argued that statistically significant gender differences often account for only negligible fractions of the variance in spatial ability (Bodner & Guay, 1997). Both natural and sexual selection have been suggested as evolutionary processes that separate females and males on spatial abilities (Bunch, 2005). Male superiority on mental rotation tasks may be the most persistent individual ability difference in the literature. Although the largest difference is in mental rotation, tests of visualization factors show differences between genders are small or null (Burin et al., 2000). Indeed, meta-analyses reveal that biological factors account for no more than 5% of variability in spatial performance (Schultz et al., 2003).

Interest in studying the relation between gender differences in spatial performance and mathematical performance lies in the reasoning that gender differences in mathematical abilities mediate those found on spatial tasks. A 1975 study demonstrated that gender differences on the
rod-and-frame test were non-significant when mathematical test performance was controlled statistically (Voyer, 1998). Hubona and Shirah (2004) report that Linn and Peterson’s 1985 meta-analysis found that men robustly outperform women on spatial perception and mental rotation tests, but that no consistent gender performance was shown on spatial visualization tests. Hubona and Shirah also state that in a 1998 article, Vecchi and Girelli demonstrated that gender differences in visio-spatial ability are limited to active processing tasks such as mentally following pathways, but do not apply to passive tasks such as recall of previously memorized positions (Hubana & Shirah, 2004). The ability to remember object location is thought to require multiple separate processes. One has to encode the precise positions occupied, assign the various objects to the relative correct locations, and achieve an integration of both types of spatial information. It seems that the male advantage in spatial memory is not a general effect but applies only to certain specific processing components (Postma, Izendoorn, & De Haan, 1998).

Hamilton (1995) stated that research into the existence of gender differences in visual cognition and related areas has been extensively reviewed, although results differ. Conventional emphasis has been made on comparison of two sample means (female vs. male). However, it is clear that considerable variation exists in performance within the genders. Although there may be statistical differences between the sexes, there is also considerable overlap between the spatial abilities of females and males. These findings strongly suggest that since 3-D mental rotation tasks demand distinct processing, any analysis should be of the task score itself and not in combination with other types of spatial task scores, otherwise spatial processes may be confounded and important effects overlooked (Hamilton, 1995).

Another explanation for the apparent sex differences in visualization lies in the impact of the gap in spatial activities experienced by the two sexes. Some studies highlight the importance
of the individuals’ interaction with the physical environment, such as play with toys or sports activities that have a spatial component to them (Haydel, 2000). A meta-analytic review by Baenninger & Newcombe in 1989 is cited by Haydel (2000). It indicated that females could benefit as well as males from spatial training programs. Therefore, the sex difference in mental rotation task performance could be the result of female students in the studies experiencing fewer spatial activities. Initial biological predispositions, sex-stereotyped values and expectations, or an interaction of these factors could all have an effect on participant abilities (Hamilton, 1995).

Improvement of spatial ability is possible, although methods to accomplish this have not been widely proven. Studies have identified a relationship between spatial activity participation and spatial ability. Findings such as these have prompted the development of training programs in visuo-spatial processing. The Baenninger and Newcombe (1989) meta-analytic study concluded that training did result in an improvement for both males and females indicating that for both sexes a mastery level of performance had not been reached (Hamilton, 1995).

Improving Spatial Ability

Numerous studies have indicated that spatial ability can be improved through training if appropriate materials are provided (Cohen et al., 2003; Kinsey, 2003; Newcomer et al., 1999; Potter & van der Merwe, 2001). Spatial visualization taps the ability of mental integration while consolidating several orthographic views into a single perspective image. Given the obvious connection between spatial thinking and transformational geometry, upon which engineering drawing is based, one might hypothesize that work with geometry would improve skills in spatial thinking (Cohen et al., 2003; Olkun, 2003).

There are many computer software programs that can help teach students about shapes and spatial relations, including such topics as geometry, computer aided design and drafting.
(CADD), graphic design, simulations, and geographic information systems (GIS). Both CADD and software for geometry education involve spatial concepts, but Kaufmann et al. (2003) state that it is important to note that while geometry education software shares many aspects with conventional computer aided design software, its aims and goals are fundamentally different. It is not intended for generating polished results, but puts an emphasis on the construction process itself.

Kinsey (2003) used three treatments to try to improve spatial abilities in engineering students enrolled in engineering drawing, but results did not show statistical significance among the three treatment types. Students in the study did indicate that a combination of methods, including 3-D physical models, observation, and hands-on computer use would be preferred. Kinsey found that when freshman university students who were identified as at risk were invited to a 3-hour session on strategies to improve their spatial ability skills, the result was that pretest course gender differences were eliminated as a consequence of the instruction on spatial strategy.

Since spatial ability is multifaceted, attempts to improve it may affect one aspect while not others. In one study, students improved orthographic projection skills after computer animated graphics, but did not improve rotational skills. It appears that providing diverse spatial activities may be key to enhancing overall spatial visualization ability. Activities should include experiences ranging from manipulation of concrete models to computer visualization (Alias et al., 2002).

As ever-increasing resources are committed to incorporating computers into classrooms, parents, policymakers, and educators need to be able to determine how such technology can be used most effectively to improve student learning. It has been shown that computers can enhance
how children learn by supporting four fundamental characteristics of learning: (Roschelle et al., 2001).

1. Active engagement
2. Participation in groups
3. Frequent interaction and feedback
4. Connections to real-world contexts

The role of visualization technologies is to provide an efficient mechanism for communication by enabling the non-technical person to see and understand concepts. Utilizing such technologies with the above four factors in mind should enhance student learning (Roschelle et al., 2001).

Cohen et al. (2003) found results in an experiment that indicated it is possible to train participants to use mental rotation and perspective by modeling these spatial strategies using animation. Interactive animation was found to be more effective than non-interactive, especially for subjects whose initial tests indicated low spatial ability. In another study, student spatial ability was tested prior to using the interactive multimedia being tested. It was found that students with low spatial ability spent significantly more time viewing high quality videos and 3-D animations than did students who tested as having high spatial ability. The visual spatial ability of users had an influence on the amount of time they spent using the animations and videos (Steinke, Huk, & Floto, 2003).

Engineering drawing such as CADD provides a context for spatial ability to be improved through practice (Olkun, 2003). Some skills involved in technical drawing are acquired through experience with simple to more complex visual patterns. To understand drawings means one can visualize the geometrical form and spatial layout of an object from the drawings. For the
unskilled observer, orthographic views found in technical drawings have perceptual limitations (Guidera, 2002). Representations of 3-D objects by means of 2-D diagrams are by no means immediately recognizable, especially by those who were not directly taught the conventions involved. Drawing perspectives or imagining the object from the given views involves mental integration of the views (Olkun, 2003). Three-dimensional drawings have significant communication advantages by representing form and space more realistically. Spatial ability in technical drawing should involve but not be limited to manipulation of different lines, curves, plane shapes, and solid figures. Transformations between those shapes should occur (Guidera, 2002).

A study done by Keller et al. (2002) used geometry education software, Construct 3d. This software allows dynamic behavior of a construction to be explored by interactively moving individual defining elements such as corner points of a rigid body and intersections between all types of 2-D and 3-D objects, including rotational sweep around an axis. Software such as Pro/Desktop® also allows the user interactive moving of individual elements, such as changing height of an object or the shape of an edge by dragging a handle to see how the change would look. The helix in Figure 1 allowed the user to adjust the angle of the rotation of the circle. Experiencing what happens under movement allows students better insight into a particular construction and geometry in general (Keller et al., 2002). Three-dimensional CADD modeling software also allows such interaction, with an emphasis on design. Therefore it is beneficial to use a 3-D solid modeling package to teach the fundamentals of computer drafting. Some research has been done on solid modeling and visualization, and not surprisingly, since the world is three-dimensional, solid modeling has been shown to improve student visualization skill more effectively than traditional 2-D drafting techniques. Given the variety of powerful 3-D solid
modeling packages available today, it no longer makes sense to teach students 2-D drafting techniques, either with a T-square or on a computer (Newcomer et al., 1999).

Figure 1. Round profile revolving around an axis

Not all studies have shown computer software to be a significant factor in improving spatial abilities. In a study using 2-D and section models, no difference was found between active and passive controls. A main effect of spatial ability was found, however. Pairwise comparisons showed that high and low spatial ability participants differed significantly in the passive condition, but not in the active (Keehner, Montello, Cohen, & Hegarty, 2004). Shavalier (2004) investigated whether a CAD-like software called Virtus Walk Through Pro could be used to enhance spatial abilities of middle school students. No significant difference was found between the control and treatment groups after 11 weeks, and no significant treatment effects were found in measures related to gender or spatial ability levels.

Although not all studies agree, many have shown that spatial ability can be improved using computer software such as geometry programs and CADD, especially solid modeling software. Instructional design for use with software is more effective when diverse activity such
as active engagement, interaction, and feedback is included. Animation can be effective, particularly for those who begin the instruction with a lower degree of spatial ability. The experience of manipulating 3-D objects so that movement of geometric elements occur improves visualization skills.

Designing Instructional Material

Without well-designed instructional activities, no software will accomplish the goal of helping students to improve spatial abilities. In Newcomer’s description of changes in instruction for design students, art-based free hand drawing techniques were used along with a nonparametric 2-D solid modeling package to help students develop basic transferable visualization skills. This method was chosen to allow students to concentrate on developing general skills instead of skills specific to a software package. Students in the study showed improved visualization and sketching skills, and indicated they enjoyed the process. One student wrote that he struggled with computer graphics in high school and junior high, but found the process used in the course helped to bridge art with computer graphics (Newcomer et al., 1999).

Mohler (2001) stated that although the particulars of identifying, measuring, and improving spatial ability are often discussed, without developed spatial abilities, students are often hindered in the learning environment and within their chosen field. Multimedia has been relatively successful as a learning tool because it draws upon more than one of the five human senses, utilizing sight and sound, the two fundamental senses vital for information reception. However, sight and sound are not enough to guarantee that students will learn from educational material. In that case, the critical component of learning using digital learning materials must be identified. Planned interactions are known to have a positive effect on learning. These are probably the most critical components of any learning environment, particularly computer-based
ones. Interaction may come from teachers, peers, or the learning materials themselves, but learning results from interaction and the level to which that interaction is unique. According to Mohler, learning theorists assert that to cognitively incorporate learning into long-term memory to reach an objective or to acquire a skill, the learner must be actively involved through practice. “The interaction or ‘doing objective’ helps the learner reach the objective and recall the information, skill, or behavior that was learned” (Mohler, 2001, p. 294). Lave and Wenger (1990) proposed a theory known as Situated Learning. One principle of this theory is that knowledge needs to be presented in a contextual way using settings and applications that would normally involve that knowledge. The other principal of this theory is that learning requires social interaction and collaboration.

The relative effectiveness of different variations of hands-on interactivity used to learn spatial visualization is an important issue for the pedagogy of computer-based learning. Hands on may be initially more helpful with people who are unfamiliar with spatial visualization. The opposite of hands on is passive observation, which is sometimes an advantage. Hands-on manipulations may divert short-term memory resources needed to comprehend a new scheme requiring the simultaneous manipulation of a larger number of mental elements. Students learning specific principles or techniques find it more beneficial to observe first, rather than solve a task. In a study, 5th graders who were less skilled in spatial visualization benefited more from computer interaction, while those more skilled in spatial visualization benefited more from observation first. Immediately applying a newly learned principle strains short-term memory (Smith, 2001).

Alagic (2003) stated that with multiple contexts, students are more likely to extract the relevant features of the concepts and develop a more flexible understanding. Care must be taken
in choosing images that facilitate student learning. Multiple representations of 3-D objects have been linked with greater flexibility in student thinking and associated with better transfer of learning.

When people are learning new, complicated ideas, it helps to interact with various representations such as diagrams, graphs, models, and animations (Alagic, 2003). Teachers can create instructional models with computer tools, but the 3-D software should also be a tool for the students to represent their own ideas. CADD software can provide an avenue to express ideas in new, dynamic, and motivating ways. Designing and building models, planning, and thinking through the processes, all provide potential for learning. Teachers can also gain insight into student thought processes when models are used as a platform for expression and discussion (Steed, 2001). Visual forms of expression are not without limitations and problems. It is important to keep illustrations simple, and for students to keep theirs simple also. Self-confidence and motivation increase with spatial ability training, and students are more motivated when they feel confident (Kinsey, 2003).

When using software, not only are there new tools to learn, but also the difficulty of maintaining orientation in 3-D space. In 3-D space, one no longer deals with only an x and y coordinate, but also with the z-axis as well. Most 3-D software applications provide different perspective views to provide the user a sense of an object’s orientation in space (Mohler, 2001; Steed, 2001). Strong and Smith (2001) stated that human/computer interface has a direct relationship to stress on the user’s cognitive ability. When designing instructional materials for computer use as well as subject matter mastery, stress is reduced if a user can easily make use of the interface, comprehend the functions, and use the tool to solve problems. Students must be able to easily navigate in a computer environment in order to focus on the topic. With this
cognitive load in mind, lesson development should follow standard formats that utilize instructional content, guided practice, checks for understanding, individual practice, and assessment.
CHAPTER 3: RESEARCH METHODS

Research Design

A quasi-experimental design was used for this study, with .05 set *a priori* as the alpha level. Intact ninth grade Technology Discovery classes were used, with participating teachers using *Pro/Desktop®* 3-D CADD software in a modular setting. The schools using 3-D CADD software were randomly assigned to one of three experimental instructional methods as described below. Teachers located in the same schools were assigned to the same instructional method. The design used a control group from schools not offering CADD instruction (No CADD Instruction Treatment Group). The dependent variable was spatial ability achievement as measured by the Purdue Visualization of Rotations Test.

Description of Instructional Method Groups

Teacher and Module Instructional Method (Experimental): This group was given instructions using researcher-developed lesson plans for teacher-directed lessons during the Design Unit of the curriculum. The lesson on design was taught using 3-D CADD modeling software, and followed by module rotations in which pairs of students used student-directed material developed by the researcher to learn more about the 3-D CADD modeling software. Both the teacher-directed and student-directed lessons utilized 3-D physical models as an aid to instruction.

Module Only Instructional Method (Experimental): This group learned about 3-D CADD modeling software without teacher-directed lessons. Instruction occurred only during module rotations in which pairs of students used student-directed curriculum material developed by the researcher to learn about 3-D CADD modeling software. The lessons utilized 3-D physical models as an aid to instruction.
Existing Material Instructional Method (Experimental): This group learned about 3-dimensional CADD modeling software during module rotations in which pairs of students used a variety of existing student-directed module material. It should be noted that there is a wide variety of materials being used by teachers across the state. Materials were identified and reported using a teacher checklist (Appendix A).

No CADD Instruction Instructional Method (Control): This group received no instruction utilizing CADD software.

Identification of the Population

Data collection was scheduled for completion by the end of September 2005. Only schools that operated on a 4x4 block schedule and offered Technology Discovery were included in the first 3 Treatment Groups of the study. These schools completed an entire course during one semester, with class periods of at least 94 minutes per day. In order to identify schools that used a 4 x 4 block schedule to teach Technology Discovery, a spreadsheet of schools that operated that schedule type during the 2004-2005 school year was obtained from the Management Information System (MIS) of the Mississippi Department of Education (MDE). The list was compared to those schools participating in the Tech Prep Initiative to identify potential study participants.

A survey (Appendix A) was sent to Technology Discovery teachers in the identified schools during the last month of school, May 2005. The purpose of the questionnaire was to verify that the school would operate on the 4 x 4 block schedule for the 2005-2006 school year, and to ascertain what CADD software and teaching methods were being used in the CADD module by each teacher. The questionnaire also asked if the teacher was willing to participate in the study. Contact with individual teachers through email and phone calls continued throughout
the summer of 2005 in order to collect as many responses as possible. Of the schools responding, 42 intended to continue to operate the schedule required for the study. Those schools using 3-D CADD in a modular setting were identified. Twelve schools that were not using the 3-D software in a module were excluded from the study. The potential population consisted of 30 schools with 44 teachers in all. Three of the teachers employed in this group of schools with 4x4 block schedules were certified Pro/Desktop® trainers. Since these individuals were unique and had a much higher level of training on the software, they could not be considered as typical Technology Discovery teachers; therefore, their two schools were excluded from the study (See Table 2).

Table 2. Initial Survey Response for the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Schools on 4x4 Block Schedule 2004-05</th>
<th>Schools Responding to Survey</th>
<th>Responding Schools Operating 4x4 Schedule 2005-2006</th>
<th>4x4 Schools Using 3-D CADD in a module</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=57</td>
<td>N=52</td>
<td>N=42</td>
<td>N=28</td>
</tr>
</tbody>
</table>

Note. Only Mississippi schools that operated 4x4 block schedule and participated in Tech Prep Initiative during the 2004-2005 school year were surveyed.

Many teachers who utilized 4 x 4 block schedules and also used Pro/Desktop® 3-D software as a module were located in the southern portion of the state, predominately in the Gulf Coastal counties. Random assignment to Treatment Groups resulted in 15 teachers from 15 schools at the beginning of the study. Schools not offering CADD and Technology Discovery were identified for use as the control group.

Population and Sample

Participating schools with intact classes provided cluster samples. Block schedule schools typically operated three classes per day. Technology Discovery was designed for a maximum class size of 26 students. There is a maximum population of 78 students per teacher if they were teaching the typical three classes per day and their enrollment was 26 students per class.
Each teacher assigned student pairs to instructional module rotations at the beginning of the school year. During the original period of the study, each class had the potential of having 12 rotations with two students per rotation for a total of 24 students per class. Some schools did not complete 12 rotations due to factors beyond the control of the researcher, e.g., closure of school due to hurricanes, equipment malfunctions, etc. In order to obtain an adequate sample, data was also collected during the spring semester. Numbers of rotations involved varied from 5 to 13, with one Existing Materials Instructional Method school participating during the fall semester, and during spring semester until the teacher left on maternity leave.

Based on the class sizes cited above, 5 schools were randomly selected for each of the 3 Treatment Groups, and 3 schools that did not offer the course were chosen for control, for an initial total of 18 schools involved in the study. The goal was to include approximately 100 students per Treatment Group in the study. This sample size was considered adequate to conduct the statistical analyses described. To avoid researcher bias, schools were randomly selected. Alternates were also selected to replace those in the original sample in case a teacher was unable to participate in the study. It became necessary to include alternates in the study due to hurricane Katrina. During the 2 semesters, 14 schools participated in the study.

Assignment to Treatment

Schools with teachers agreeing to participate were listed in an alphabetical numbered list. Schools were assigned to Instructional Method Groups 1, 2, and 3 using random numbers generated by a randomizer program (Urbaniak & Plous, 2005). Teachers in these schools were notified in which Instructional Method they would participate. Teachers received a phone call to discuss the study procedures, treatment, and test administration. Instructional materials, tests, information forms, instructions for test administration, and return envelopes were mailed. Each
teacher received an email with the parental consent form attached prior to materials being mailed. Standard consent forms were used to obtain consent from parents and students to participate in the study (Appendix B, IRB Approval #3076).

Procedure Development

Teachers administered the Purdue Visualization of Rotations test as a pretest to all Technology Discovery students in their classes. The pretest was given near the beginning of the semester. The posttest was taken at least 5-7 school days after each student completed the CADD module rotation. The amount of time between module and posttest was chosen to measure student achievement at an equivalent amount of time after instruction. The original study design called for the pretest to occur during the first few weeks of the fall 2005 semester. Due to hurricane Katrina, which struck the Mississippi Gulf Coast in late August, 2005, the study and population had to be revised. Data from module rotations occurring during both fall and spring semesters were used. Some teachers participated during either fall or spring semester, with three teachers participating both semesters.

Teachers assigned students to rotation schedules at the beginning of the semester, using methods learned during teacher training for Technology Discovery. They were asked to adjust the rotations to ensure that no other CADD or Spatial Information Technology module was completed prior to the module under investigation, nor in the week prior to the posttest. Other than the adjustment stated above, their usual assignment procedures for rotations were applied.

Students in the control group (No CADD Instruction Method) took the Purdue Visualization of Rotations test with a five week interval between pretest and posttests. Schools agreeing to participate as control groups administered the test in ninth grade English I classes in
order to provide the appropriate equivalent sample population. English I classes were used because the course was required of all ninth grade students.

All students were asked to complete a brief Student Information Sheet (Appendix C) to provide information on gender, ethnicity, and whether they were currently enrolled in art or geometry. The information sheets were completed at the time of the pretest.

Treatment Development

Lesson plans and instructional material were developed by the researcher during the summer of 2005. The researcher is a certified Pro/Desktop® trainer, highly qualified to develop material for the software. Instructional sessions were developed using PowerPoint. An existing instructional tutorial for Pro/Desktop® CADD software was utilized in the final lesson.

Students in the Kinsey study (2003) indicated that they would prefer a combination of methods, including 3-D physical models, observation, and hands-on computer use while learning to use CADD software. Kinsey found that pre-course gender differences were eliminated when students attended a three-hour session on improving spatial strategies. Roschelle et al. (2001) stated that utilizing computer technologies should enhance student learning when the four factors of active engagement, participation in groups, frequent interaction and feedback, and connections to real-world contexts are kept in mind while designing instruction. In designing the instructional materials, these factors were incorporated.

The development of the instructional material for the Teacher and Module Group (1) was designed to include observation, group interaction, 3-D physical models, and hands-on computer use. The observation portion of the treatment was incorporated into a teacher-delivered lesson for the curriculum Design Unit, utilizing Pro/Desktop® as a tool for teaching design. Lesson plans for 160 minutes of teacher-directed instruction were designed (Appendix D). Physical
models were used by the teacher in the lesson. The models were then located in the CADD workstation for student use with the instructional module.

Findings by Cohen et al. (2003) indicated it is possible to train participants to use mental rotation and perspective by modeling these spatial strategies using animation. Alias et al. (2002) stated that activities should include experiences ranging from manipulation of concrete models to computer visualization. Both module materials for learning the CADD software and physical models were prepared to support instruction for both the Teacher and Module and Module Alone instructional methods (1 and 2). Student material included rotation of the objects being modeled on the computer. Mohler (2001) stated that in computer based environments, mental focus should be placed on exercising visual abilities or the skills one wishes the student to acquire.

The connection between geometry and engineering drawing (Keller et al., 2002; Lowrie, 1994; Smith, 2001) lead to the inclusion of a review of basic geometric shapes and terms in the modular instructional materials. In addition, physical model activity reinforced geometry concepts. CADD was explained in connection with real world concepts, and student activity included feedback as well as reinforcement and practice of concepts. The student-directed module instructional material was developed for approximately 450 minutes of modular instructional time. Both instructional methods 1 and 2 used this material (Appendix F).

Five Mississippi teachers who were certified as Pro/Desktop® trainers reviewed the material for face validity. These teachers suggested improvements for physical models and adjustments to PowerPoint slides, including wording and the order of the module sessions. Adjustments were made prior to dissemination of materials.

The Existing Materials instructional method group (3) was instructed to continue to use materials that were in use during the 2004-2005 school year. The primary materials used were
tutorials utilized in the training of teachers. Some additional material distributed during training was also in use, as well as tutorials available from the Internet. The *No CADD Instruction* method (4) used no software and did not study CADD.

**Teacher Preparation for the Study**

In order to facilitate consistency, teachers participating in the study received both oral and written instructions about study procedures. They were contacted at least two times each by telephone and email prior to beginning the study. Instructions were developed and mailed with study materials. Instructions for teachers included how to administer the pretest, the student information checklist, and behavior to avoid that might influence students during both testing and module instruction. They were also instructed to record events that disrupted instruction, such as student absence, or events that affected one or more classes. One teacher reported two interruptions of classes during initial testing, while another reported a student as absent during three days of the five day instructional rotation. Teachers utilizing the teacher-directed Design Unit lessons were given additional written instruction on the use of materials provided, with a telephone call to determine if written instructions were understood. (See Table 3)

**Table 3. Instruction Provided to Teachers Participating in the Study of the Effect of 3-D CADD on the Development of Spatial Ability**

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Administration, and submission of data</td>
</tr>
<tr>
<td>1: Teacher with module</td>
<td>3-D student module material</td>
</tr>
<tr>
<td></td>
<td>Teacher-centered instruction</td>
</tr>
<tr>
<td></td>
<td>Use of physical models</td>
</tr>
<tr>
<td>2: Module alone</td>
<td>Test Administration, and submission of data</td>
</tr>
<tr>
<td></td>
<td>3-D student module material</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Use of physical models</td>
</tr>
<tr>
<td>3: Existing materials</td>
<td>Test Administration, and submission of data</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>4: No CADD</td>
<td>Test Administration, and submission of data</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

Note. Verbal and written instructions were provided to each teacher.
Instrumentation

Various instruments used to measure spatial ability were investigated for possible use in this study. The Purdue Visualization of Rotations Test (PVRT) was chosen. Other tests considered were the Sheperd-Metzler, Foam Board, Paper folding, and the Wheatley test (Sjolinder, 1998). An online test was investigated, but it was under development and not ready for use. Factors considered in choosing an instrument were content, appropriateness for the population, ease of administration and scoring, the amount of time required to administer the test, cost effectiveness, availability, availability of reliability data, and whether or not special training was required to administer the test.

The Purdue Visualization of Rotations Test (PVRT) was used for both the pretest and posttest. It is appropriate for use with adolescents and may be administered both in groups and individually. According to the test developers, Bodner & Guay (1997), this test is among the spatial tests least likely to be confounded by analytic processing strategies. The test was designed to measure the participants’ ability to visualize the rotation of 3-dimensional objects. The instrument was chosen because of its high correlation with similar instruments measuring visualization that were not cost effective to use. The PVRT format used had 30 questions (Appendix E). In each question, an object was pictured in one position, and then it was shown in a second image, rotated to a different position. Participants were shown a second object and given five choices, one of which matched the rotation of the example object. They were asked to select the object that showed the same rotation as the example for that question. See Figure 2 for a sample question. The test is timed and students are given 15 minutes to complete the 30 test items.
Reliability for the PVRT was reported by Bodner & Guay (1997) using Kuder-Richardson 20 internal consistency test values of .80, .78, and .80 for samples of 758, 850, 1273, respectively. Split Half reliabilities were reported of .83, .80, .84, .85, .82, and .78 for samples of 757, 850, 127, 1273, 1648, and 158, respectively.

Figure 2. Sample Question from Purdue Visualization of Rotations Test

Data Collection

Technology Discovery teachers collected all data used in instructional methods 1, 2, and 3 of this study. Their data collection consisted of administering the pretest, posttest, consent forms, and student information checklist. The checklist was attached to students’ pretest answer sheets. Teachers were provided with pre-addressed, stamped envelopes to return pretest and posttest results, student information checklists, and consent forms. Teachers were reminded regularly by phone call and email to administer the Purdue Visualization of Rotations posttest for each student completing the 3-D CADD rotation. Data collected for the control group was obtained from English I teachers in those locations, with assistance from administrators. Although each student participated in the pretest, only those who returned the consent form and learned about CADD during the research period were included in the study.

Consent forms, the spatial ability pretest, and the student information form were administered as soon as possible after schools began or resumed for the semester. The spatial
ability post-test was administered at least 5-7 school days after the completion of each CADD module rotation in order to measure achievement consistently for all students.

Data Analysis

Data was entered into SPSS statistical software. Nominal variables were coded as follows: Gender: female = 1, male = 2; Ethnicity: categories of black, white, Hispanic, Asian, and other were coded 1 = yes, 0 = no. The co-enrollment variable of art and geometry were coded 1 = yes, 0 = no. The a priori alpha level was set at .05. Descriptive statistics including numbers and percentages were used to analyze the data for Research Question 1. Analysis of covariance was used for Research Question 2 to determine if there was a significant difference in student achievement among instructional treatment methods when the pretest scores were held constant. The dependent variable was the posttest, the covariate was the pretest, and the fixed factor was the instructional treatment method. Analysis of covariance with simple contrasts was used to analyze the data for Research Question 3. The dependent variable was the posttest; covariates were the pretest, demographic and personal variables of gender, ethnicity, and co-enrollment in art, geometry, or both. The fixed factor was the instructional treatment method. Contrasts (simple) were as follows:


c. Existing Materials Instructional Method (3): 3-D software with existing module materials.

d. No CADD Instruction Instructional Method (4): No instruction on software.
CHAPTER 4: RESULTS

The purpose of this quantitative study was to determine if there was a difference in the development of spatial abilities of ninth grade Technology Discovery students as measured by the Purdue Visualization of Rotations Test after students experienced one of three differing instructional methods. The dependent variable was the posttest score on the Purdue Visualization of Rotations Test. The analysis of data and results are offered for each of the research questions. First, a description of total study participants and characteristics for each instructional treatment is presented. This description is followed by information about analysis conducted on the remaining two research questions.

Schools Participating in the Study

Three instructional methods and a control group were utilized. Students were ninth-grade students in Mississippi. Schools assigned to instructional method groups consisted of those operating on a 4 x 4 block schedule during fall or spring semesters during the 2005-2006 school year, and requiring Technology Discovery for ninth grade students. Initially, 15 teachers at these schools were identified and randomly assigned to 3 treatment groups. Because the majority of schools identified as both operating on a block schedule and also using Pro/Desktop® in an instructional module were located near the Gulf Coast, nine of the teachers who began the study dropped out when hurricane Katrina struck the Mississippi Gulf Coast in August, 2005.

Teachers who had been assigned to instructional methods as alternates for the study were contacted in mid-September, 2005, to locate additional participants. Four schools with a total of nine teachers agreed to enter the study in the fall; however, a school with three teachers dropped out the following week, citing equipment failure as the reason. Additional teachers participated during the spring semester. Six of the original coastal schools agreed to participate during the
spring semester, but four failed to conduct study activities. The number of schools in the revised sample was 14, including 10 schools that offered Technology Discovery and 4 that did not.

There were multiple teachers at some schools. Tables 4 and 5 address participation of schools.

Table 4. Schools Assigned to Instructional Treatment Groups for the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Instructional Method</th>
<th>Number of Schools Fall Semester</th>
<th>Number of Teachers Fall Semester</th>
<th>Number of Schools Spring Semester</th>
<th>Number of Teachers Spring Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher with Module Treatment Group</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Module Alone Treatment Group</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Treatment Group Existing Materials Treatment Group</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>No CADD Instruction Control Group</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>


Table 5. Overall Participation of Mississippi Schools in Instructional Methods for the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Teacher and Module Group</th>
<th>Module Only Group</th>
<th>Existing Materials Group</th>
<th>No CADD Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 school fall and spring</td>
<td>2 schools fall and spring</td>
<td>1 school fall and spring</td>
<td>2 schools fall only</td>
</tr>
<tr>
<td>2 schools fall only</td>
<td>1 school fall only</td>
<td>1 school fall only</td>
<td>2 schools spring only</td>
</tr>
<tr>
<td>1 school spring only</td>
<td></td>
<td>1 school spring only</td>
<td></td>
</tr>
</tbody>
</table>

Note. Schools participated during the 2005-2006 school year.

Reduction of Data

The total number of students for whom data was collected was 523. Examination of pre and posttest score sheets revealed that some had been marked using obvious patterns such as marking all answers in one column or creating geometric patterns. Twenty-nine cases were eliminated from the sample due to patterns marked on the score sheets, indicating the students had not actually tried to answer test questions. One school was found to have dates on posttests that indicated that 16 of the posttests were taken two days after the pretests. These were eliminated because they did not meet the study procedures. Four students either failed to put their names on score sheets, or left the posttest form blank. Outlier analysis was done plotting
pretest and posttest scores on the x and y axis using a box plot. Ten outliers were identified and removed from the remaining sample as a result of the outlier analysis. The number of observations in the revised sample was 464.

Research Question 1: Characteristics of Population

The purpose of Research Question 1 was to determine demographic characteristics of students enrolled in Technology Discovery classes participating in the instructional method groups, and of non-Technology Discovery students participating in the control group. The demographic and personal variables included in this research question were gender, ethnicity, co-registration in art, and co-registration in geometry. The original research question included economic status of the school; however, it was not possible to identify either the individual economic status of the student or of the individual school. Because the economic status of the school district was the closest information available to that desired, and using the economic status of the school district rather than individual schools would result in inaccuracy, the variable was excluded.

Descriptive statistics including numbers and percentages were used to analyze the data for Research Question 1. Table 6 contains the number and percentage of participants per school and instructional method. Table 7 contains the number of students for each of the four instructional method groups.

Sample Characteristics

The number of students who reported ethnicity as black was 149 (32.1%); those students who reported ethnicity as white was 295 (63.6%). Six (1.3%) students reported ethnicity as Hispanic, five (1.1%) reported ethnicity as Asian, and nine (1.9%) reported ethnicity as other. There was a higher percentage of white students in each of the instructional method groups,
ranging from approximately 63% to 75%. The control group contained more black students (52.4%) than students of other ethnic backgrounds. Table 8 provides information about ethnic groups by instructional method.

Table 6. Treatment, Number, and Percentage of Students per School in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>School #</th>
<th>Instructional Method</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Teacher Instruction and Module</td>
<td>32</td>
<td>6.90</td>
</tr>
<tr>
<td>2</td>
<td>Teacher Instruction and Module</td>
<td>53</td>
<td>11.42</td>
</tr>
<tr>
<td>3</td>
<td>Teacher Instruction and Module</td>
<td>38</td>
<td>8.19</td>
</tr>
<tr>
<td>4</td>
<td>Teacher Instruction and Module</td>
<td>10</td>
<td>2.16</td>
</tr>
<tr>
<td>5</td>
<td>Module Alone</td>
<td>70</td>
<td>15.10</td>
</tr>
<tr>
<td>6</td>
<td>Module Alone</td>
<td>62</td>
<td>13.36</td>
</tr>
<tr>
<td>7</td>
<td>Module Alone</td>
<td>15</td>
<td>3.23</td>
</tr>
<tr>
<td>8</td>
<td>Existing Materials</td>
<td>32</td>
<td>6.90</td>
</tr>
<tr>
<td>9</td>
<td>Existing Materials</td>
<td>33</td>
<td>7.11</td>
</tr>
<tr>
<td>10</td>
<td>Existing Materials</td>
<td>36</td>
<td>7.76</td>
</tr>
<tr>
<td>11</td>
<td>No CADD Instruction</td>
<td>32</td>
<td>6.90</td>
</tr>
<tr>
<td>12</td>
<td>No CADD Instruction</td>
<td>21</td>
<td>4.53</td>
</tr>
<tr>
<td>13</td>
<td>No CADD Instruction</td>
<td>10</td>
<td>2.16</td>
</tr>
<tr>
<td>14</td>
<td>No CADD Instruction</td>
<td>20</td>
<td>4.31</td>
</tr>
</tbody>
</table>

Note. N=464

*Percentage not calculated to equal 100 % due to rounding error.

Table 7. Total Number and Percentage of Students per Instructional Method in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Instructional Method</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Instruction and Module</td>
<td>101</td>
<td>21.77</td>
</tr>
<tr>
<td>Module Alone</td>
<td>164</td>
<td>35.34</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>116</td>
<td>25.00</td>
</tr>
<tr>
<td>No CADD Instruction</td>
<td>83</td>
<td>17.89</td>
</tr>
<tr>
<td>Total</td>
<td>464</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 8. Instructional Method and Ethnic Background of Students Participating in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Teacher Instruction and Module</th>
<th>Module Alone</th>
<th>Existing Materials</th>
<th>No CADD Instruction</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Black</td>
<td>20</td>
<td>19.8</td>
<td>44</td>
<td>26.9</td>
<td>41</td>
</tr>
<tr>
<td>White</td>
<td>76</td>
<td>75.2</td>
<td>114</td>
<td>69.5</td>
<td>73</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1</td>
<td>1.0</td>
<td>3</td>
<td>1.8</td>
<td>1</td>
</tr>
<tr>
<td>Asian</td>
<td>2</td>
<td>2.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2.0</td>
<td>3</td>
<td>1.8</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>101</td>
<td>100</td>
<td>164</td>
<td>100</td>
<td>116</td>
</tr>
</tbody>
</table>
The number of females in the study was 254 (54.7%). The number of males in the study was 210 (45.3%). When comparing the number of students of each gender by treatment group, each group contained more females (over 54%) than males Table 9 provides information about gender by instructional method.

Table 9. Gender of Participants in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Gender</th>
<th>Teacher Instruction and Module</th>
<th>Module Alone</th>
<th>Existing Materials</th>
<th>No CADD Instruction</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
<td>54.5</td>
<td>90</td>
<td>54.9</td>
<td>63</td>
</tr>
<tr>
<td>Male</td>
<td>46</td>
<td>45.5</td>
<td>74</td>
<td>45.1</td>
<td>53</td>
</tr>
<tr>
<td>Totals</td>
<td>101</td>
<td>100</td>
<td>164</td>
<td>100</td>
<td>116</td>
</tr>
</tbody>
</table>

The majority of students (73%) were not co-enrolled in either art or geometry during the semester in which they participated in the study. The number of study participants who reported they were not enrolled in art or geometry during the semester in which they were engaged in the study was 339. Nearly a quarter of the students in the instructional method Teacher Instruction and Module were co-enrolled in geometry. There were 61 (13.1%) enrolled in art, 48 (10.3%) enrolled in geometry, and 17 (3.4%) students enrolled in both art and geometry. The number and percentage of students co-enrolled in art, geometry, or both is presented in Table 10 for each instructional method.

Table 10. Participants Co-enrolled in Art and/or Geometry by Instructional Method for the Study of Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Courses</th>
<th>Teacher Instruction and Module</th>
<th>Module Alone</th>
<th>Existing Materials</th>
<th>No CADD Instruction</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>No Art or Geometry</td>
<td>53</td>
<td>52.5</td>
<td>133</td>
<td>81.2</td>
<td>94</td>
</tr>
<tr>
<td>Art</td>
<td>17</td>
<td>16.8</td>
<td>24</td>
<td>14.6</td>
<td>14</td>
</tr>
<tr>
<td>Geometry</td>
<td>24</td>
<td>23.8</td>
<td>4</td>
<td>2.4</td>
<td>7</td>
</tr>
<tr>
<td>Both Art &amp; Geometry</td>
<td>7</td>
<td>6.9</td>
<td>3</td>
<td>1.8</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>101</td>
<td>100</td>
<td>164</td>
<td>100</td>
<td>116</td>
</tr>
</tbody>
</table>
Table 11 contains the number and percentage of students of each ethnic background by gender and instructional method. The number of black females is higher for each group except the instructional method Existing Materials. The highest percentage of white males was found in the instructional method Teacher Instruction and Module.

Table 11. Ethnic Background and Gender Reported by Instructional Method for Participants in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Teacher Instruction and Module</th>
<th>Module Alone</th>
<th>Existing Materials</th>
<th>No CADD Instruction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Black</td>
<td>16</td>
<td>29.2</td>
<td>4</td>
<td>8.7</td>
<td>25</td>
</tr>
<tr>
<td>White</td>
<td>35</td>
<td>63.6</td>
<td>4</td>
<td>8.7</td>
<td>62</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Asian</td>
<td>2</td>
<td>3.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>100</td>
<td>46</td>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>

Co-enrollment in the subject areas of art, geometry, or both, is reported by gender and instructional method in Table 12. The number of females and males who were enrolled in neither art nor geometry is fairly balanced for the three instructional method groups. The control group had a slightly higher number of females who were enrolled in neither course.

Table 12. Gender of Participants Co-enrolled in Art and/or Geometry by Instructional Method for the Study of Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Courses</th>
<th>Teacher Instruction and Module</th>
<th>Module Alone</th>
<th>Existing Materials</th>
<th>No CADD Instruction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>No Art or Geometry Art</td>
<td>29</td>
<td>51.8</td>
<td>24</td>
<td>51.2</td>
<td>73</td>
</tr>
<tr>
<td>Art</td>
<td>9</td>
<td>16.1</td>
<td>8</td>
<td>17.4</td>
<td>13</td>
</tr>
<tr>
<td>Geometry</td>
<td>14</td>
<td>25.0</td>
<td>10</td>
<td>21.7</td>
<td>1</td>
</tr>
<tr>
<td>Both Art &amp; Geometry</td>
<td>4</td>
<td>7.1</td>
<td>3</td>
<td>8.8</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>55</td>
<td>100</td>
<td>46</td>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>
Research Question 2: Differences in Spatial Ability Posttest Achievement with Pretest Covariate

This question asked if differences exist in spatial ability test scores of Technology Discovery students as measured by the Purdue Visualization of Rotations Test, when the pretest scores were controlled, and students were instructed using differing instructional treatment methods. The instructional method were as follows:

a. Teacher and Module Instructional Method Group (1)--- Teacher-directed instruction followed by modular student-directed learning

b. Module Only Instructional Method Group (2)--- Instruction utilizing modular student-directed learning

c. Existing Material Instructional Method Group (3)--- Instruction utilizing existing curriculum materials in modular student-directed learning

d. No CADD Instruction Instructional Method Group (4)--- No instruction using CADD software

A one-way analysis of covariance (ANCOVA) was conducted in order to determine if there was a difference in student achievement among treatments. The independent variable of instructional treatment included the four levels described in research question 1. The dependent variable was the posttest, the covariate was the pretest, and the fixed factor for the analysis was the instructional method.

A preliminary analysis was conducted to determine if the variances in the posttest scores were equal among the treatment groups. The non-significant Levene’s Test ($F_{(3, 460)} = .71; p = .548$) suggests that the variance of the posttest scores was approximately equal for the four treatment groups. Therefore, equal variance across treatment groups was assumed. In addition, a model lack of fit test was conducted to determine if there was any evidence that the effects of
the treatments are nonlinear. The non-significant results of the test of significance of lack of fit 
\( F(88, 368) = 1.25; p = .086 \) indicate that there is no significant evidence that the effects of the instructional treatments are nonlinear. As a result, the effects were assumed to be linear.

A test for interaction between the method and pretest scores was also conducted. Table 13 reports the results of this test. The interaction between the method factor and the pretest covariate was not significant, \( F(3, 456) = 1.83, p > .05 \), indicating that the differences on the posttest among groups does not vary as a function of the covariate. The pretest was considered to be an appropriate covariate and was used as the covariate in the analysis of covariance.

Table 13. Analysis of Covariance for Interaction Between Instructional Method and Pretest Covariate in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Type I Sum of Squares</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>( \eta^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>3</td>
<td>741.58</td>
<td>247.19</td>
<td>15.12</td>
<td>&lt;.001</td>
<td>.09</td>
</tr>
<tr>
<td>Pretest</td>
<td>1</td>
<td>8575.95</td>
<td>8575.95</td>
<td>524.11</td>
<td>&lt;.001</td>
<td>.54</td>
</tr>
<tr>
<td>Method*Pretest</td>
<td>3</td>
<td>89.69</td>
<td>29.90</td>
<td>1.82</td>
<td>.141</td>
<td>.01</td>
</tr>
<tr>
<td>Error</td>
<td>456</td>
<td>7461.47</td>
<td>16.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>464</td>
<td>93039.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. \( R^2 = .55 \) (Adjusted \( R^2 = .55 \))

Table 14 reports significant differences among the means for instructional methods, \( F(3, 459) = 6.6, p < .001 \), partial eta square = .041. According to Green and Salkind (2003) the partial eta squared level of .041 indicates a moderate relationship between posttest scores and teaching methods, with pretest scores as the covariate. A significant difference among the means indicates that post hoc pair-wise comparisons should be conducted to identify which instructional methods were effective.

Table 15 presents the unadjusted and adjusted means of posttest scores for each instructional method and the control group with the covariate included. The adjusted mean for the Teacher Instruction and Module group is larger than the adjusted means for each of the other instructional treatment groups and also larger than the control group.
Table 14. ANCOVA Test for Differences Between Means for Method with Pretest Covariate in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Type III Sum of Squares</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>1</td>
<td>8575.95</td>
<td>8575.95</td>
<td>521.29</td>
<td>&lt;.001</td>
<td>.53</td>
</tr>
<tr>
<td>Method</td>
<td>3</td>
<td>325.52</td>
<td>108.51</td>
<td>6.60</td>
<td>&lt;.001</td>
<td>.04</td>
</tr>
<tr>
<td>Error</td>
<td>459</td>
<td>7551.16</td>
<td>16.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>464</td>
<td>93039</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. $R^2 = .55$ (Adjusted $R^2 = .55$)

Table 15. Posttest Unadjusted and Adjusted Mean Scores of Students per Instructional Method with Pretest Covariate in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Instructional Method</th>
<th>n</th>
<th>$M$</th>
<th>SD</th>
<th>$M$</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Instruction and Module</td>
<td>101</td>
<td>15.01</td>
<td>5.97</td>
<td>14.38</td>
<td>.41</td>
</tr>
<tr>
<td>Module Alone</td>
<td>164</td>
<td>12.56</td>
<td>5.41</td>
<td>12.59</td>
<td>.32</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>116</td>
<td>11.37</td>
<td>5.87</td>
<td>12.30</td>
<td>.39</td>
</tr>
<tr>
<td>No CADD Instruction</td>
<td>83</td>
<td>12.66</td>
<td>6.83</td>
<td>11.97</td>
<td>.45</td>
</tr>
<tr>
<td>Totals</td>
<td>464</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Covariate in the model is evaluated at the following values: pretest=11.49.

A pair-wise comparison was conducted using the Bonferroni procedure (Table 16). The comparison of methods indicates that the test scores for the treatment Teacher Instruction and Module is significantly higher than the test scores for the other instructional methods.

Table 16. Pairwise Comparison of Instructional Methods with Pretest Covariate for the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Instructional Method</th>
<th>Mean Difference</th>
<th>SE</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Instruction and Module</td>
<td>1.78(*)</td>
<td>.51</td>
<td>.004</td>
</tr>
<tr>
<td>Module Alone</td>
<td>2.06(*)</td>
<td>.56</td>
<td>.001</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>2.29(*)</td>
<td>.60</td>
<td>.001</td>
</tr>
<tr>
<td>No CADD Instruction</td>
<td>-1.78(*)</td>
<td>.51</td>
<td>.004</td>
</tr>
<tr>
<td>Module Alone</td>
<td>-2.06(*)</td>
<td>.56</td>
<td>.001</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>.29</td>
<td>.49</td>
<td>1.000</td>
</tr>
<tr>
<td>No CADD Instruction</td>
<td>.52</td>
<td>.55</td>
<td>1.000</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>-2.06(*)</td>
<td>.56</td>
<td>.001</td>
</tr>
<tr>
<td>Module Alone</td>
<td>-.29</td>
<td>.49</td>
<td>1.000</td>
</tr>
<tr>
<td>No CADD Instruction</td>
<td>.23</td>
<td>.59</td>
<td>1.000</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>-2.29(*)</td>
<td>.60</td>
<td>.001</td>
</tr>
<tr>
<td>Module Alone</td>
<td>-.52</td>
<td>.55</td>
<td>1.000</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>.23</td>
<td>.59</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*p<.05 level.
Research Question 3: Differences in Spatial Ability Posttest Achievement with Multiple Covariates

This question asked if differences exist by instructional method group in the spatial ability of Technology Discovery students as measured using the Purdue Visualization of Rotations Test scores when spatial ability pretest scores are controlled, and explanatory factors of gender, ethnicity, co-registration in either art and/or geometry are added to the model. Analysis of covariance with simple contrasts for the explanatory factors was conducted to analyze the data for this research question. The dependent variable was the posttest score; the covariate was the pretest score, and additional explanatory factors were gender, ethnicity, co-enrollment in art, and co-enrollment in geometry. The fixed factor was the instructional treatment method.

A correlation matrix was developed in order to ensure that all covariates were significantly correlated to the posttest scores. Gender was not significantly correlated to the dependent variable posttest scores. Because of this, it was not included in further analysis. Table 17 reports the correlation matrix results.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statistic</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>$r$</td>
<td>.73 (**)</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Gender</td>
<td>$r$</td>
<td>.09</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>.05</td>
</tr>
<tr>
<td>Ethnicity-White</td>
<td>$r$</td>
<td>.30 (**)</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Ethnicity-Black</td>
<td>$r$</td>
<td>-.31 (**)</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Art Co-enrollment</td>
<td>$r$</td>
<td>.12 (*)</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>.01</td>
</tr>
<tr>
<td>Geometry Co-enrollment</td>
<td>$r$</td>
<td>.21 (**)</td>
</tr>
<tr>
<td></td>
<td>$p$</td>
<td>&lt;.01</td>
</tr>
</tbody>
</table>

Note. $N=464$  
** $p<.01$  *$p<.05$

An analysis was conducted to determine if the variances in the posttest scores were equal among the treatment groups when the fixed factors were included. The non-significant Levene’s
Test \( F(3, 460) = 1.11; p = .344 \) suggests that the variance of the posttest scores was approximately equal for the four treatment groups, and equal variance across treatment groups was assumed. A model lack of fit analysis was conducted. The result of the test of significance for lack of fit was non-significant \( F(212, 288) = 1.02; p = .433 \).

An initial ANCOVA was conducted that included the interaction effects shown in Table 18. The interaction between the dependent variable posttest and covariate pretest was not significant. Interaction between the dependent variable posttest and ethnicity was not significant, nor was interaction between posttest and co-enrollment in either art or geometry. Since no significant interactions existed, the interaction effects were removed from the ANCOVA prior to conducting the final analysis.

Table 18. Analysis of Covariance for Interaction Between Posttests by Instructional Method Groups with Pretest Covariate and Explanatory Factors in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Type I Sum of Squares</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>( \eta^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>1</td>
<td>8575.95</td>
<td>8575.95</td>
<td>521.10</td>
<td>&lt;.001</td>
<td>.53</td>
</tr>
<tr>
<td>Method</td>
<td>3</td>
<td>741.58</td>
<td>247.19</td>
<td>15.11</td>
<td>&lt;.001</td>
<td>.09</td>
</tr>
<tr>
<td>Ethnicity-white</td>
<td>1</td>
<td>27.07</td>
<td>27.07</td>
<td>1.65</td>
<td>.200</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Ethnicity-black</td>
<td>1</td>
<td>8.83</td>
<td>8.83</td>
<td>.54</td>
<td>.464</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Co-enrollment in Art</td>
<td>1</td>
<td>13.90</td>
<td>13.90</td>
<td>.85</td>
<td>.358</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Co-enrollment in Geometry</td>
<td>1</td>
<td>3.25</td>
<td>13.25</td>
<td>.81</td>
<td>.370</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Method * pretest</td>
<td>3</td>
<td>72.83</td>
<td>24.28</td>
<td>1.48</td>
<td>.22</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Method * Ethnicity, white</td>
<td>3</td>
<td>132.27</td>
<td>43.76</td>
<td>.66</td>
<td>.58</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Method * Ethnicity, black</td>
<td>3</td>
<td>52.29</td>
<td>17.43</td>
<td>1.06</td>
<td>.366</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Method * Art Co-enrollment</td>
<td>3</td>
<td>1.49</td>
<td>30.50</td>
<td>1.856</td>
<td>.136</td>
<td>.01</td>
</tr>
<tr>
<td>Method * Geometry Co-enrollment</td>
<td>3</td>
<td>7.65</td>
<td>2.55</td>
<td>.155</td>
<td>.926</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Error</td>
<td>440</td>
<td>7231.59</td>
<td>16.46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>464</td>
<td>93039.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. \( R^2 = .56 \) (Adjusted \( R^2 = .55 \))

Table 19 reports the final analysis of covariance. This analysis resulted in a significant outcome for instructional method \( F(3, 455) = 15.02, p < .001 \). The strength of the differences
between the fixed factor instructional method and the dependent variable posttest was moderate as indicated by a partial eta squared of .09 (Green & Salkind, 2003).

Table 19. Analysis of Covariance for Differences among Posttests by Instructional Method Groups with Pretest Covariate and Explanatory Factors in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Source</th>
<th>Type I Sum of Squares</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>8575.95</td>
<td>1</td>
<td>8575.95</td>
<td>521.10</td>
<td>&lt;.001</td>
<td>.53</td>
</tr>
<tr>
<td>Method</td>
<td>741.58</td>
<td>3</td>
<td>247.19</td>
<td>15.02</td>
<td>&lt;.001</td>
<td>.09</td>
</tr>
<tr>
<td>Ethnicity-white</td>
<td>27.07</td>
<td>1</td>
<td>27.07</td>
<td>1.65</td>
<td>.200</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Ethnicity-black</td>
<td>8.83</td>
<td>1</td>
<td>8.83</td>
<td>.54</td>
<td>.464</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Co-enrollment in Art</td>
<td>13.91</td>
<td>1</td>
<td>13.91</td>
<td>.85</td>
<td>.358</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Co-enrollment in Geometry</td>
<td>3.25</td>
<td>1</td>
<td>3.25</td>
<td>.81</td>
<td>.370</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Error</td>
<td>7488.11</td>
<td>455</td>
<td>16.46</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>93039.00</td>
<td>464</td>
<td>16.46</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$R^2 = .56$ (Adjusted $R^2 = .55$)

Table 20 presents the unadjusted and adjusted means of posttest scores for each instructional treatment and the control group. The adjusted mean for the Teacher Instruction and Module group is larger than the adjusted means for each of the other instructional treatment groups and also larger than the control group. In order to determine whether the difference in means was statistically significant, further analysis using the Bonferroni post hoc procedure was conducted.

Table 20. Posttest Unadjusted and Adjusted Mean Scores of Students per Instructional Method in the Study of the Effect of 3-D CADD on the Development of Spatial Ability

<table>
<thead>
<tr>
<th>Instructional Method</th>
<th>n</th>
<th>Unadjusted M</th>
<th>SD</th>
<th>Adjusted M</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Instruction and Module</td>
<td>101</td>
<td>15.01</td>
<td>5.97</td>
<td>14.19&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.42</td>
</tr>
<tr>
<td>Module Alone</td>
<td>164</td>
<td>12.55</td>
<td>5.41</td>
<td>12.61&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.32</td>
</tr>
<tr>
<td>Existing Materials</td>
<td>116</td>
<td>11.37</td>
<td>5.87</td>
<td>12.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.38</td>
</tr>
<tr>
<td>No CADD Instruction</td>
<td>83</td>
<td>12.66</td>
<td>6.83</td>
<td>12.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.46</td>
</tr>
<tr>
<td>Totals</td>
<td>464</td>
<td>12.81</td>
<td>6.04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Covariates appearing in the model are evaluated at the following values: pre = 11.49, Ethnicity-White = .64 Ethnicity-Black = .32, Geometry Class = .14, Art Class = .17

The Bonferroni procedure was conducted for multiple comparisons among instructional groups. Examination of pair-wise comparisons in Table 21 indicated that the mean difference
for instructional method group Teacher Instruction and Module was significant at the .05 level when compared to the mean differences for each of the other instructional treatment groups and the control group. This indicates that the instructional method Teacher Instruction and Module was more effective in increasing achievement scores for spatial ability than the other instructional methods.

Table 21. Pairwise Comparison of Instructional Methods for the Study of the Effect of 3-D CADD on the Development of Spatial Ability

| Instructional Method                  | Comparison Method                  | Mean Difference | SE  | p  
|--------------------------------------|------------------------------------|----------------|-----|---
| Teacher and module with models       | Module with models                 | 1.58 (*)       | .54 | .02
|                                      | Existing material                  | 1.85(*)        | .57 | <.001
|                                      | No CADD                            | 1.99(*)        | .63 | .01
| Module with models                   | Teacher and module with models     | -1.58 (*)      | .54 | .02
|                                      | Existing material                  | .26            | .50 | 1.00
|                                      | No CADD                            | .40            | .57 | 1.00
| Existing material                    | Teacher and module with models     | -1.85(*)       | .57 | .01
|                                      | Module with models                 | -.26           | .50 | 1.00
|                                      | No CADD                            | .14            | .61 | 1.00
| No CADD                              | Teacher and module with models     | -1.99 (*)      | .63 | .01
|                                      | Module with models                 | -.40           | .57 | 1.00
|                                      | Existing material                  | -.14           | .61 | 1.00

*aAdjustment for multiple comparisons: Bonferroni.
*p<.05
CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to determine if there was a difference in the development of spatial abilities of ninth grade Mississippi Technology Discovery students as measured by the Purdue Visualization of Rotations Test after students experienced one of three differing instructional methods using 3-D CADD solid modeling software. The CADD software used was Pro/Desktop®, a 3-D parametric modeling program. Over 300 Mississippi teachers were provided with the software during the fall of 2003. The study was conducted to see if the students benefit from its use.

The review of literature showed that there are many factors that may effect spatial ability, including gender, ethnic background, socioeconomic status, and formal learning of subjects such as art and geometry. Literature also indicated that spatial ability can be improved, and that improvement in spatial ability is related to student achievement in the academic subjects of math and science. With these factors in mind, a research design was developed to test student spatial ability achievement both before and after CADD instruction.

During the 2005-2006 school year, 14 schools participated in the study. Results for 464 student pre and posttests were analyzed using analysis of covariance. The independent variables were method of instruction, gender, ethnic background, and co-enrollment in art and/or geometry. The dependent variable was the posttest. The pretest was a controlling covariate in the analysis.

Although many individual students in the three CADD method groups showed gains in achievement, two of the instructional methods did not appear to be any more effective overall than the control group that received no CADD instruction. Only one of the instructional methods
used showed statistical significance. This method included teacher-lead instruction followed by student-directed modular instruction. The method also included 3-dimensional physical models; however, the models were also used with another instructional method with no apparent effect. Since the two groups used the same instructional materials, it is reasonable to assume that teacher-lead instruction was the likely factor affecting student achievement.

This result has implications for improving spatial ability, and also for the field of Technology Education. Since the mid 1980’s, modular Technology Education labs have been implemented in schools throughout the country. Most rely heavily on student-directed learning using computer assisted instruction. It appears that teacher-lead instruction must be combined with student-directed learning in order for modules to be effective learning environments for most students.

The National Research Council of the National Academies report *Learning to Think Spatially* (2006) concluded that spatial thinking is pervasive and vital across a wide range of domains of knowledge. The report proposed that spatial thinking be included in the list of abilities necessary to be considered literate, and that education include an emphasis on learning to think spatially. One method for achieving this goal is the use of 3-D modeling software with appropriate instructional activities.

Conclusions

Research Question 1

Research Question 1 asked what demographic characteristics describe Technology Discovery students involved in the study. The demographic information was presented in Chapter 4.
1. Less than 30% of Technology Discovery students are black. Fewer than 5% of the students are either of Hispanic, Asian, or other ethnic backgrounds. The majority of students, nearly 70% are white. Because Mississippi public schools average slightly more than 50% black students enrolled statewide, the finding of less than 30% black students in the classes is unusual.

2. Over half of the Technology Discovery students are female.

3. In each of the three instructional groups, the black females outnumber black male Technology Discovery students. White females outnumber white males in two of the three groups, while males are the majority in the third group. Among students of other ethnicity, males are the majority in one group, females in another group, and one group has equal numbers of males and females.

4. The majority of Technology Discovery students are not enrolled in art or geometry. Less than 15% are enrolled in art, less than 10% in geometry, and less than 3% enrolled in both art and geometry.

5. The distribution of Technology Discovery males and females enrolled in art, geometry, or both classes is higher for females.

Research Question 2

Research question 2 asked if differences existed in spatial ability test scores of Technology Discovery students as measured by the Purdue Visualization of Rotations Test, when the pretest scores were controlled, and students were instructed using differing instructional methods.

6. There is a difference in spatial ability based on the method used to instruct students using 3-D CADD modeling software. The instructional method of Teacher with Module is
more effective in improving spatial ability achievement scores than the other two methods.

Alias et al. (2002) stated that activities while learning CADD should include experiences ranging from manipulation of concrete models to computer visualization. Both the instructional methods Teacher with Module and Module Alone included concrete model manipulation and computer visualization with an emphasis on rotation of figures. The differing factor was the teacher-lead lesson that introduced the software as a tool to design things.

Various factors may affect instruction, but the teacher-lead lesson was the likely factor for the Teacher with Module group’s gain in spatial ability achievement. Rochelle et al. (2001) stated that social contexts such as teacher-directed group lessons give students the opportunity to successfully accomplish more complex skills than they could manage alone. Working on a task with others not only provides opportunities to replicate what others are doing, but also to discuss the task and ideas involved. The meaning and correct usage of ideas, symbols, and representations are modeled in a well-crafted lesson that requires critical thinking and interaction from students. Through informal group discussion, students and teachers can provide clear guidance, and ensure misunderstood concepts are corrected. Situational Learning theory (Lave & Wenger, 1990) contends that knowledge needs to be presented in a context that would normally involve that knowledge. Learning as it normally occurs is a function of the activity, context and culture in which it occurs. This contrasts with most typical classroom learning activities which involve abstract knowledge presented out of context. The teacher-directed lesson in the study was designed in the context of using the CADD tool to assist in designing an item that students could relate to easily, while involving them in decision making and calculations needed to
accomplish the goal. This reflected the situational learning principle that stated that learning requires social interaction and collaboration.

According to Potter & van der Merwe (2001) mental imagery develops through action, and can be developed through activities which involve imitation such as teacher demonstration of a concept, with students then replicating the action as guided practice, a form of imitation. These factors are believed to contribute to the success of the teacher-lead instruction combined with the modular instruction.

7. There is very little difference among achievement of students who studied CADD using the Module Alone method, the Existing Materials method, and students who did not study CADD.

The instructional methods Module Alone and Existing Materials were both based on self-directed student learning. Review of test scores indicated that some students gained significantly in the ability to mentally rotate an object. Others showed little or no gain. Battista (2002) cited the theory of constructivism as a basis for instructional design. The theory proposed that to understand new ideas, students must personally construct meaning using their own knowledge and reasoning. Student-directed modular learning relies on this theory, and yet it was not supported by this study.

Various factors may account for the lack of gain. Due to the typical teacher-centered learning environment students are familiar with, students may not consider instruction that is student-directed to be as important as traditional instruction. Constructivist learning theory suggests that by reflecting on experiences, students construct their own understanding of the world. In order for students to learn in this manner, they must actively participate in the planned activities of a lesson. In a modular learning environment, some students may not seriously
concentrate on the lessons provided, considering themselves as passive learners responsible for only material that is presented by teachers and expected to be tested.

According to Mohler (2001) learning theorists assert that to cognitively incorporate learning into long-term memory, the learner must be actively involved through practice. Alias et al. (2002) prescribed diverse spatial activities to engineering students, ranging from manipulation of concrete models to computer visualization activities. The influence of different types of spatial activities on the improvement of spatial ability was taken into account in the design of both teaching and learning activities for this study. The teacher-directed lesson required student involvement, as did the student-directed material. The design was crafted to include activities for guided practice and individual practice intended to reinforce learning. Physical models were included in the early lessons so that students could handle representations of the work plane seen on the computer, add layers the plane to better understand the locations of parts of the computer model, and to examine the models from different angles as they manipulated them. These manipulations were linked to views seen on the computer.

Although multimedia has been relatively successful as a learning tool, it is not enough to guarantee that students will learn from educational material. Multimedia alone is intriguing at best, but it does not necessarily require the user to be actively controlling or necessarily thinking about what is being presented (Mohler 2001). Students who learn well in a self-directed environment will utilize planned interactions known to have a positive effect on computer-based learning. Interaction may come from teachers as they introduce the topic to be studied; it may come from peers as students assist each other in understanding instructions and use of the software; or the learning materials themselves may require student action such as manipulating the 2-dimensional model so that it becomes a 3-D figure using the software as a tool.
Learning utilizing 3-D CADD software results from planned sequential interactions that build on concepts learned, and the level to which that interaction is unique. Utilizing physical 3-D models to increase student understanding of images presented on the computer allows them to compare features, making a real-world connection between the computer image and an object they can hold and change the position of. In the instructional materials for the module, students were asked to rebuild models the instructions guided them to make, and to alter the model using their own preferences and the tools provided by the software. In order to produce the finished airplane model in one lesson, they must make choices to change what is basically a series of connected rectangles, altering planes and edges for aerodynamic and aesthetic purposes.

Learning research shows that students learn best by actively “constructing” knowledge from a combination of experience, interpretation, and structured interactions with peers and teachers (Rochelle et al., 2001). By independently altering the basic airplane model, students interpreted the instructions, experimenting and combining their knowledge of the software tools. They interacted with their module partner, and may have sought opinions from the teacher and other students. Ultimately, they no longer relied on step-by-step instructions to take action. They have learned to use the software as a tool to design 3-D objects. However, in order to learn, they must have actively participated in the lessons.

If the workstation was equipped with only one computer, one of the pair of students may have dominated manipulation of the software. Students who were required to take responsibility for their own learning may not have interacted appropriately with provided materials, passively allowing a partner to interact more with the software. When students are placed in the relatively passive role of receiving information, they often fail to develop sufficient understanding to be able to apply what they have learned to other situations (Rochelle et al, 2001).
From another perspective, for some students, hands-on manipulations may divert short-term memory resources needed to comprehend simultaneous manipulation of a larger number of mental elements (Smith, 2001). Steinke et al. (2003) found that some students required observation with no activity in order to process new concepts. Trainers who work in computer labs have observed that it is often necessary to have students turn the computer monitor off in order to prevent student activity while they are introducing new procedures. In a student-directed learning environment, students must take responsibility for their own learning without relying on prompting from teachers. In most instances, this requires reading or listening to instructions while also manipulating the computer. For some students, this may result in cognitive overload.

Research Question 3

Research question 3 asked if differences existed by instructional method group in spatial ability of Technology Discovery students as measured using the Purdue Visualization of Rotations Test scores when spatial ability pretest scores, gender, ethnicity, co-registration in art, and co-registration in geometry of the school were controlled.

8. The variables of gender, ethnicity, and co-enrollment in art or geometry do not affect spatial ability.

The factor of gender is not relevant in the analysis for this study. Gender was omitted from the ANCOVA due to a lack of significant correlation with the posttest score as detected in the correlation matrix. This agrees with findings by Burin et al. (2000) that stated differences between genders are small or null in tests of visualization factors, including mental rotation. Bodner and Guay (1997) argued that statistically significant gender differences often account for only negligible fractions of the variance in ability. That argument was supported by the findings
of this study. The findings do not support the literature reporting male superiority on mental rotation as reported in the 1985 meta-analysis that found men outperform women on mental rotation tests (Hubona & Shirah, 2004).

Ethnic background has also been cited as a factor related to spatial ability, with white males performing consistently better on tests of spatial ability factors included in the NAEP mathematics assessment instruments (Ritz, 2004). Findings from this study did not support spatial ability difference among ethnic groups for mental rotation.

Although many researchers, including Reynolds and Wheatley (1999) contended that strong spatial sense permits students to formulate image-based solutions to mathematics problems, co-enrollment in geometry was not found to affect development of spatial ability. The number of students enrolled in geometry may have been too small to properly study this effect. Art was included as a factor because of the relation between imagery and spatial visualization. No change in spatial ability development was found related to student enrollment in art.

9. The use of 3-dimensional CADD modeling software affects student spatial ability development when a combination of teacher-lead and student-directed instruction is used with 3-dimensional physical models.

This method accounted for 15% of the positive change in achievement in spatial ability. Guidera (2002) stated that the increased use of 3-D parametric modeling programs is bringing about a fundamental shift in the use and instruction of CADD to a model-centric paradigm that may ultimately have a tremendous impact on learning; however, there was little literature available referencing 3-D parametric modeling. The Pro/Desktop® software uses 3-D parametric modeling. The instructional method group that experienced use of this software with an introduction to its navigation through a teacher-lead lesson generally gained in spatial ability.
Smith (2001) found those who were less skilled in spatial visualization benefited more from computer interaction, while those more skilled in spatial visualization benefited more from observation first, without immediately applying a newly learned principle. Immediate application of new concepts strains short-term memory. In the effective instructional method, student introduction to software controls and the resulting actions of virtual objects were done separately from module lessons. This perhaps lead to less strain on short-term memory for students experiencing this instructional method.

As computers and other electronic devices are more frequently utilized by students and in the delivery of instruction, studies comparing differences in spatial abilities and factors of ethnicity and gender are needed to determine if the apparent gap between male and female response to tasks involving mental rotation may be reduced as a result of these devices.

Based on the findings of this study and the review of literature, it is recognized that little is known about how the use of Computer Aided Design and Drafting technology affects student spatial ability development. Continued research in this area is both vital and needed. A similar replication of this study would contribute to the research and knowledge base for both CADD instruction and spatial ability improvement. Further data is needed to identify whether conclusions are valid and the instructional method using 3-D CAD modeling contributes consistently to improvement in the development of student spatial ability. Similar results could guide future development of CADD instruction and contribute to the goal of the National Research Council of the National Academies to include an emphasis on learning to think spatially in education systems.
Recommendations for Further Research

1. Instructional material was examined for face validity. It is recommended that examination of instructional materials for content validity be done if the study is replicated. In order for the existing instructional material to be used in further studies, the content of the material should be examined to determine if it actually address the objectives for each lesson.

2. It is recommended that training of all teachers involved in the study be done to assure consistency among treatment delivery if the study is replicated. Training teachers by modeling the Design Unit lesson would enhance the likelihood of the Teacher with Module Group being delivered effectively, and also emphasize the correct use of the 3-D models provided for both the Teacher with Module Group and the Module Alone Group.

3. It is recommended that individual student economic status be collected in future studies of the effects of 3-D CADD modeling software to add valuable data. Such information may be useful in determining if 3-D CADD modeling software might assist student populations who are considered to be at risk to improve spatial ability. Previous research showed that lower economic status students lag behind other groups when tested on spatial ability.

4. Continued research that further specifically examines development of spatial ability when using 3-D modeling software is recommended to determine if it may improve academic abilities as well as spatial abilities. Numerous studies indicate a high correlation between mathematics achievement and spatial ability. Other studies have found that spatial ability affects student achievement in science as well as other subjects.
5. There is little research available regarding the use of 3-D CADD modeling software. It is recommended that as this software increases in use in schools, studies be undertaken to determine how students at other grade levels are affected by its use, and what instructional methods may be effective in enhancing the use of this powerful tool.

Recommendation for Practice

6. It is recommended that teacher-lead instruction be utilized to introduce students to 3-D CADD modeling software prior to modular instruction or other student-directed learning of this topic. Teacher introduction of the software menus and navigation can prepare students to use the software, reducing confusion and increasing student success.

7. It is recommended that 3-D CADD software be introduced as a tool during a lesson such as Design to establish its relevance as a general tool for use in more areas than CADD.

Much of the literature reviewed (Keller et al., 2002; Lowrie, 1994; Olkun, 2003; Smith, 2001) indicated a positive connection between spatial ability and achievement in mathematics. Geometry education has proven to be a powerful means of improving spatial abilities according to Kaufman et al. (2003). If student academic achievement in such subjects as mathematics can be improved through the use of geometry-based 3-D CADD modeling software, students will benefit in both academic areas and in the improvement of spatial ability vital to many careers and to functioning in our world. In conclusion, continued research is warranted to determine if using 3-D modeling software may improve academic abilities as well as spatial abilities.
REFERENCES


APPENDIX A: SURVEY

TEACHER SURVEY

Teacher Name: ___________________ Phone: ___________ School: ____________________________

1. What type of schedule will your school operate during the 2005-2006 school year?
   4 x4 block schedule: ___  Regular schedule: minutes ____  Modified block schedule: A/B
   Modified block notes: ____________________________________________________________

2. What CADD software are you using in a module for students?
   Pro/Desktop ___  AutoCAD LT ____  D&M ____  Other:___________

3. If Not using Pro/Desktop, what instructional material are you using?
   Original Module ____  Teacher Modified Module ___  Teacher Written material ___

4. If Pro/Desktop, what instructional material is being used? (Underline or highlight any that apply)
   a. Tutorials from teacher training
   b. Tutorials downloaded from a web source
   c. Simon Badcock Book from the cd provided
   d. Playground tutorial from the cd provided
   e. Boxford book from the cd provided
   f. Book purchased separately
   g. Material developed by another teacher: _________________________________
   h. Self-developed material as module
   i. Self-developed material with whole class
   j. PowerPoint presentations from the Blackboard site
   k. Use as enhancement on multiple workstations
   l. Other (please specify) _________________________________

5. Do you instruct students as a whole class on how to use CADD prior to module rotations? ____
   If yes, how many hours?  1  2  3  5  6  7..8  9..10  Other __________

6. Do you currently use any physical 3-dimensional models to assist in instruction? (underline or
   highlight):  Blocks   Car assembly   Clear box to simulate Cartesian coordinates
   Other: __________________

7. Will you be willing to participate in research conducted during the fall 2005 semester? _____

8. Will you inform your administration that you are participating in a study? ______

   The testing materials will be provided and scored without cost. No scoring or data entry is required of the teacher. Individual student names are not included in the study. The study material is not included in student grading procedures. No evaluation of teacher effectiveness is included in the study.
## APPENDIX B: CONSENT FORMS

### Parental Permission Form – Spatial Abilities Study

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>Effect of CADD Software on Development of Spatial Ability of Ninth Grade Students (CADD = Computer Aided Drafting and Design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Site:</td>
<td>Your Child’s Ninth Grade Technology Discovery Class</td>
</tr>
<tr>
<td>Investigators:</td>
<td>The investigator is available to answer questions, M-F, 8:00 a.m.-4:30 p.m.: Ms. Lynn Basham, Mississippi Department of Education, Jackson, MS, 601-359-3940.</td>
</tr>
<tr>
<td>Purpose of Study:</td>
<td>To determine if there is a difference in the development of spatial abilities of ninth grade Technology Discovery students by the instructional methods used.</td>
</tr>
<tr>
<td>Inclusion Criteria:</td>
<td>Students in the 9th Grade Technology Discovery Class.</td>
</tr>
<tr>
<td>Description of Study:</td>
<td>Students in 15 Mississippi high schools will take a 30 item multiple-choice spatial ability pretest and complete a student information form. The student information form asks students to indicate their gender, ethnicity, whether they are enrolled in Art, and whether they are enrolled in Geometry. Then, students will receive instruction relative to the development of spatial abilities in one of three formats: 1) using existing CADD software module only, 2) using existing CADD software and students receiving a copy of a new instructional module and 3) using existing CADD software and receiving approximately 3 hours of teacher instruction on the development of spatial abilities in addition to the new CADD module instructions. After completing the spatial abilities instruction, the student will take a 30 item multiple-choice spatial ability post-test.</td>
</tr>
<tr>
<td>Risks:</td>
<td>There are no known risks.</td>
</tr>
<tr>
<td>Right to Refuse:</td>
<td>Participation is voluntary, and your child will become part of the study only if both child and parent agree to the child’s participation. At any time, either the student may withdraw from the study or the student’s parent may withdraw the student from the study without penalty or loss of any benefit to which they might otherwise be entitled. The student will not receive any special benefit for participating and the student will not be penalized if he/she does not participate.</td>
</tr>
<tr>
<td>Privacy:</td>
<td>Student privacy is guaranteed. Results of the study may be published, but no names or any personally identifiable information will ever be included in any publication.</td>
</tr>
<tr>
<td>Financial Information:</td>
<td>There is no cost for participation in the study, nor is there any compensation to the students, parents, or teachers for participation in the study.</td>
</tr>
<tr>
<td>Signatures:</td>
<td>I have read and understand the information in the parental information form. I understand that I may direct additional questions regarding study specifics to the investigators listed above. Also, if I have questions about my child’s rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutional Review Board, Louisiana State University, (225) 578-8692. I will allow my child to participate in the study described above and acknowledge the Investigator’s obligation to provide me with a signed copy of this consent form.</td>
</tr>
<tr>
<td>Parent’s Signature:</td>
<td>___________________________, 2005</td>
</tr>
<tr>
<td>Date:</td>
<td>_____________, 2005</td>
</tr>
</tbody>
</table>
The parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent from to the parent/guardian and explained that by completing the signature line above he/she has given permission for his/her child to participate in the study.

____________________  _____________, 2005
Signature of Reader                   Date
Student Assent Form – Spatial Abilities Study

I, _____________________ (print your first and last name in the blank), agree to be in a study to determine if there is a difference in the development of spatial abilities of ninth grade Technology Discovery students in Mississippi by the instructional methods used. I will take a pretest exam and complete an information form on which I will record my gender, ethnicity, whether I am enrolled in Art, and whether I am enrolled in Geometry. Then, after I study CADD, I will take a post-test exam. I can decide to stop being in the study at any time without getting in trouble.

_________________________  ______  _____________________, 2005
Student's Signature  Age  Date

_________________________  _____________________, 2005
Witness*  Date

*Note: Witness must be present while the student reads this agreement and not just the signature by the minor. The witness should explain anything that the student does not understand.)
Parental Permission Form--Spatial Abilities Study  
(Form for Control Group)

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>Effect of CADD Software on Development of Spatial Ability of Ninth Grade Students (CADD = Computer Aided Drafting and Design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Site:</td>
<td>Your Child's High School.</td>
</tr>
<tr>
<td>Investigators:</td>
<td>The investigator is available to answer questions, M-F, 8:00 a.m.-4:30 p.m.: Ms. Lynn Basham, Mississippi Department of Education, Jackson, MS, 601-359-3940.</td>
</tr>
<tr>
<td>Purpose of Study:</td>
<td>To determine if there is a difference in the development of spatial abilities of ninth grade students by the instructional methods used.</td>
</tr>
</tbody>
</table>
| Inclusion Criteria: | 1. Students in selected 9th Grade in schools where a Technology Discovery Class is offered.  
2. Students in selected 9th Grade in schools where a Technology Discover class is not offered. |
| Description of Study: | Your child is in a school where a Technology Discovered Class is not offered. Your child will only be asked to take a 30 item multiple-choice test of spatial ability so that the spatial ability of students like your child can be compared to the spatial ability of students who take specialized courses in schools that teach spatial ability. The student information form asks students to indicate their gender, ethnicity, whether they are enrolled in Art, and whether they are enrolled in Geometry. This personal information will only be used for comparison to the other students and to improve the quality of education programs. |
| Risks: | There are no known risks. |
| Right to Refuse: | Participation is voluntary, and your child will become part of the study only if both child and parent agree to the child's participation. At any time, either the student may withdraw from the study or the student's parent may withdraw the student from the study without penalty or loss of any benefit to which they might otherwise be entitled. The student will not receive any special benefit for participating and the student will not be penalized if he/she does not participate. |
| Privacy: | Student privacy is guaranteed. Results of the study may be published, but no names or any personally identifiable information will ever be included in any publication. |
| Financial Information: | There is no cost for participation in the study, nor is there any compensation to the students, parents, or teachers for participation in the study. |

I have read and understand the information in the parental information form. I understand that I may direct additional questions regarding study specifics to the investigators listed above. Also, if I have questions about my child’s rights or other concerns, I can contact Robert C. Mathews, Chairman, Institutional Review Board, Louisiana State University, (225) 578-8692. I will allow my child to participate in the study described above and acknowledge the Investigator's obligation to provide me with a signed copy of this consent form.

Parent's Signature: __________________________, 2005  
Date: ________________

The parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent from to the parent/guardian and explained that by completing the signature line above he/she has given permission for his/her child to participate in the study.

Signature of Reader: __________________________, 2005  
Date: ________________
Student Assent Form – Spatial Abilities Study
(Form for Control Group)

I, _____________________ (print your first and last name in the blank), agree to be in a study to determine if there is a difference in the development of spatial abilities of ninth grade Technology Discovery students in Mississippi by the instructional methods used. I will take a 30 item multiple-choice test and complete an information form on which I will record my gender, ethnicity, whether I am enrolled in Art, and whether I am enrolled in Geometry. I can decide to stop being in the study at any time without getting in trouble.

______________________  ________________, 2005
Student's Signature   Age          Date

______________________  ________________, 2005
Witness*                   Date

*Note: Witness must be present while the student reads this agreement and not just the signature by the minor. The witness should explain anything that the student does not understand.)
APPENDIX C: STUDENT INFORMATION SHEET

Spatial Ability Study

Name: _______________________________________________________________

Circle Gender:     Female     Male

Circle Race:  White   Black  Hispanic  Asian  Other (specify) ____________

Are you currently enrolled in an Art class?  Yes  No

Are you currently enrolled in a Geometry class?  Yes     No
Teacher Guide to Playground Design Activity

PRIOR TO LESSON:
- Work through the Playground.PDF tutorial to familiarize yourself with concepts and how the Pro/Desktop software works in the activity. You end up with a giant Lego type block.
- Work through the Session 2 Geometry PowerPoint
- Read through the questions that guide the lesson.
- If possible, have the lesson in a computer lab so all students can work through it with you. If not, the next best thing is to project the computer screen. If this is done using a TV and scan converter, have the software menu drawn/posted larger on the whiteboard

ANTICIPATORY SET:
- Session 2 Geometry PowerPoint with 3 D models
- TERMS: cylinder, cube, Work plane, extrude

INSTRUCTION BASE:
Tell the students about the design brief. The class is a company that will design a playground toy from recycled rubber. The client wants playground blocks that will be useable and durable outdoors.

QUESTION TO STUDENTS:
- What are some things we have to keep in mind when designing something for children?
  Safety
  Durability
  Weight
  Scale
• Discuss why each is important. Scale is going to need to be the starting point. How big should the blocks be? Too small and they get thrown or taken home. How big would be good? (The tutorial uses a 1-foot cube)

USE SOFTWARE:

• Use the clipboard to illustrate a plane. Add the transparency with the XY axis to relate it to the Pro/Desktop Screen. Pointing out which “tool” you are using, draw a 1-foot square on the work plane in the view that lets you look straight down on the plane.

• Dimension the square.

QUESTION TO STUDENTS:

What does extrusion mean?

It means pushing a material through a shape so the material keeps that shape---toothpaste and frosting, play dough, PVC pipe…Add the transparency with the square to the clipboard.

USE SOFTWARE:

• Change the view to enhanced

• Open the extrude menu box

• Name the extrusion Block 1, Show them that Add material is checked, and Above Work Plane is checked.
• Hold the transparent clipboard up and place the cube on top and underneath to show the importance of checking the right box. Type in the distance as 12, pointing out that the measurement is (in) for inches.

• Show the resulting cube:

![Image of 3D cube model]

• Use the manipulate tool 🔄 to make the cube show different sides. Use the autoscale 📊 to return to the working view. Add the graph paper cube onto the square on the clipboard and move it in different positions.

SAVE FILE!

QUESTION TO STUDENTS:

• What is wrong with this design?

• It has sharp edges and corners that are dangerous.

• If it is supposed to be injection molded, it is too straight to come out of the mold. Imagine in a square cake pan had sharp corners and no slant of the sides. The cake would be more difficult to remove from the pan in one piece.

USE SOFTWARE:

• Fix the molding problem first.
• Go to the Feature Browser.

• Re-open the extrusion menu box, (not Chamfer as in the picture.

• Choose Redefine

  \[\text{Select Edges} \rightarrow \text{Select Faces} \rightarrow \text{Supress} \rightarrow \text{Redefine...}\]

  \[\text{Group} \rightarrow \text{UnGroup} \rightarrow \text{Pattern...} \rightarrow \text{Unpattern}\]

• The extrusion menu box will reopen.

• In the Taper angle box, type a number suggested by the students, (the larger the better)

• Mind them how big a degree is. Type 3 into the Taper angle

•nt to get the block out of the mold easily.

• What is still wrong with the design? Sharp edges!

• Use the select edge tool while holding the shift key to select all the edges except the

  \[\text{bottom.} \quad (\text{all selected edges should be red})\]

• Get the round (fillet) tool

• Type 0.25 (not 2.5 as in the picture)

  \[\text{Round Edges} \rightarrow \text{Round} \rightarrow \text{Constant radius} \rightarrow \text{Variable radius}\]

  \[\text{Tangent edges} \rightarrow \text{Smooth transition}\]

  \[\text{Radius (in): 0.25}\]

• SAVE FILE!

QUESTION TO STUDENTS:

• What else may be a problem with our design?

• How much does a cubic foot of rubber weigh? (Have them guess).

• A cubic foot of manufactured rubber weighs 95 pounds. How can the design be changed?
USE SOFTWARE:

- Use the manipulate tool to show the bottom of the block.

- Use the select face tool to select the bottom surface (it will turn red).

- Get the Shell tool. Decide how thick the walls of the block should be for durability and weight. Shell the block to that thickness an inch is good).

SAVE FILE!

QUESTION TO STUDENTS:

What would make it easier to use?

What would make this more fun on a playground?

Putting holes in the sides would make it easier to use because children could pick it up more easily and that would reduce weight. Put those in later.

Adding a connector on top like Lego or Mega blocks could make it more fun.

USE SOFTWARE:

- Use the manipulate tool to show the bottom of the block as if looking at it straight.

QUESTION TO STUDENTS:

- How far should it be from side to side inside the Block?

USE SOFTWARE:

- Use the work plane view tool to look directly down on the top of the block.
• Use the select face tool to select the top of the block. Right click and choose New Sketch from the pop up menu. That lets you draw on top of the block.

• Get the draw circle tool and draw a 10-inch circle on the center of the block top.

**QUESTION TO STUDENTS:**

• What next?

**USE SOFTWARE:**

• Get the extrude tool and make the circle 1 inch high with a 3 degree taper.

• Use the select face tool to select the top of the circle.

• Get the round (fillet) tool and round the edge between 0.1 and 0.25, whichever looks best for the connector.

**GUIDED PRACTICE:**

• Next, select a side of the block using the appropriate tool. Right click, choose new sketch.

• Ask the students what shape to make the hole in the side. Draw the shape,

• Ask them what tool is needed? (choose the extrude tool, and this time check below the work plane and remove material, 1 inch.)

• Do the same thing to the other 3 sides. The holes in the sides do not have to match.

**REVIEW:**

• The goal was to design a playground block from recycled rubber. Issues were safety, durability, manufacturing, weight, and would it be fun.

**ADDITIONAL MATERIAL:**

• If using a computer lab, **Independent Practice** can take place to design the same block individually, or to design double versions that could be used to connect.

• Using the Playground tutorial to generate a working engineer drawing is preferred.
• If there is time, make an album design using background and material

NOTES:
APPENDIX E: TEST INSTRUMENT

Purdue
Spatial Visualization Tests
Roland E. Oury

VISUALIZATION OF ROTATIONS

Do NOT open this booklet until you are instructed to do so.

© Copyright, Purdue Research Foundation, 1976
3  IS ROTATED TO

4  IS ROTATED TO

5  IS ROTATED TO

6  IS ROTATED TO
7  \( \text{IS ROTATED TO} \hspace{1cm} \)

\( \text{AS} \hspace{1cm} \text{IS ROTATED TO} \)

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8  \( \text{IS ROTATED TO} \hspace{1cm} \)

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Answer Sheet for the Purdue Spatial Visualization Test - Visualizations of Rotations

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26. A ( ) ( ) ( ) ( )
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27. A ( ) ( ) ( ) ( )
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28. A ( ) ( ) ( ) ( )
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29. A ( ) ( ) ( ) ( )
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30. A ( ) ( ) ( ) ( )
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    C ( ) ( ) ( ) ( )
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Student Number ___ KEY ___
APPENDIX F: MISSISSIPPI PRO/DESKTOP CADD MODULE

Module Instructional Material for Treatment Groups 1 and 2

Session 1
The first thing required in most Technology Discovery labs is module inventory. Do the inventory process for this module.

Take the Pretest and hand it in.

Find the icon on the computer desktop that is labeled Session 1 CADD. Double Click on the PowerPoint and watch it.

After you complete the assignment at the end, move on to Session 2.

MISSISSIPPI PRO/DESKTOP CADD MODULE
Session 2A

Find the icon on the computer desktop for Session 2A Geometry. View the PowerPoint. After you finish your terms, get the transparent clipboard located in the workstation.

Look at the clipboard and the transparencies that go with it as planes. It does not matter what angle you hold them; they are always planes.

The Base Plane transparency has an X and Y-axis marked on it like the software you will use.

Add the transparency with a blue square to the clipboard. If a Square is projected up the Z axis (we don’t have one to model, you have to imagine it) a block or cube is formed. Place the 4” Cube cardboard box on the blue square and you have the third dimension, Z. Because all sides are 4”, you have a cube.

In Pro/Desktop you will use a term called **extrude** to send the flat shape into 3 dimensions.

Take the Blue Square transparency of the clipboard and put the one with a red line on it. Notice that the line is on the negative side of the Y-axis. You will be able to draw anywhere around the axes with the software.

Now add the transparency with the small orange rectangle. There is a foam ring that fits on the clipboard with the axis plane and the rectangle plane. It is an example of an action called Revolve that you will do. The shape that produces the ring is a rectangle.

Put the models away and move on to PowerPoint Session 2B-Views.

After you get a feel for views, you will start using the software.
SESSION 2: Geometry

Cylinder
- When the shape of a circle is projected straight up, it becomes a cylinder
- A cylinder is the shape of a can, a pipe, and things like AA batteries

Terms to Know
Familiar terms you will be using:
- Circle
- Radius
- Diameter
- Cylinder, Cone
- Plane
- Square, Cube
- Rectangle
- Triangle, Pyramid

Cone
- A cone is basically a pyramid that has a circle for a base instead of a square.
- If you slice cones at different angles, you get other figures.

Circle
- A circle is all points of a line the same distance from the center.
- Radius is how far from the center of the circle to the edge
- Diameter is how far across the circle through the middle

Sphere
- We will just describe a sphere as a ball, but obviously, it is circular.
- We can make them easily in several ways in our CADD programs.
Angles

- Angles are made when 2 lines or 2 planes intersect. The point where they meet (intersect) is the vertex.
- We measure angles using degrees and a protractor.

Rectangle

- A rectangle is like a square, but 2 parallel sides are length, and 2 sides another length.
- Rectangles can be made 3D. Then they are polyhedrons, but we will just call them blocks.

Square

- A square has all sides the same length, and all corners are 90 degree angles.

Symbol for 90 degree angle

3 inches

Triangle

- Triangles have 3 lines that can be any length.
- The angles where the lines connect can be different, but will add up to 180 degrees.
- This makes a triangle a 3 sided figure.

Cube

- A cube is a 3 D (3-dimensional) square.
- All sides are the same size.
- Project a square up and you get a cube.

Pyramid

- Triangles can be used to make pyramids and other shapes.
Planes
- A plane is a flat, two-dimensional object. It may be visualized as a flat, infinite piece of paper.
- Most of the basic work in geometry, graphing, and trigonometry is performed in two dimensions. (In other words, in a plane.)

Geometry
- We make a lot of things using geometric shapes
- We may use a formula to calculate something later.
- Geometry (from the Greek words Geo = earth and metro = measure)

Student Action
- Write definitions for underlined terms.
- Sketch and label the shapes in your notebook.
- Write a journal entry about what you find most difficult to understand about shapes and math.
Computer Aided Drafting and Design (CADD)

Mississippi Technology Discovery

Pre-Test

- Before you begin, you need to take the Pre-test.
- Your teacher may have it on the computer, or it may be a paper test.

Using This Module

- The entire module can be viewed as PowerPoints, but you may use paper guides of the slides to avoid switching back and forth between programs
- Sessions 1 and 2 are PowerPoint Only

CADD Objectives

Students will:
1. Describe terms and concepts related to Computer Aided Design, 3-D Design, and Drafting Technology
   a. Define terms and concepts related to Computer Aided Design, 3-D Design, and Drafting Technology
2. Describe the process of creating a two-dimensional model
3. Investigate career opportunities related to Computer Aided Design, 3-D Design, and Drafting Technology and identify the related Mississippi Workforce Career Cluster
4. Apply principles and concepts of Computer Aided Design, 3-D Design, and Drafting Technology
   a. Apply mathematical and/or science concepts related to Computer Aided Design, 3-D Design, and Drafting Technology
5. Apply communication concepts verbal and/or oral related to Computer Aided Design, 3-D Design, and Drafting Technology
6. Explore and demonstrate applications of Computer Aided Design, 3-D Design, and Drafting Technology

Drawing

- Drawing is making pictures using something to mark lines. We’ve usually done it for fun, but we also do it to communicate.
- When you draw things, other people see your symbols and think of what you mean.
Drawing is a universal language.

- Not all languages are written using the alphabet we use. But graphic symbols can communicate information, no matter what language you use.
- Using the signs, you can find restrooms, directions, fuel, & food. You can know that cows or deer or snow mobiles are likely to cross the road.

What is Drafting?

- Drafting is drawing using tools to clearly represent what a thing looks like, its sizes, and how it is put together.
- Before computers were common, all drafting was done using hand tools.

What is Drafting Used For?

- Every product that is produced in industry has some drafting involved, and most production relies on it.

Building are also made using technical drawings produced by drafting.

Drafting is now most commonly done using computer software.

As you know, using a computer speeds up many things that people used to do by hand.
A drawing of a complicated part that could take 6 weeks to produce is now done in a fraction of the time.
Computer Aided Manufacturing

- In addition to designing things, CADD drawings can be converted by computer to machine language that allows a machine to make a part without an operator setting it up from technical drawings.

Module Software

- You will be using software called ProDesktop.
- It is a 3D modeling software that lets you design things easily.
- If your school has software that is good for floor plans, you may also be using that.

What is CADD?

- CADD stands for Computer Aided Drafting and Design.
- In Technology Discovery, you will not only produce a technical drawing, but also design things using 3 dimensional (3D) modeling software.

Student Action

- Review your terms (There are 3 underlined in the slides).
- Write a sentence telling what CADD is used for.
- Think of something you may want to design later.
- The next few slides are student designs. You may find you enjoy design and would like to use this software at home. Ask your teacher for a copy if so.

CADD Software

- There are quite a few CADD software packages on the market. Some are extremely advanced, some will just do basic things.
- Some are easier to do house plans.
- Some are easier to make smaller things that will be produced.
Opening the Software

- If using Powerpoint, reduce the size of this Presentation so that you can see both it and the CADD program.
  
- Double click on the ProDesktop icon on the computer desktop. If it takes up the whole screen, reduce it, too.

Starting Out

- To start a new design, go to File> New
- Choose Design

(you have to have a design, or you can't make an Engineering Drawing or an Album)

Maximizing the Design Window

This part is the design window. It has a green workplane that will surround what you draw first.

The workplane is similar to a clean sheet of plastic, or a piece of paper.

Click the box in upper right corner to maximize.

Session 3
Getting Started with ProDesktop

Lynne Basham
MS Technology Education Coordinator
Getting the Drawing Ready

- Go to **Tools > Options**
- Choose the **Units Tab**
- Set the drawing paper to inches

Activity 2: Extruding a Shape

- It is often easier to start a new design than to cut many line pieces
- Close the design you have been drawing on by clicking the X for that part of the screen (Not the program)
- Start a new design

Activity 1: Drawing Tools

- To the Right on the Screen You Will Find the Drawing Tool Bar Menu
- Click on the Straight Line Tool and It Will Look Like It Is Pushed in
- Move Your cursor to the Design area, Hold Down the Left Mouse Button and Drag a Line Anywhere.
- The green outline will move to surround what you draw.

Drawing a Cube Profile

- Get the Rectangle Tool
- Drag a shape, but this time hold down the shift key while you do it. That will make all sides equal. This makes a Profile of a square
- A Profile is a shape that has all the lines connected.
- If a gap disconnects them, error messages of Invalid profile pop up.
- Most profiles fill in with color when you draw them. This one was not set to fill in.

Try Each Tool in the Design Area

- Click on each tool and draw a shape. It does not matter if they overlap right now.

- When you get to the bottom tool, use it to remove some lines. It will look like a pair of scissors, and any line it lights up will disappear when you click

Adding Dimensions

- Get the **Sketch Dimension** Button
- Using the **Sketch Dimension** button will let you label the size.
- It will also let you change size
**Adding a Dimension**

- Touch a line with the cursor, hold down the left mouse button, and drag away from the shape.
- Double click on the new line with the numbers in it. It should change color.

**Setting the Height of an Extrusion**

- Type 5 for the distance.
- Make sure Add Material and Above Workplane are checked.
- (You can also just drag the yellow box up to where you want it.)
- Now you have a Cube (5" x 5" x 5").

**Changing Size**

- Double click again and it changes color again. The Properties box appears.
- Make the length 5 inches.
- It is important to label your sizes with the sketch dimension tool as you go.
- This helps you calculate things, and also transfers to the engineering drawing.

**Activity 3: Selecting Parts of an Object**

- The Selection Tool Bar Menu looks like this.
- The tool chosen in this view is used to select lines.
- If you touch a line on the bottom of the cube with this tool, the line changes color.
- Sometimes your design seems to disappear. Click the Select Line tool to get it back.

**Extruding the Square**

- The Features Tool Bar Menu looks like this.
- Click on the first button. This is the Extrude tool. It will let you make the shape 3 dimensional.

**Activity 3: Selecting Parts of an Object (continued)**

- The Select Edge tool is used to select edges of 3D objects.
- Try it on the cube. A line should change color on an edge of the cube.
Selecting Surfaces of an Object

- The Select Face tool is used to select surfaces of 3D objects.

Selecting a Surface

- Touching the cursor just inside the top outline on the cube, click the mouse button.
- The top of the cube should change color.

Activity 4: Changing a Surface

- With the top of the cube selected, get the feature button that will round things.
- When you click it, a menu will come up to put the radius size in. The size in this example is 2.25 inches.
- Type it, click okay, and the cube should look like this.

Changing Another Surface

- Use the down arrow to turn the object on the screen upside down.
- Get the Select Face tool and highlight the bottom.
- Use the Round Tool and set the radius at 2.25.
- When you click Okay, the object should look like this.

Activity 4: Changing a Surface

- The Feature tool bar has 4 buttons that make things 3 dimensional.
- The other 5 buttons are used to change surfaces.

More Changes

- If you draw a new cube and use the chamfer tool instead of the rounding tool, when you select the top, the cube might look like this.
**Selecting Edges**
- The whole top or side of an object may not need to be rounded or slanted.
- To choose only one edge of an object, you need the **Select Edge** Tool.
- To use it, touch the cursor to an edge of your object. The edge should change color to red (it may be hard to see).

**Student Activity**
- If using PowerPoint, close or minimize this presentation.
- Draw a profile shape.
- Extrude it.
- Label it using **Sketch Dimension** tool.
- Change the shape by rounding and chamfering edges or surfaces (remember you can use the arrow buttons on the keyboard to move the object). Try another surface change button if you want.
- Remember you can always start a new drawing if things get too confusing.

**Different Edge Changes**
- Select an edge and use the rounding tool on it.
- Select a different edge and use the chamfer tool to slant it.
- Use the Sketch Dimension tool to change a size.

**Practice What You’ve Learned**
You know how to:
- Start a new design.
- Choose Drawing Tools.
- Make a Shape called a **Profile**.
- Make the Shape 3 Dimensional by **Extrusion**.
- Turn a Shape Using Arrow Keys.
- Select a **Line**.
- Select a **Surface**.
- Select an **Edge**.
- Round a surface or an Edge (Fillet).
- Slant a Surface or an Edge (Chamfer).
- Use the Sketch Dimension tool to label size.

**Planes**
- Planes are the imaginary flat surfaces we use to keep track of where we are.
- Each drawing actually starts out with 3 planes:
  - Base
  - Frontal
  - Lateral
- This drinking glass was drawn from one plane.
Workplanes Browser

- The Workplanes browser allows us to look at what planes are being used, and what sketches we have of an object. This sketch is named initial.

Unequal Chamfer

- For this pyramid, we set the top distance to 2.49 (almost half the block).
- The other distance is set for 5 inches so the slant will go all the way to the bottom of the 5 inch cube.

Feature Browser

- The Feature browser allows us to look at what we have done to an object.
- To switch to Feature browser, use the drop down arrow and select Features.

Pyramid

- Now the cube has changed to a pyramid because the top has so much slanted off from it that the sides shifted.

Altering Practice

- Start a new design, and once again draw a 5 inch cube to practice altering.
- Select the top surface of the cube. (if you don't remember how, see Session 3)
- Get the Chamfer tool. You are going to do an unequal chamfer.

Change Views of the Object

- Use the button to rotate the pyramid and see it from different angles. You can use arrow keys too.
- Use the View onto Workplane button to see it from the top.
- Use the autoscale button to fit the object on the screen.
Adjusting Features
- If you do not like the look of a change you make, you can adjust it by going to the Feature Browser.
- This shows that we extruded the square that is on the initial drawing.
- It also shows that we chamfered extrusion 1.

Removing Features
- We can use the feature browser to delete something we did.
- Right click on the feature you want to remove (in this case, the chamfer).
- Choose delete. The shape will not change until you click the green update light near the top.
- You should have your cube back as a cube shape.

Changing cube from a pyramid
- Go to the Feature Browser. Highlight Chamfer 1 and right click on it.
- Choose Redefine.

Removing Features
- Sometimes we get a failure notice for a feature. This is usually because we are asking for the wrong thing.
- When we get a message like that, a red X will show over the feature in the Feature Browser.
- To get rid of the error, close the error message and drag the red X feature to the recycle bin. (You can also right click on it and delete it.)
- If you do not remove the error, it keeps appearing every time you use a new feature.

Redefining a Feature
- The chamfer menu used to make the sides of the cube slant appears.
- Change 2.49 to 1
- Hit Okay.
- The cube sides shift back out to the new number.

These are the sizes from the top view.

Changing Extrusion
- We can use the feature browser to change the extrusion we did.
- Right click on the feature you want to change (in this case, the extrusion).
- Choose redefine. Change the distance from 5 to some other number. If all sides are not 5 inches, it is not a cube any more.
- We will call any extruded rectangles that are not equal side Blocks.
Shell Feature
- Now that you have a solid block, we can make it hollow.
- Select a face (It does not matter if it is the top or side)
- Get the Shell tool from the Feature toolbar

Practice changing the block
- Select some edges to round
- Select an edge to chamfer
- Redefine one of your features
- If you get an error message, read it carefully.
- Be sure to throw the red X away
- Try deleting the feature Extrusion 1. What happens? Why?

Shelling a Solid Object
- When you have a surface selected and the shell tool, a window opens to type in what distance to offset from the outside in.
- Type .5 and hit Okay

Review Session 4
- You learned how to switch from the Workplanes browser to the Feature browser
- You learned how to adjust or redefine a feature
- You learned how to delete a feature
- You learned how to Shell a solid object

Feature Practice
- You should have something like this
- Now, redefine the shell. Change the offset to 1
- Delete the shell
- Try to shell a different surface

Revolve a Profile
Lynn Basham
Revolving

In CADD, Revolve means to send a shape around a center axis, usually 360°.
- The easiest way to think of it is like some party decorations that have a that unfolds from flat to round.

Profiles of Decorations

To get the bell shape, the decoration first has a profile. This kind of decoration has a cardboard profile with tissue paper attached to unfold.
- The profile looks sort of like this. It is flat.

Other Profiles

- The turkey tail profile is like this when it is flat.
- The ball profile is a half circle when it is flat.
- If a hula hoop had a flat profile, it would be a circle.

Making a Revolve

In ProDesktop, a revolve starts with an axis on the base workplane.
- It will go on the initial drawing, so the name needs to change from Initial to Axis.
- Right click on the word Initial to rename the sketch axis.

Drawing the Axis

Before drawing the straight line, use the View Onto Workplane button to look straight down on the work plane like looking at a piece of paper.
- Get the Straight Line tool, hold the Shift key, and drag a line down the window.
- It does not matter how long it is, as long as it is straight.
Adding a New Sketch to the Workplane

- Revolves use 2 sketches on one workplane.
- Add a new sketch to the base workplane by right clicking on the word Base
- Select New Sketch

Naming the New Sketch

- Type profile in as the name in the New Sketch window.
- The Filled box is not checked in this picture. Check it and hit Okay

Adding a Profile

- Get the Rectangle drawing tool and drag a rectangle just to the side of the green arrows
- Get the Sketch dimension tool and make the bottom line on the rectangle 0.625 inches. (see session 3 if you forgot how)
- Make the side .5 inches
- Save the Design!!!
Looking Straight onto the Object

- When Okay is clicked, the drawing should look like this.
- Click the Isometric View button.
- You can also use the Down Arrow key on the keyboard to change the angle.

(Numbers in picture are examples)

Distance Changed

- Change the distance by double clicking on the numbers twice so that the Properties box opens.
- Type .125 so that the whole will be .25 inches in diameter.

Revolved Rectangle

- Look closely at your object.
- Do you see the profile? Right now, it is in Constraint setting to show details. It is still a rectangle.
- Click the Select Parts button to see only the object.

(Numbers in picture are examples)

Revolved Wheel

- Now the object looks like a wheel. (If it doesn't, did you hit the update button?)
- Calculate the overall diameter of the wheel and write it down.

Changing Distance

- To change the size of the hole in the object, the distance from the axis to the profile has to change.

Get the Sketch Dimension tool, touch it to the Axis so that the axis changes color.
- Hold the Shift key and touch the inside edge if the rectangle and drag up while you are holding the mouse button.

(Numbers in picture are examples)

Removing the Revolve Feature

- Go to the Feature browser.
- Select the Revolve 1 feature, right click, and delete it.
- That will put you back to a rectangle as the profile.
Making a Wheel

- You are going to follow some sketches to make the rectangle into a wheel profile.
- First draw a smaller rectangle on your original one.
- Then, cut the top line out of the new box, and the line segment from the original.
- That leaves a rectangle with a notch.

Rounding a Corner

- Next, get the Arc (also called fillet) tool.
- Touch it to the corner, hold down the left mouse button, and push toward the other corner until you like the arc.

New Wheel Profile

- If you want to make a few other changes to the profile, now is the time.
- Next the profile will be revolved.

Revolving the Wheel

- Go to the Feature menu or Feature toolbar. Choose Revolve Profile; make sure the profile and axis are in the correct places.
- Set the angle for 360°.
- When you hit Okay, a wheel should appear.

Revolve Trouble Shooting

- When a complex figure gives an Invalid Profile error, usually there is a spot where the lines don't meet, or they cross.
- Check that all the places you should have connections are clean.
Examine the Wheel

- Put it in Isometric view, rotate it with the arrow keys. You may want to go back and change a feature.

Save the design as wheel with your initials.

Practice What You Have Learned

You Know That:

- A Revolve sends a 2 dimensional profile revolving around an axis.
- The axis and profiles must be on the same workplane.
- Changing the distance between the axis and profile changes the object.
- A profile can be changed by deleting the revolve in the Feature browser.

Sweep Along a Helix

Session 6

Making a Sweep

In ProDesktop, a Sweep starts with an axis on the base workplane (the same way as a revolve).
- It will go on the initial drawing, so the name needs to change from Initial to Axis.
- Right click on the word Initial to rename the sketch axis.

Drawing the Axis

Before drawing the straight line, use the View Onto Workplane button to lock straight down on the work plane like looking at a piece of paper.

Cursor position

Get the Straight Line tool
- Position the cursor on the green axis so that the Coordinates showing are 0, 0.

Student Activity

- Start a new drawing
- On the Initial Sketch, draw an axis line
- Add a sketch to the Base Plane (look at slide 8 if you forgot how)
- Label the new sketch profile
- Draw a profile of a familiar object; ball hoop, clock frame, ring, a different wheel, etc. Remember to dimension and save your design as you go.

Back to Main Menu
Drawing the Axis

Hold the Shift key, and
drag a line down the
window.
It does not matter how long
it is, as long as it is straight.

Adding a Profile

Get the Circle drawing tool
and drag a circle just to the
side of the green arrows.
Get the Sketch dimension tool
and make the diameter of the
circle 0.50 inches. (see
session 3 if you forgot how)

Save the Design!!!

Adding a New Sketch to the Workplane

- Sweeps use 2 sketches
  on one workplane.
- Add a new sketch to the
  base workplane by right
dclicking on the word
  Base.
- Select New Sketch.

Sweep Along Helix

- From the Feature Menu, choose
  Sweep Profile, Along
  Helix.
- Make the Pitch 1.8.

Naming the New Sketch

- Type profile in as the
  name in the New Sketch
  window. (Just like with a
  revolve)
- The Filled box is not
  checked in this picture.
  Check it and hit Okay.

Completed Helix Sweep

- A figure similar to the
  one shown should occur
  when you hit Okay.
Next, practice doing a sweep with a more complicated profile
1. Set up the new Design with an axis drawn on the 0, 0 coordinates
2. Add a New Sketch named profile
3. Get the circle tool. The new profile will start with that, but much more will be added.

Draw a 2 inch circle near the axis
Use the Sketch Dimension Tool if you are not sure the circle is 2 inches

Get the Straight Line Tool
Drag a line across the top of the circles
Next, parts of the circles and line will be deleted.

Using the circle tool again, touch the inside of the first circle
A small square should appear to show the center
Pull a circle inside the first circle. This makes concentric circles

Get the Delete Line Segment tool
Cut the segments of circles shown in these pictures

Cut the segment of line shown in these pictures
**Valid Profile**
- A profile shaped similar to a horse shoe should fill.
- This profile is ready to sweep along a helix.

**Changing The Pitch**
- Go to the Feature Browser, highlight Helix 1
- Right click and choose Redefine
- Change the pitch to a different size

**Pitch Angle**
- The pitch for this sweep is 65 degrees
- The result is something like this

**Spiral Too Short**
- If the spiral is not long enough, the axis can be changed to make it longer
- Get the Select Line tool
- Highlight the axis line (axis has to be the active sketch)

**Spiral Too Tight**
- If the angle of the pitch had been less, the spiral figure might be tighter than it should be. A pitch of 45 degrees instead of 60, is an example

**Increasing Axis**
- With the axis selected, pull the line to make it longer
- Click the Update button
- The spiral should change to match the axis
Practice What You’ve Learned

- You learned how to make a Sweep along a helix by putting 2 sketches on the base plane.
- You learned how to change the angle of the spiral by Redefining it.
- You learned how to change the length of a spiral by changing the axis.
- If you have time, make another profile to sweep on a helix.

Back to main Menu

Shape 1-Axle

- The first shape you make in this lesson will only take a minute, but you need it to go with the wheel you made earlier.
- Open a new design, drag a small circle, use the Sketch Dimension tool to label the size as 0.25”.
- Extrude the circle to 2.6875” long.
- Save the design 2 times as axle1 and axle2.

Combining Shapes

Session 7
Lynn Basham

Combining Shapes

There are 2 basic ways to combine shapes.
1. Making assembly drawings that add parts together
2. Adding new sketches to existing surfaces or axes.

The first shape you make now is to be added to a toy van later.

The other shapes will teach you about adding to existing designs.

Shape 2-Table

- Start a new design
- Starting at coordinates 0,0 (the corner of the green axes arrows) drag a 24” radius circle & add a dimension so you can tell the correct size. The dimension box may say radius or diameter. If it says diameter, double the number. Use Auto scale to see the whole circle.
- Extrude the circle 1.5 inches.

Table Pedestal

- Rotate the table top so you are looking at the bottom side. Use the Select Surface tool to turn the bottom red.
- Right click, choose New Sketch labeled pedestal.
- Drag a 3” radius circle in the middle, add a dimension to make sure of radius or diameter.
- Extrude it 30”.
- Select the bottom surface of the pedestal, right click, New Sketch labeled bottom.
Table Bottom
- Drag a 12" radius circle on the new sketch
- Extrude it 2"
- Now you have a round table, experiment with shaping the edges so the table looks good and will be safer.

Tail Fins
- Draw a rectangle 1.5" long and 1" wide at the back of the block line.
- Dimension the sides.
- Save.
- Repeat on the other side.

Shape 3-Plane
- Open a New Design
- Draw a block 2" wide and 8" long.
- Dimension it.
- Extrude it 2" tall.
- Save as Plane

Shape Fins
- Use the Straight Line tool to shape the fins, drawing angles and snipping the lines you don’t need.

New Sketch
- Select the bottom side with the Select Face tool, right click and choose new sketch named plane bottom
- Look directly down onto the new sketch

Wings
- Add rectangles on either side that are 6" long and 2" wide
- DIMENSION THEM
  - That way you know all sides are matching
  - The location of the wings is up to you.
**Wings & Fins**

- Shape them the same way you did the tail fins
- You should be ready to extrude the Fins and Wings

**Top Fin**

- At the back of the block, draw a 1.5 x 0.25 rectangle at the middle. The software only lets you draw the rectangle on one side of the middle, so draw another to match it.
- Delete both middle lines to get a valid profile. Dimension it.
- Save drawing
- Extrude the fin 2" above the workplane

**Extrude Wings and Fins**

- When the plane was designed, an error occurred. An invalid profile lets you know a line needs to be cut or connected.
- This one had one line that missed being deleted when shaping the wings

**Contouring Plane**

- Now you have a plane with a fuselage, 2 wings, and tail fins.
- You can experiment with rounding and chamfering edges to make it aerodynamic.
- You may want to add a circle to the front for a nose cone.
- Save your design. You may want to improve it aerodynamically later.

**Extrude**

- When extruding the wings & fins, it is important to check "Below Workplane"
- Extrude them .5 inches
- When you rotate the Drawing, it should look like this

In this session you learned to:

- Add new sketches to add shapes
- That you can contour basic shapes to improve your designs, by changing edges and surfaces
- 2 ways to combine shapes are to add sketches and to make assemblies of parts
Van Design and Assembly

Prepared by Stephen Yaffe, Edited by Lynn Basham

Conventions of this Tutorial
- Since most people who will attempt this tutorial have already had some exposure to Pro/ENGINEER, steps have been taken to speed up the design process. Rather than using icon-based instructions, keyboard shortcuts are presented, as they are faster and more efficient. Some of the commands (extrude, revolve, etc.) will also be shown in brackets but with the Control key or Alt key, followed by a plus sign (+) as a prefix, and multiple key strokes separated by commas.
- Example: to create an extrusion using keys rather than the icon, first press the Alt key, then while holding it, press and release the R key once, then press and release the E key, and finally release the Alt key.
- In notation form, extrusion looks like this: [Alt + R, E].
- Sequential operations may be indicated by commands separated by an arrow (>). For example, the following command: [C] > Drag a circle means – type the C key on your keyboard to select the circle sketching tool, and then drag a circle.
- Set Up
- There are a few things you will need to do to get your computer ready for this tutorial. This project has been done in WINCH95. The first thing you will need to do is make sure that the unit of measurement on your computer is set to inches.

Van Body
- Open a new Design File
  - [Ctrl + N] > [Enter].

Steps To Project Holes For The Axels To Go Through
- Select the top face of the extruded rectangle ([F]).
- Right click (while the surface is red) > select New sketch > Name it ‘holes’.

Sketching and Extruding a Rectangle
- Drag a rectangle [R].
- Drag a dimension line on one side and an adjacent side (see picture) [Z].
- Double click on one number box > enter 3.8” in the dialogue box.
- Double click on the other number box > enter 6” in the dialogue box.

Extruding a Block
- Use the Extrude tool [Alt + R, E]
- Add material,
- Distance = 2”.
- Above workplane.
- OK.
Adding Wheel Positions

- To view straight down on the face, use [Shift + W].
- Drag a line of about 0.75" from the bottom of the rectangular face, and 1.5" from either side.
- The 0.75 will give a good distance to the 1.5" diameter wheels.
- While the line is red (selected), toggle construction (Ctrl + 6).
- When you toggle the line, it will turn to dashes.

Making Hole Profiles

- Drag a circle centered on one endpoint of the construction line.
- Hold [Shift] and drag a second circle on the other endpoint (holding shift constrains the circles to be equal radius).
- Click on one circle and drag a dimension line.
- Double click on the number box at the end of the line and enter a value of 0.25, diameter [Z] (both circles will be that diameter).

Distance from the van bottom

- To add the distance dimensions so you can change them, get the Sketch Dimension tool and click on the line.
- Click the bottom edge of the van and drag to the side while you hold the mouse button.
- Double click on the number box and make sure the distance is 0.75.

Projecting the Holes Through the Block

- Get the Projection tool.
- Name the profile "axles".
- Subtract material.
- Through entire part.
- OK.

You may get an error message saying the sketch has been used. Click yes.

Creating Dimensions

- To make sure the ends of the line are 1.5" from the sides, get the Sketch Dimension tool and click on the end of the line.
- Click and drag up while holding the mouse.
- To make sure the line is 3", use the Sketch dimension tool and click on the line and drag up.

Note: You only have to dimension one side as 1.5" because the 3" two sizes subtracted from the 6" block leaves 1.5"

Taper edge to create "Windshield"

- The van model in your workstation is flat on front.
- This is to allow you to choose your own angle for the windshield.
- Lay the protractor with the bottom line matching a front edge. Choose an angle between 2 and 80 degrees.
**Shaping the windshield**

- Select the front top edge of the block.
- Choose the Chamfer edges tool.
- Check the angle box.
- Type your angle in the angle space.
- Put a number in the setback space, such as 4.
- Look at the drawing and see if that was what you had in mind. Change the offset number until you like the shape.
- Hit OK.

**Assemble the Van Parts**

- Open a new Design File [Ctrl + N].
- OK.
- This Design file will be used for assembling the van. Always open a NEW file for assemblies.

**Soften Edges**

- Select 5 vertical edges (see picture):[E]
- Right Click> select Round Edges > Radius = 0.1”.
- OK.
- Save file for future assembly.
- Save file as Van on where your teacher allows saved files

**Add the Van to this New File**

- Select the Van> [Alt + A, A]
- OK.
- While the Van is Selected (red) Right click
- Select Fix Component (this makes the van stationary, simplifying further assembly).
- Look at the model in your workstation to help decide what parts to select.

**Soften Faces**

- Select top edges > Hold [Shift] > select bottom edges (see picture).
- Click on the two circles [E] (this deselects these edges so that they won’t round).
- Right click > Select Round Edges > Radius = .25”
- OK.

**Bring in the Axel and constrain it to the Van**

- Select the Axel[Alt + A, A]
- OK.
- Select the cylindrical face of the Axel [F] > Hold [Shift]
- Select the cylindrical face of the hole in the Van (see picture).
- Right click > Select Center Axes - Axel will be constrained to the Van as stated.

Save the assembly often!
Add the Other Axle

- Repeat above steps for the second Axel

NOTE: Sometimes when you bring in a part to an assembly, it cannot be seen because it is inside of the first part, or on the other side. You may have to rotate the drawing to find the new part.

Constrain the Axel and Wheel to the Van

- Select the outside flat face of the Van [F]
- Hold [Shift] & Select the inside face of the Wheel (you may have to rotate the drawing to see the inside face of the wheel)
- Right click
- Select Offset Enter 0.2"
- Select Mate,
- OK

Bring in the Wheel and constrain it to the Axel

- Select the Wheel [Alt + A, A]
- OK
- Select the inside cylindrical face of the Wheel [F]
- Hold [Shift] > Select the cylindrical face of an Axel.
- Right click > Select Center Axes

Attach three more wheels

- Follow the above steps to complete the assembly.
- Look at the Components Browser. Notice the components listed & how they are attached. These are mating conditions. If you click on the + sign by each constraint, you will see what the components are constrained

Matching Surfaces

- Select the flat end face of the Axel [F]
- Hold [Shift] and Select the outside flat face of the Wheel
- Right click > Select Align.

Prepare to add color & texture

- Save file for future use [Ctrl + S]
- Save file as Van Assembly
- Do not close the file after saving, it must be open for the next step

Look at the model in your workstation to help decide what parts to select
Open an Album File

- Select Album,
- OK > Ctrl + N
- This will let you apply different materials and backgrounds to your design

Apply materials to taste

- Once you are satisfied with the position of your van assembly, move your mouse to the Object Browser
- Click on the down arrow & Select Material
- Click on the + sign next to the bag labeled "non-metal"

Import the Van Assembly

- At the File menu at the top of the screen, Select the Image menu
- Select New Image
- Select Van Assembly
- (The van assembly drawing must still be open)

Apply a material to the Van

- Use the Select Part Tool to make the van lines red
- Select the "wood, plain" bag and drag it onto the body of the van (all the lines in the van must be illuminated)

Position Van

- Click and drag the van around so that it looks "right" on your screen. (Spacebar)
- If you cannot move it to an effective orientation, move your mouse over a different axes arrow to select another range of motion.
- [Shift + Z] to zoom in or out
- [FB] Or hit the Update button at the center top of the screen

Apply the Material

- Click on the Update button or [FB] and the material you chose will appear on your van
- Drag other material bags onto the wheels and axles in your van design (make sure that the lines that define your parts illuminate before letting go of the bag)
- Hit update to see what you have created. [FB]
Apply a background

- Go to Image in the file menu at the top of the screen.
- Select Image Properties [Alt + Enter].
- Select the Effects Tab.
- From the Foreground field, choose None.
- From the Background field, choose Clouds. (F5).

Album Picture Complete!

- If you have followed the instructions above, you should have an image that resembles the one at the front of the tutorial. You might also have selected different materials.
Three-Dimensional Models for Teacher Lesson on Design Using CADD

Plane: Transparency Sheet with green axis arrows and green border, grid transparency for X and Y axes, intersecting planes to illustrate Z Axis

3-d shapes: Foam circle, ball, cube, block, wooden car model

Using Pro/Desktop:

  Transparency with square drawn on it
  Cube to place on square
  Cube to talk about shell
  Cube with circle on top
  Cube with cylinder on top
  Ruler to use with scale discussion
  Foam circle to demonstrate profile revolving around axis

Three-Dimensional Models for Student Lessons Using CADD

Plane: Transparent acrylic clip board

  Intersecting planes to simulate Z axis
  Transparencies for various activities in color coded folders

Extrude: cardboard model of cube

Profile: Colored Shapes on transparencies

Revolve: hoop to slide over transparency

Sweep: Spring

Assembly: Wooden model of toy car with removable wheels
APPENDIX G: INSTITUTIONAL REVIEW BOARD APPROVAL FORM

IRB #: 3076
LSU Proposal #: Revised: 04/15/2005

LSU INSTITUTIONAL REVIEW BOARD (IRB) for HUMAN RESEARCH SUBJECT PROTECTION

Study exempted by Louisiana State University Institutional Review Board
203 B-1, David Boyd Hall
578-8692 FAX 6792
Office 203 B-1, David Boyd Hall
225-578-8692
Robert C. Mathews, Chair

APPLICATION FOR EXEMPTION FROM INSTITUTIONAL OVERSIGHT
Developmental Approval Only

Unless they are qualified as meeting the specific criteria for exemption from institutional oversight, all LSU research/ projects using living humans as subjects, or samples or data obtained from humans, directly or indirectly will require the approval of an IRB/ IRB. This form helps the PI determine if a project may be exempted, and if not, to request an exemption.

Instructions: Complete this form.

Exemption Applicant: If it appears that your study qualifies for exemption send:

(A) Two copies of this completed form,
(B) a brief project description (adequate to evaluate risks to subjects and to explain the responses to Parts A & B),
(C) copies of all instruments to be used. If this proposal is part of a grant proposal include a copy of the proposal and all recruitment material.
(D) the consent form that you will use in the study. A Waiver of Written Informed Consent is attached and must be completed only if you do not intend to have a signed consent form.

Send one copy of the
submissions to:
ONE screening committee member (listed at the end of this form) in the most closely related department/discipline or to IRB office.

If exemption seems likely, submit it. If not, submit regular IRB application. Help is available from Dr. Robert Mathews, 578-8692, rcb@lsu.edu or any screening committee member.

Principal Investigator K. Lynn Basham Student? yes/ Y/N
Ph: 601-359-3942 E-mail: kbasham@cc.u.edu Dept/Unit SEEMED

If Student, name supervising professor Joe Kotlik Ph: 2-5753
Mailing Address:
School of Human Resources Ph:
Project Title: Effect of 3-D CAD modeling software on development of Spatial Abilities of Ninth Grade Students.

Agency expected to fund project none

Subject pool (e.g., Psychology Students) Mississippi Public School Ninth Grade
Circle any "vulnerable populations" to be used (children <18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

I certify that my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. If the project will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted.

PI Signature K. Lynn Basham Date 2-2-2005 (no per signatures)

Screening Committee Action: Exempted Not Exempted Category/Paragraph
Reviewer Robert C. Mathews Signature RM Date 2/4/05

Part A: DETERMINATION OF "RESEARCH" and POTENTIAL FOR RISK

This section determines whether the project meets the Department of Health and Human Services (HSS) definition of research involving human subjects, and if not, whether it nevertheless presents more than "minimal risk" to human subjects.
VITA

K. Lynn Basham graduated from the University of Southern Mississippi in 1985 with a Master of Science degree in vocational industrial education. She earned a Bachelor of Science degree in industrial arts education from the University of Southern Mississippi in 1977, with a minor in instrumental music.

In August, 2006, she joined the Virginia Department of Education as state specialist for technology education, with responsibility for curriculum projects including geospatial technology and development of new initiatives such as computer modeling and simulation technology. From 1989-2006, she was employed by the Mississippi Department of Education as technology education supervisor, responsible for the development and implementation of instructional and training projects worth over $55,000,000. Prior to supervising technology education, she worked as the industrial arts/technology education assistant supervisor from 1986-1989, with primary duties as the state advisor for the Mississippi Technology Student Association. From 1981-1986, she taught industrial arts/technology education for the Petal School District in Petal, Mississippi. She was employed as a drafter in the engineering department of Howard Industries in Laurel, Mississippi, from 1979-1981. Prior to working in industry, she taught industrial arts for Caruthersville Public Schools, Caruthersville, Missouri, from 1977-1978.

Lynn holds numerous professional honors, having been actively involved in professional organizations throughout her career. She served as Region 2 representative for the International Technology Education Association (ITEA) Board of Directors from 2000-2002, on the Council for Supervisors Steering Committee from 1993-1995, and is currently President of the International Technology Education Association Council for Supervisors (ITEA-CS). She
received the 2004 ITEA-CS Distinguished Service Award and ITEA-CS Outstanding State Supervisor Award in 1992 and 2001. She is a member of The Technology Teacher Review Board, and is also a member of the ITEA Council for Technology Teacher Education. She served as a reviewer for the Standards for Technological Literacy: Content for the Study of Technology (ITEA, 2000).

Other memberships and leadership positions include Mississippi Valley Technology Teacher Education Conference member, Southeastern Technology Education Conference member and President, and membership in the Association for Career and Technical Education, American Association for Training and Development, and American Society for Curriculum Development. She has served as training project manager and facilitator for various projects including curriculum writing teams for technology education, spatial information technology, and CADD, and as a writing team member for polymer science. She is a certified Pro/Desktr® trainer and has served as a reviewer for the National Science Foundation.

Lynn has been continually involved with the Technology Student Association, Inc., currently serving as Virginia Corporate Member, and previously Mississippi Corporate Member, State Advisor, National Board Member, Executive Committee member and President, Competitive Events Committee member, and national conference team member. She began her involvement with TSA as local chapter advisor for Petal Junior High School.