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Visual literacy and the integration of parametric modeling in the problem-based curriculum

Matthew Benedict Assenmacher

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Visual Literacy and the Integration of Parametric Modeling
in the Problem-Based Curriculum

by

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Dissertation

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Abstract

This quasi-experimental study investigated the application of visual literacy skills in the form of parametric modeling software in relation to traditional forms of sketching. The study included two groups of high school technical design students. The control and experimental groups involved in the study consisted of two randomly selected groups of students. The participants were exposed to eight weeks of technical drawing and parametric modeling instruction prior to the start of the study.

The potential applications of emerging technologies for the purpose of integrating visual literacy into the curriculum are not fully understood. Society is moving towards a more immediate form of communication (Galante, 2011). Visual forms of communication are becoming more prevalent methods for sending and receiving information. Research suggests that visual literacy skills have a correlation to the ability to problem solve, which ultimately can be beneficial to student learning (Matusitz, 2005). The application of visual literacy skills through the use of parametric modeling software may provide students with better learning experiences in visualization, conceptualization, and communication of images that will allow them to become better problem-solvers.

Through this study, the researcher focused on the relationships between the independent and dependent variables in order to perform a statistical analysis of the data. The participants of the study were presented with a pre-test, a treatment, and a post-test relating to visual literacy. The treatment was presented to the participants in the form of a technical design problem that required the participants to apply problem-solving skills in order to devise a solution through the use of either traditional forms of sketching or through the use of parametric modeling. Data were collected and recorded in order to assess the outcome and effects of the variable.

Although the research suggests that there is a correlation between visual literacy skills and the ability to solve problems, this particular study failed to show this correlation. Struggling learners showed no improvement in visualization skills after using parametric modeling software. The two methods used to create the technical design problem showed no statistical significance between the success of the design and the method that was used to create the design. No statistical differences were found between the visualization skills of any of the participants regardless of the methods used in the study. In addition, gender seemed not to be a significant factor in the study when comparing the visualization skills of the participants.

There are recommendations, based on the results of this study, for future investigation in this area. Increasing the duration of the study over the course of a school term, could produce different results that were difficult to determine by the limited time constraints of this particular study. Other testing methods could be investigated for future studies that could produce additional information that was not produced in this study. Limiting the prior knowledge of the participants could also produce different results in the outcome of visualization skills. Investigating specific demographics that were not included in this study would also be of interest to be the academic community.

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Chapter 1: Introduction and Background

Overview

The modern student is becoming increasingly familiar with many forms of visual media (Beldarrain, 2006). As a result, learning styles are becoming more sophisticated and are requiring more graphical representation in instruction. The use of graphics in educational instruction has recently shown to have a positive effect on the overall learning experience (Mayer, 2001). Technology developments have allowed new possibilities for integrating visual literacy into the curriculum. Image-based instructional methods have great potential to expand in a variety of ways that not only meet the learning needs of students but provide rigor as well.

The current generation of students, born between 1982 and 2005, is known as the Millennial Generation (Strauss & Howe, 1991, p. 36). The Millennial Generation has noticeably changed the way learning and the delivery of instruction is taking place (Price, 2009). The modern student requires fresh and innovative learning experiences that explore emerging technology as a way to deliver instruction and present relevant information using multimedia in a visual-based graphics format (Stokes, 2001).

Many schools struggle with incorporating digital media into the curriculum despite the technology that is readily available (Jordan, Mehnert, & Harfmann, 2007). An area that shows a great deal of potential for integrating graphics in education, for the purpose of problem solving, is design. One of the primary means for developing and communicating design ideas in a 3-dimensional visual format is through the use of parametric modeling.

Struggling learners have been found to depend on instructional modifications in the form of visual images. When forms of visual literacy are integrated into the classroom curriculum, struggling learners engage in higher level discussions and in turn benefit from critical thinking

(Ivey & Fisher). Visual literacy can help lower performing students increase their understanding and retention of course material (Hibbing & Rankin-Erickson, 2003).

Parametric modeling is a way to control various parameters of a virtual computer-aided design (CAD) model that is generated from points, lines, surfaces, and other coordinate-based geometry (Hoffmann & Juan, 1993). These CAD-based solid models can be designed and modified to represent objects in a virtual environment. A parametric model allows the user to see a virtual representation of an object in order to gain better understanding of the geometry and design. The features of a parametric model can be created or modified to the designers' specifications. The result is a completely detailed model of an object that reflects the ideas of the designer for the purpose of communication. The use of parametric modeling allows for the opportunity to visually explain concepts in a virtual environment. "Worldwide, parametric modeling systems are part of a technology education reform movement that seeks to improve critical thinking and multidimensional problem-solving skills, while also inspiring and preparing a growing number of students to become the engineers, designers and technologists of tomorrow" (Rynne, 2008 p. 2).

The development of spatial visualization skills is the result of the experiences, interactions, and understanding of various objects. Higher spatial visualization skills occur from being exposed to a wide variety of experiences and understanding of objects (Mack, 1992). Parametric modeling software can provide students with the ability to design and truly analyze virtual objects in order to gain a better understanding of the specific features and spatial relationships of the objects (Gillespie, 1995).

At a high school campus in a Midwest community, curriculum changes have recently occurred within the drafting and design program that resulted in an engineering-based program

that emphasizes physics, structures, and motion. Since CAD is the primary instructional tool used in the program, it seems natural to integrate the concept of visual literacy into the curriculum. CAD modeling can allow for many positive learning outcomes in drafting and design, as well as other subject areas. The potential problem-based learning outcomes for any subject area are unclear. Therefore, the purpose of this research is to observe the educational outcomes that result from integrating CAD-simulated, problem-based lessons into the drafting and design curriculum.

Statement of the Problem

The visualization skills of high school technical design students, resulting from implementing the use of parametric modeling as a form of visual literacy in a problem-based curriculum, are not fully understood.

Purpose of the Study

Curricula of all forms have placed an emphasis on the issue of learning through the application of problem solving. Many of the problem-solving experiences that are presented to students are procedural story problems that typically result in no real mental models of the problem in order to obtain a solution (Jonassen, 2003). This can result in a lack of understanding by the student and may prevent the student from obtaining the skills for solving similar problems in the future.

CAD software can provide students with the capability to create three-dimensional virtual models that can simulate a visual representation of various problems. Research, dealing with spatial representation and the assembly of objects, shows that a student understands information about an object better with the assistance of a three-dimensional object (Pillay, 1998). Although there seems to be a relation between problem-solving skills and visual literacy, the potential

applications for CAD-related technology are not fully understood.

This study will focus on three objectives. The first objective is to compare the impacts and effectiveness of parametric modeling in the problem solving process to traditional written and oral explanations of a design problem in a high school CAD classroom. The second objective is to analyze how the problem-solving skills of the participants are affected by the use of parametric modeling software in a high school CAD classroom. The third and final objective is to determine if the use of parametric modeling has any impact on the participants' visualization abilities in a high school CAD classroom.

Significance of the Study

Studies have shown a correlation between problem-solving ability and visualization skills (Mack, 1992). Technology, in the form of parametric modeling software, offers many potential means for constructing a visual solution to a problem. Although problem-solving skills are an area of focus in education, it is not fully understood how existing and developing visual technologies can be used effectively in order to increase the ability to problem-solve.

The concept of visual literacy in education is not exactly a new idea. Images have been used throughout history in order to explain concepts as visual information. From the crude cave paintings of early humans to the sophisticated computer-generated models designed in the modern era, the application of visual literacy is ever-present. Although various forms of visual literacy are present throughout history, modern technology is allowing for more complex methods for visually explaining information.

Today's students are exposed to an abundance of visual information that is literally available to them at their fingertips. Researchers estimate that by the time a student reaches the age of 21, he will have spent 5,000 hours reading, 10,000 hours playing video games, and 20,000

hours watching television (Prensky, 2003). Additionally, a recent survey regarding the Internet use of students between the ages of 9 and 17 ranked obtaining new and exciting information as the number one reason students use the Internet, followed closely by communication (Grunwald, 2003). It is reasonable to assume that visual forms of technology have a strong presence in the way that students learn.

All forms of educational materials, from traditional textbooks to the latest learning technologies, are changing to adapt to this rich visual environment (Lowe, 2000). Technology is constantly evolving in ways that are allowing for more diverse methods for integrating visual literacy into the curriculum. More accessible forms of visual technology, such as interactive tablets, SmartBoards, and CAD software, are becoming more easily available in the classroom (Klopfer, 2008). Many forms of modeling software are very affordable or, in some cases, available for free. Parametric modeling can provide learning opportunities that actively involve students in problem-solving tasks (Cordova & Lepper, 1996; Oblinger, 2004). Research regarding the educational benefits from integrating visual literacy in this form remains to be investigated further. However, there is evidence that some research has begun to establish links on how simulations may have the potential to enhance the learning outcomes for students in a positive way (Garris et al., 2002).

An idea can be designed into a parametric model that could be animated to create a simulation that could be used for educational purposes. “The process of creating visual representations can lead to deeper understanding of the scientific concepts being portrayed as knowledge” (Pérez Echeverria, Postigo, & Pecharroman, 2010 p. 212). This technology has many educational possibilities, including the design of interactive mathematic games, three-dimensional simulations of ancient ruins, or even virtual instructions on automobile engine

repair. The applications of this technology are limited only to the creativity and ideas of the user.

Although this form of technology has a great deal of potential to promote visual literacy in education, there are issues that remain to be resolved. As the technology becomes more accessible, instructors need to be provided with proper training on how to use and integrate the technology effectively. Educators are also faced with designing beneficial methods for infusing this form of visual literacy into the classroom. Research, in this area, is only beginning to investigate the educational capabilities. “The potential for research confirming positive relationships between modeling and problem solving is great. No empirical research has examined the effects of using technology tools for representing problems on problem solving performance” (Jonassen, 2003, p. 377).

Conceptual Framework for the Study

This study focuses specifically on two groups made up of demographically similar high school technical design classes: the control group and experimental group. These groups were selected based on convenience, accessibility, and their involvement in a technical design class. Both groups had working design and traditional drafting skills, and both groups contained 35 participants.

A pre-test, in the form of the Purdue Spatial Visualization Test of Rotations, was administered to both of the groups in order to collect the initial data on the students’ ability and understanding of spatial relationships. This test was chosen due to the relevance to the study and the closeness to which the test resembles the type of visualization skills required for the design problem.

Prior to the study, all participants learned some basic knowledge related to technical drawing. This instruction took place over an eight-week period. During this time, the

participants learned how to create a proper refined pencil sketch of a 3-Dimensional object, how to measure and design using traditional drafting tools, and how to create and assemble basic 3-Dimensional CAD models. In addition, the participants learned the knowledge to analyze a technical problem and devise a working solution by applying the elements of technical design.

Once the pre-test data were collected, a technical design problem was presented to both groups. The design problem required both groups to create images of a robotic gripper design that has rotational movement. The groups received the same written and oral information regarding the design problem. However, the experimental group was allowed to use parametric modeling software as a visualization tool during the design process. The control group did not use any parametric modeling software and relied on more traditional forms of design through the use of sketching.

Once the designs of the robotic gripper were complete, the participants were instructed to properly label the rotational movements of the gripper assembly design with arrows. The arrows showed the rotational direction for each part of the gripper assembly that would allow the gripper to open. The solution to the design problem was analyzed to see if the arrow directions were labeled properly. Once the designs were complete, both groups were instructed to take the Purdue Spatial Visualization Test of Rotations again as a post-test. Data was collected from the post-test assessment, and the results were compared with the pre-test to determine if any correlations or patterns existed.

During this phase, data was examined to determine any potential impacts of visual literacy through the form of parametric modeling. A complete analysis of the data examined the results of the study after the process of the study was complete. This research focused on how the students applied visual literacy skills while solving the technical design problem.

Research Hypotheses

The study explores the following null hypotheses:

Ho1: The visualization skills of struggling learners, as measured by the Purdue Spatial Visualization Test of Rotations, will show no significant improvement as a result of using parametric modeling software.

Ho2: There will not be a significantly higher rate of success of the final technical design as a result of using parametric modeling software. The success of the design is determined by the labeled arrows correctly showing the rotational direction of the technical design components.

Ho3: The visualization skills of the participants, as measured by the Purdue Spatial Visualization Test of Rotations, will not significantly increase as a result of using parametric modeling software.

Theoretical Framework

Visual literacy is becoming an increasingly important aspect of a high school learning experience. Increased learning opportunities, through technological advancements in visual graphics and multimedia, allow for better understanding of concepts (Mayer, 2001). Visual literacy allows for deeper interaction with text-based information while providing opportunities for analytical thinking (Klopfer, 2008). This form of communication requires visualizations skills that allow students the opportunity to understand visual concepts in order to solve problems.

Although previous studies contribute insight into the vast subject area of visual literacy, they leave several opportunities for further exploration. Among the studies dedicated to visual literacy, several do not focus on students enrolled in a public high school. This is significant due

to the active participation of students and amount of federal funding that is dedicated to high school technical education programs. Some previous studies also address areas of concern with regard to the methodology and execution of the study.

This study addresses how parametric modeling can be used as a form of visual literacy in order to allow students the skills needed in the problem-solving process. This research was conducted in order to better understand the implications of visual literacy in a high school technical design course. The research is appropriate to the field of education and provides investigative conclusions and insight related to the topic of visual literacy.

Delimitations

The research study is limited to 70 students who are currently enrolled in a high school technical design class. The students were limited to using traditional forms of drafting and design or the use of Autodesk Inventor design software, specifically. Specific 3-dimensional models were observed and drawn during the learning process. The use of parametric modeling software and sketching may produce similar outcomes through different stylistic approaches and methods. Additionally, all participants were limited to the same time constraints during the pre-test, treatment, and post-test phases of the study. The participants were allowed 55 minutes for the pre-test, 55 minutes for the post-test, and three 55-minute sessions (165 minutes in total) to complete the treatment portion of the study.

Assumptions

There are some assumptions that had to be made prior to conducting this study. It was assumed that the participants of this study were actively involved in a high school CAD design course. All of the work performed by the student was independent of other students in the class. The participants also understood the design and modeling operations required, and they

possessed the skills necessary to participate in the study.

All of the participants will have previous working knowledge and application of parametric modeling software as well as traditional drafting methods. All of the participants of the study will use either CAD software or traditional drafting methods to generate concepts and ideas. The work and outcomes of the participants will be documented in order to collect the resulting data from the study.

In addition, it is assumed that all participants understand design and modeling operations, possess the skills that are necessary to participate in the study, and have basic language skills and working knowledge of computer technology. The work of the participants will be performed by the individual student and will not be influenced by incidental contact with others. It is also assumed that the participants will participate in the study truthfully, in a manner that reflects their own personal views.

Definition of Terms

Computer Aided Design (CAD): The use of computer hardware and graphics software to generate technical designs, drawings, virtual models, and other types of visual graphics.

Graphics: A visual image representation used to explain a concept or idea.

Model: A three-dimensional, visual, or mathematical representation of an object or design concept (ITEA, 2000, p. 240).

Parametric Modeling: “An information structure process that permits deriving specific solid models, using deterministic algorithms. Moreover, the specific shape derived depends on parameters that are explicit in the information structure and must be valued for obtaining a specific solid shape” (Hoffman & Joan-Arinyo, 1998, p. 907).

Problem-solving: The creative, procedural process for understanding a question,

designing a potential solution, carrying out the plan, and evaluating the outcome (ITEA, 2000, p. 240).

Spatial Relationships: The proximal relationships describing the distance and direction between objects, features, or geographical locations (Goodchild, 1987).

Spatial Ability: The ability to create, preserve, recover, and change well-structured visual images (Lohman, 1993).

Spatial Visualization: The ability to understand the details, size constraints, and relative position in space of an object (Guilford & Lacey, 1947, as cited in Mack, 1992).

Struggling learners: High school students who are placed on academic accommodations due to limited learning abilities.

Technology: The combined use of physical artifacts, knowledge, and processes by which humans modify nature to meet their needs (Pearson & Young, 2002).

Visual Literacy: Visual literacy is defined as the ability of a learner to interpret, understand, and process graphic information (Clark, p. 451).

Visual Representation: A symbol, sign, or image that depicts other objects or events (Kozma & Russell, 2005).

Chapter 2: Literature Review

Overview of Visual Literacy

Visual literacy refers the ability to interpret and understand symbolic, graphic, and other forms of visual media in order to form meaning. The communication of information through visual literacy can be applied in many forms. Pictorial graphics, virtual models, and electronic media are just some of the many forms of visual images that can be used. The use of these images can provide a variety of details that allow for better communication of information that could not be understood from using text alone.

Visual literacy is one part of the learning process that is an acquired skill which can evolve as technology advances. The ability to communicate visually is a skill of importance that is required for success within the context of American educational system (Matusitz, 2005). “Although visual literacy has had an important role in education, no serious consideration followed the initial explorations until the 1960’s, when rapid advances of technology and pervasive mass media inspired scholars to re-examine the impact of visual communication on society and culture” (Galante, 2011, p. 116). The relevance of a visual language began to gain recognition as part of a cognitive learning process.

Historical Significance

Historically, visual literacy has had a fundamental role in education. Archeological records support evidence that the oldest forms of visual literacy are nearly 30,000 years old, while written forms date back only 4,000 years (Galante, 2011). Some of the earliest forms of pictorial communication are depicted in the cave paintings of early humans. These images act as a historical record of events that can be interpreted by future generations. This evidence suggests that visual literacy is possibly the oldest form of literacy, and it remains to be a form that is

widely used in the modern world.

Ancient civilizations produced large volumes of symbolic pictorials describing daily routines, instructions for construction processes, mathematic concepts, and ritualistic behavior. As civilizations evolved, the visual form of communication became more elaborate. Technology evolved to the point where images were represented by symbols and characters that formed pictured alphabets that have specific meaning (West, 1997). Similar to musical notes, these symbols depict a man-made language with no distinction between words and pictures.

Once the printing press was invented, type and illustrations became separated and the usage of illustrations began to decline. Written text was believed to allow for increased learning from reading words rather than seeing pictures (Knupfer, 1994, p. 41). With the introduction of technology, such as the camera, combined with changing attitudes, visual materials would play in an ever-increasing role.

Society began to change as visual literacy increased. Entire professions were created from the existence of printmaking, graphical work, photography, and fine art. Other broader areas were additionally affected by the growth of visual literacy methods. Technology, education, healthcare, and business are just some of the many areas that use forms of visual literacy. Today, technology offers new forms of digital imagery, multimedia, interactive graphics, and virtual modeling that allow for more sophisticated forms of visual literacy. Visual elements in education and learning are increasing as the integration of images and visual presentations with textbooks, instructional manuals, classroom presentations, and digital interfaces broadens (Benson, 1997; Branton, 1999).

Although the academic community is embracing visual forms of curriculum and various formats, the connection between visual and verbal information is evident throughout history. It

will continue to expand and society will continuously need to understand and learn the evolving forms of visual literacy in order to effectively communicate.

Recent history shows a reversal in the separation between text and graphics, with an increased reliance on visually oriented approaches to information presentation. Images can be applied to communicate information a variety of methods (Walsh, 2002). This is changing how visual media are being used in education (Warnick, 2012).

Technical Design

With regard to technical design, courses were traditionally taught using manual drafting tools such as T-squares, triangles, French curves and other implements, in order to produce drawings made with a pencil on paper (Harris & Myers, 2007). Two-dimensional views were commonly used to communicate information that represented an existing or potential three-dimensional object (Barr, 2004). Plane descriptive geometry and analytical geometry were developed “as a series of projections with enough accuracy and robustness to serve as the basis of communication for the design and manufacture of complex, highly engineered objects and structures” (Batchelor & Wiebe, 1995, p. 3).

Single-view drawings were developed into orthographic projections, where multiple views of the same object could be seen from different planes. These 2-dimensional projections would also be used to develop 3-dimensional views such as an isometric view (Wiebe 1991). Although the traditional forms of drafting were effective, the methods were time-consuming, and drawings could not feasibly represent all of the desired views while maintaining a high level of detail and accuracy. Technology led to the emergence of computer-aided design (CAD), where the traditional drafting tools were no longer needed and the design possibilities became limitless.

CAD technology applied the principles of traditional drafting methods delivered through

a computer-based visual format (Barr, 2004). As the CAD software developed, the interface became more intuitive, and 3-dimensional models became easier to create. The realistic models were sometimes difficult to understand using the traditional stationary views, so an orbiting viewpoint was developed that would allow the user to rotate a model in a virtual space in order to see the object from any conceivable vantage point (Scribner & Anderson, 2005). This development not only allowed for the opportunity to see the entirety of the object but also to communicate the details of the design for the purpose of learning and understanding. Technical design instructors can use CAD tools in order to design and manipulate 3-dimensional models, which will provide opportunities to enhance individual learning (Mackenzie & Jansen, 1998).

Education

Students learn and gain knowledge in a variety of forms. One potential outcome resulting from the learning process is the ability to apply the acquired knowledge as a means to develop a solution to a potential problem, demonstrating that the student has intellect in a particular area. In education, this is often referred to as the theory of multiple intelligences. “An intelligence is the ability to solve problems, or to create products, that are valued within one or more cultural settings” (Gardner, 2011).

There are nine areas that are included in the theory of multiple intelligences. Among these intelligences are visual-spatial, musical-rhythmic, verbal-linguistic, bodily-kinesthetic, logical-mathematical, interpersonal, intrapersonal, existential and naturalistic (Gardner, 1983). Visual, auditory, and verbal forms of learning tend to be more prevalent in education. Additionally, variation in learners is present in those who may have difficulty with comprehending the spoken or written language, particularly those with language barriers, learning disabilities, and hearing disorders (Flattley, 1998). Visualization skills can be developed

with practice.

Struggling Learners

Visual literacy has shown to have a positive effect on increased comprehension of lower performing students (Ivey & Fisher, 2006). Students with learning difficulties tend to rely on instructional modifications in the form of visual images. The integration of visual literacy can help lower achieving students increase their understanding and retention of course material (Hibbing & Rankin-Erickson, 2003). Struggling learners are able to better engage in higher level discussions and in turn benefit from critical thinking, when forms of visual literacy are used in the delivery of the curriculum (Ivey & Fisher).

Struggling learners can fall behind in their schoolwork unless they are provided with the proper assistance needed to enable success (Fisher, 2006). Lower achieving students typically experience a great deal of frustration when attempting to understand the information found in textbooks (Vaughn & Edmonds, 2006). This problem is not due to a lack of background knowledge or intelligence, but the direct result of reading difficulties (Vaughn & Edmonds). To promote better understanding and higher achievement by struggling students, teachers can modify their instruction methods and incorporate visual materials in order to assist textbook comprehension (Marzano, Pickering, & Pollock, 2001, p. 73). Graphics and other forms of visual literacy can improve the overall comprehension of material through the connections of nonlinguistic communication (Ivey and Fisher 2006).

Problem Solving

Studies that examined the relationship between learning and problem solving found that students could often solve problems without learning from the problem or process (Pillay, 1998). The capacity of working memory was often exceeded by the information of the task such as

categorizing the information, making comparisons, and comprehending the problem. In learning situations, this cognitive load often is too great to allow effective learning to take place, even if the problems are being solved. If the cognitive load can be reduced and effective cognitive skills acquisition techniques can be employed during the instructional process, learning the desired objectives or skills is more likely to take place.

The problem-based curriculum is a focus of modern education. Through this type of learning experience, students are presented with situations that require the application of knowledge in order to devise a working solution. The skill set of the student is challenged in a way that allows the student to devise, execute, and reason using the information acquired during the learning process. One of the challenges with a problem-based curriculum is addressing the needs of society while challenging students to think about a problem in a unique way that is free of the restraints presented by society.

The problem-solving process can be applied to nearly all forms of knowledge. It is not strictly limited to the confines of academia. The problem-solving process can be applied to tasks related to a career, or it can be used to make personal decisions on a daily basis. Although the problem-solving process can be used commonly in engineering, mathematics, and science, it is an important part of technology education due to the hands-on approach to solve problems (McCormick, 2004).

Problem solving in general is considered to be a major component of the technical design process (Custer, 1995). During the design process, a designer “typically, does not know in advance what the goal state will be, although he usually has criteria to evaluate potential goal states” (Carroll, Thomas, & Malhotra, 1980, p. 143). The designer must rely on visualization skills and the ability to solve technical problems as the design advances towards completion.

Occupational Significance

Several careers specifically require visual literacy skills. Fields such as education, technology, business, and healthcare are just a few of the many career-related areas that require visual literacy (Pearson & Young, 2002). Even daily career-related tasks, such as designing a presentation, using or creating a website, or operating an office machine all require forms of visual literacy.

The importance of visual literacy skills can be found in the day-to-day experiences one may typically encounter. A cellular phone contains symbols and menus that require the user to understand graphic information. Several iconic signs and images must be understood by the driver of an automobile. Maps, graphs, and diagrams also communicate information using visual models (Lynch, 2001). These are just some of the many examples of how forms of visual literacy are infused into our society.

Parametric Modeling

One form of visual literacy that can be used to communicate complex ideas using 3-dimensional representation is parametric modeling. Parametric modeling uses computer-aided design technology to create virtual models of an object. The software has the capability to perform complex algorithms and geometric calculations in order to present the object that is created by the designer. This type of software, once very costly, now comes in a variety of user-friendly formats that are inexpensive and, in some cases, free to download.

Parametric modeling has become the most widely used method for designing a 3-dimensional representation of an object. Parametric modelers are often much more efficient because the dimensions can easily be changed. The design tool's simplicity allows for better efficiency and freedom to make changes within the geometry of a model (Murray, 2003).

Three-dimensional modeling has progressed from various stages of evolution in technology. Earlier forms of modeling were based on wireframe structures that evolved from 2-dimensional CAD images. Wireframe modeling (Figure 1) consists of “lines and arcs joined end to end to make up a 3-D model” (Murray, 2003, p. 10). Geometry, such as edges and vertices, were represented as connected lines. Curved surfaces could also be represented, but the definition of the model was limited. This made more complex models difficult to create. One advantage that wireframe models have over more complex modeling forms is that they were very efficient in their data calculation and could be run on slower computers due to the limited visual output (Bertoline & Wiebe, 2003). Figure 1 depicts an example of a wireframe model.

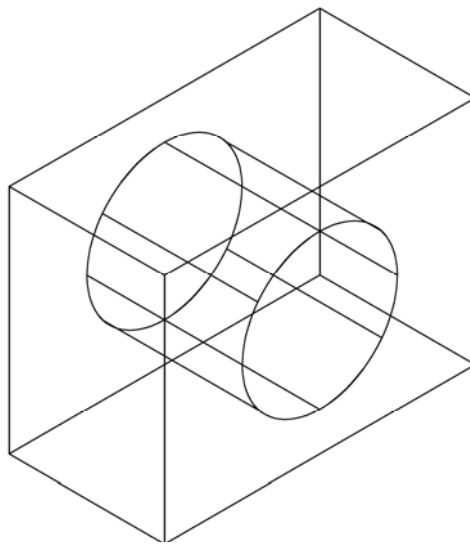
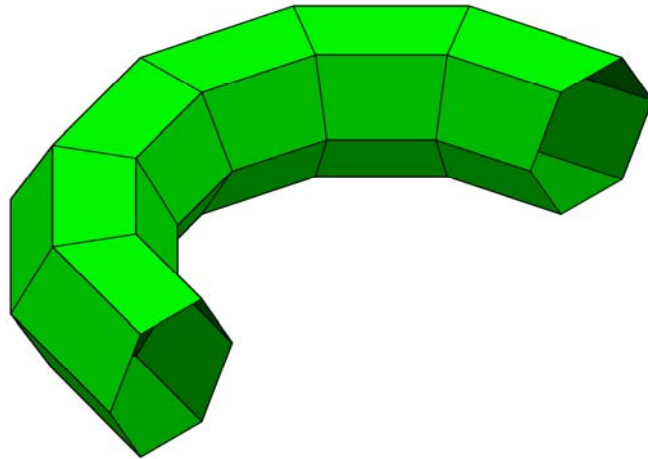


Figure 1. An example of a wireframe model

Image Created by: Matt Assenmacher using Autodesk Inventor

Another form of 3-dimensional modeling is surface modeling. Surface modeling (Figure 2) evolved from wireframe modeling and allowed the user to view both the edges that were created from the geometry of the object and the definition of surface features, typically represented by a shade of color or surface material. Unlike a wireframe model, the geometry of a

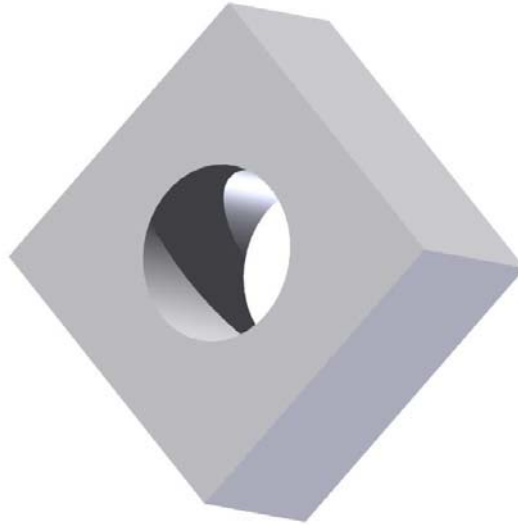
surface model can allow for the definition and the degree of curved surfaces. Surface models are used widely in industry, especially on projects that require extremely critical surface definition such as the wing of an airplane, the body of an automobile, or the hull of a ship (Bertoline & Wiebe, 2003). Figure 2 depicts an example of a surface model.



*Figure 2. An example of a surface model
Image Created by: Matt Assenmacher using Autodesk Inventor*

One of the more widely used methods for designing a three-dimensional object is parametric modeling. Parametric modeling uses specific geometric constraints in order to construct a solid model. In earlier forms, basic shapes such as cubes, cylinders, cones, and spheres could be created as a basic platform for a model that could be modified by the user. Modern parametric modeling allows the user to design extremely complex shapes and surfaces. The solid model contains geometric information that not only describes the outside surfaces and textures but the internal properties of the model as well. The dimensions of a parametric model (Figure 3) can be altered fairly easily in order to affect the geometry of the object. In many cases, this type of modeling offers simpler design tools that allow designers to be more efficient, the modeling software is easier to use, the models are easier to visualize, and the solid models can be

easily converted into other graphic forms (Murray, 2003). Figure 3 depicts an example of a parametric solid model.



*Figure 3. An example parametric solid model
Image Created by: Matt Assenmacher using Autodesk Inventor*

Parametric modeling software can provide students with the capability to create three-dimensional virtual models that can simulate a visual representation of various design problems. Research, dealing with spatial representation and the assembly of objects, shows that a student understands information about an object better with the assistance of a three-dimensional object (Pillay, 1998). Although there seems to be a relation between problem-solving skills and visual literacy, the potential applications for parametric modeling design are not fully understood.

Gender

With regard to gender, the use of solid modeling is an effective method for closing the gender gap in spatial visualization (Devon et al., 1994). Studies have found that differences do exist in the spatial visualization abilities of males and females (Branoff, 2000). When comparing younger children, studies showed that there are very little or no spatial visualization differences

between males and females prior to middle school. Once the children have grown to become teenagers, significantly different levels of visualization skills were apparent, with males having a higher ability than females. In studies where differences were evident, males typically had stronger visualization skills (McGee, 1979). In one particular study, females produced higher visualization scores than males, which was inconsistent with other previous studies. One possible explanation for this could be that the small number of five females may not have been a strong representative sample, and one female had exceptional gains, which skewed the results (Gillespie, 1995).

Additional Research

Other studies have been previously attempted in the area of visual literacy. One similar study, conducted at a southern university, involved 47 solid-modeling students who were divided into design groups (Koch, 2006). Both groups were given the task of creating a foam prototype of a mechanical system that converted lateral movement into rotational movement. One design group was limited to using parametric modeling software, while the other group was limited to using traditional forms of sketching.

The results of the study showed that there were no noticeable differences between the methods used to design the prototype and the success of the prototype. The spatial ability of the subject seemed to be the contributing factor to the overall success of the prototype. The researcher hypothesized that the problem-solving ability of the students will increase as improvements are made to parametric modeling software used in design.

The design of the study had several flaws. The design problem was extremely vague and therefore made the set time constraints difficult for the subjects to complete the prototype. The design of the treatment made the success of the prototype design inherently difficult for the

participant because the design itself was vague and could be interpreted by the participants in many ways. It was also determined that the participants needed additional technical design skills prior to participating in the study. In addition, the participants need previous skills in constructing a prototype prior to participating in the study.

Chapter 3: Methods and Procedures

This study was a quasi-experimental design. It involved two groups of high school technical design students who were presented with a mechanical design problem. After completing a pre-test in the form of the Purdue Spatial Visualization Test of Rotations, the two groups were randomly appointed to be either the control group or the experimental group. The data from the pre-test were analyzed and categorized appropriately.

The students were presented with a technical design problem and were given three 55-minute sessions to analyze the problem and design a working solution to the problem. After the final designs were completed and analyzed, the students were given a post-test in the form of the Purdue Visualization of Rotations Test. Data from the post-test were recorded and analyzed in order to assess any potential effects of the dependent variable. Due to convenience and the limitations of availability, this study did not use a true random selection approach.

Two groups of 35 participants (a total of 70) participated in the study. Two participants were excluded from the analysis. These participants were absent for the majority of the design project portion of the study. Although the participants did complete the pre- and post-test portions of the study, the incomplete testing segment made the resulting data invalid.

The study sample of 68 participants was selected from two class sections of a CAD and technical design students. The participants were selected based on the similarity of the sample groups, the previous knowledge of the participants with relation to the study, and the convenience to the researcher.

Research Design

For this study, the students were tested on their ability to visualize three-dimensional objects that were presented in a variety of rotated forms. A specific test was administered as a

pre- and post-test in order to compare the resulting data. The Purdue Spatial Visualization Test of Rotations was selected as the instrument to use in this study.

Some other tests were considered for this study, including the Paper Folding test, the Sheperd-Metzler test, and the Wheatley test. Other types of visualization tests exist in an online format as well. There were many factors to consider when selecting the testing instrument. The test that worked best for this study had relevant content and a simple design; was cost-effective and easy to administer and score, was not time-consuming, and did not require special training to administer.

The Purdue Spatial Visualization Test of Rotations was designed to measure the ability to visualize the rotation of a variety of three-dimensional objects. This testing instrument was chosen for its basic design and relevance to the study. The design of the Purdue Spatial Visualization Test of Rotations is also convenient with 30 multiple-choice questions.

In order to ensure test-retest reliability, a pretest was given at the start of the study, and a post-test was administered once the study is near completion. Although this particular study was a quasi-experimental study, an existing qualitative study found that The Purdue Spatial Visualization Test of Rotations has high construct validity with regard to spatial visualization ability (Branoff, 2000; Guay, 1980). The reliability and validity coefficients of the PSVT are between 0.65 and 0.67 (Guay, 1980). These analyses support the belief that the Purdue Spatial Visualization Test of Rotations is a good measure of spatial and visual ability.

The test itself provides visual examples of three-dimensional, isometric figures. The examples depict a single object displayed as two different isometric views. The difference between the views is the direction that it was rotated in the example. The example image below shows a comparison of the rotation that occurred between the views above. The student was to

determine what direction the example image was rotated, in order to solve the answer to the test question. The student answers the question by selecting from a list of five multiple-choice answers. A sample image from this test can be seen in Figure 4.

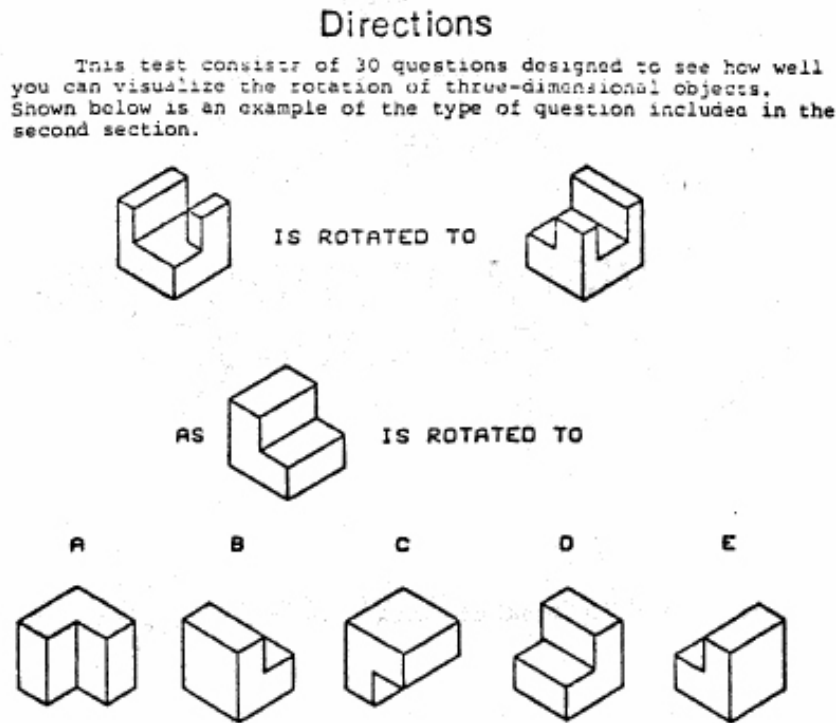


Figure 4. Purdue Visualization of Rotations Test

In order to begin the study, the variables needed to be defined. The dependent variable used in this study was the spatial ability of participants. The independent variable for this study was the method of design that was used during the development of the prototype. These methods were assigned to the groups as either sketching and traditional forms of technical drawing on paper, or through the use of parametric modeling software used to design a three-dimensional model. All of the participating students had previous skills in creating a working sketch for a design solution as well as understanding of parametric modeling. Therefore, the method used for

developing the prototype was selected as the independent variable for this study.

The students who participated in this study were not previously students of the researcher. Although the students attended the same high school where the researcher also acted as an instructor, the researcher had no prior influence on the students. The control group of the study was composed of students who were enrolled in a technical design class and who were using only sketching for the duration of the study. The experimental group consisted of students enrolled in a technical design class that used parametric modeling software for the duration of the study. The software that was used was Autodesk Inventor 2013.

A pre-test, in the form of the Purdue Spatial Visualization Test of Rotations, was given to both of the groups in order to collect data on the spatial ability of the students. The test was administered through the use of NetOp software, which allows the researcher to deliver the test in a digital, interactive format that compiles and records the results as the students submit the test. After the pre-test were completed and all data were collected, the students were presented with a design problem. Both groups received the same written and oral information relating to the design problem. However, the control group was limited to using traditional technical sketching on paper during the design process. The experimental group was limited to using three-dimensional CAD modeling software during the design process. Both groups were presented with the same design problem.

The design problem required the participants to create a design based on a robotic gripper assembly that was provided. The robotic gripper included multiple parts that move, based on rotational motion. This is reflective of motion depicted in the pre and post-tests. The completed designs required that the participants include designs for all of the individual components that were included in the assembly, as well as a pictorial design that depicts the assembly of the

robotic gripper.

After the participants completed the designs, they were instructed to label the completed assembly of the robotic gripper with arrows that depicted the rotational motion required to make the robotic arm open. The success or failure of the designs was determined according to the correct or incorrect labeling of the rotational arrows. All of the designs were categorized and evaluated for accuracy. The resulting data collected was analyzed for any patterns.

After the participants completed the design problem and the resulting data were analyzed, the participants were given the Purdue Spatial Visualization Test of Rotations again as a post-test. Data from the post-test were collected. All of the data were additionally categorized. The results from the pre- and post-test were analyzed using an analysis of the variance (ANOVA) and a t-test to compare the means. This form of analysis was selected due to the similarities and size among the sample population.

The design of the pretest, treatment, and posttest stages of research is depicted in Table 1.

Table 1. Study Design

Design Groups	Pre-test	Test	Post-test
Control Group	The Purdue Visualization of Rotations Test	Design problem solution using sketching	The Purdue Visualization of Rotations Test
Experimental Group	The Purdue Visualization of Rotations Test	Design problem using parametric modeling software	The Purdue Visualization of Rotations Test

Population, Sample, and Subjects

The high school academic calendar consisted of two 18-week semesters that are broken up into three marking periods. An academic course ran for the duration of one semester. Each marking period within a semester acted as an instructional deadline for both teachers and students. For the purpose of this study, the data collection process was scheduled to be

completed by the end of the fifth marking period, during the second semester (March 2013).

All of the participants in this study learned the fundamentals of drafting and design during the first marking period. The experimental phase of this study took place during the second marking period. This allowed time for the teacher to properly instruct the curriculum and for the students to learn the information. This also allowed for a conservative amount of time to conduct the study and to collect the data.

The study took place at a high school campus located in the Midwest. The surrounding middle-income community was a hybrid between a rural and city development. Students who attended the high school primarily lived in the local area but some students commuted from neighboring county districts through the school of choice program. This study took place within a technology department classroom at the high school. The two groups had similar demographic and educational backgrounds. Since the two groups were relatively similar, they were used as the basis for this experimental study. This information was made available to the researcher through a virtual information database provided by the high school. More specific demographics will be discussed in Chapter 4.

There are two groups, or classes, of 35 students (a total of 70 students) who participated in the study. The groups contained predominantly male students between the ages of 14 through 18. The majority of the students who participated were freshmen and sophomores, but there were also some junior and senior level students as well. The ethnic makeup of the students was primarily Caucasian. Generally, the students enrolled in a technical design course at the high school (such as CAD Mechanical Drawing) were interested in mechanical design and architecture. It was not uncommon for these students to enroll in each of the course sections made available at the high school. These students tend to enroll in higher education programs in

a technical field.

The two groups of students were selected due to their availability and convenience to the researcher. The sample size used in this study was considered adequate to perform the proper statistical analyses. However, for the purposes of replication, it is worth noting that this study was conducted using a specific administration for a specific demographic sampling.

The design-studio lab style classroom consisted of 35 drawing tables with a CAD station available at each table. The 2003 facility was fairly new, and the technology was updated in 2011. The room has several other features in addition. Some of these included plotting stations, interactive instructional board technology, digital tablets, projection and video editing equipment, and other audio-visual equipment. The facility was unique and was designed with the assistance of industry professionals to reflect an environment that the students may encounter in the workplace. Figure 5 shows a photo of the classroom layout.



Figure 5. Classroom layout

Photo by: Matt Assenmacher

Validity and Reliability

There are several factors that were considered for this study when dealing with internal validity. Changes caused by the instrument were potentially documented through an analysis of the data. All subjects were tested in a safe and familiar environment to avoid any anxiety. A pre- and post-test were given, and patterns could be documented that suggest any changes that occurred as the result of the instrument.

Some factors could be unpredictable with regard to the history of the study. Unforeseen events such as a high school emergency or building evacuation could compromise the integrity of the study. Schedule flexibility and rescheduling of interrupted days helped to avoid issues relating to validity history.

Maturation of the study was limited by the overall duration of the study. The entire study took place over the course of one week. The briefness of this study allowed for an entire analysis of the subject while avoiding maturation as a result of a prolonged duration.

Regression towards the mean was avoided through a proper analysis and categorization of the resulting data. All data were analyzed to determine whether any patterns exist. Any extreme scores or outliers were investigated for their significance in the study and potentially eliminated if they were determined to be invalid.

In the event of mortality, a participant had the ability to drop out of the study for any reason at any time. Any incomplete data resulting from a subject exiting the study were eliminated from the final data analysis of the complete study. This avoided any undesired statistics resulting from incomplete data.

Experimenter bias was avoided in the study by clearly defining the parameters of the study and following them exactly. Additionally, the experimenter did not provide any personal

input or guidance that in turn may affect the resulting data. The experimenter strictly administered the study, collected the data as they were presented, and analyzed the data through statistical software. Selection bias was considered in this study since the study sample was selected based on convenience to the researcher.

There were several factors that had to be considered for this study when dealing with external validity. In order to minimize the Hawthorne Effect, the participants of the study were situated in familiar surroundings. The researcher remained as unobtrusive as possible while eliminating any personal bias.

In order to minimize the novelty or disruption effect of the treatment, a pre- and a post-test were given in order to collect data from different time periods of the study. The data were thoroughly analyzed and compared. The data analysis suggested potential outcomes that may have been influenced by the treatment.

To minimize pre- and post-test sensitization, the researcher ensured that the participants possessed a basic understanding of the skills needed to participate in the study. The researcher additionally made all reasonable accommodations for the comfort and ease of the testing experience. The design of the treatment did not allow the results of the post-test to be influenced towards a desired outcome.

The data analysis was generated from the data collected during the pre- and post-tests as well as from the design problem treatment phase of the study. The results were transcribed and converted to a written format. The data were analyzed to find patterns that provided further explanation of visual literacy that relate to parametric modeling and the problem-solving process. A thorough analysis of the data generated common themes that supported the validity of the results. This sorted data was further analyzed using data analysis software, such as SPSS, N-

Vivo, or HyperResearch. This thorough analysis helped to ensure validity and reliability of the statistical data generated from the study.

Human Subjects Approval

Before the study took place, a consent agreement form was created based on the guidelines of Eastern Michigan University's Human Subjects Review Committee and the Participation Policy Guidelines of the school district involved. Approval was required from all of the students who participated because they were high school students under the age of 18. Parental consent was obtained by all of the participants. Any participant had the ability to withdraw at any time, and the results of the study were made available upon request.

Treatment

The design problem used in this study was developed by the researcher with the assistance of industry professionals and qualified educators. The researcher is a professional CAD and Architectural Design instructor who is certified as a highly qualified high school teacher. The researcher is well experienced in designing and administering a wide variety of treatments for multiple learning styles.

Procedure

Previous to the experiment, all of the 68 participants were registered in a high school entry-level technical drawing and CAD course. The participants had learned eight weeks of curriculum. In this time, the students became proficient in the elements of design, sketching, orthographic projection, and basic modeling and assembly using 3-Dimensional CAD software.

Several weeks prior to the start of the experiment, the principal of the high school was informed of the potential experiment, and his permission was authorized to conduct the study. The instructor of the participants was also approached and informed of the study. He was asked

permission to use his students as potential participants. The instructor also agreed to allow the students to participate in the study.

The study was submitted to the Eastern Michigan University Human Subjects Review Committee (UHSRC). The UHSRC approved the study under the condition that the researcher and participants work within the guidelines of the university. All participants were informed of the study and given a letter that explained the details. The letter required that all participants acquire the signed consent of a parent or legal guardian before participating in the study. Although the participants agreed to participate in the study, they were free to leave the study at any time for any reason without consequence. Once all of the letters of consent were signed and returned, the study could begin.

The study began on a Monday and ran each of the five days, for 55 minutes, until Friday. The control group and experimental groups participated in the study separately at two designated times during the day. The study took place during the regular high school day. This had the potential to present logistical challenges with regard to interruptions and other unknown occurrences. All students were informed that attendance was crucial to the success of the study.

The study took place in a CAD lab setting that had computers that were loaded with CAD software as well as traditional drawing tables with drawing tools. All instructions for the study were delivered by the researcher using oral and visual means. The researcher used a computer attached to a projector to explain information that required the use of a computer and a data projector to explain any visual information. The instructor also had photocopied handouts for any part of the study that needed to be referenced by the participant.

All participants were randomly assigned a number in order to associate the data to a particular participant. At no time were any names used in this study that could identify the

student. The numbers assigned to participants were used to code and organize the data in order to investigate trends that occurred from the results.

On the first day, both the control and experimental groups were informed that they would be taking a pre-test for the study in the form of the Purdue Spatial Visualization Test of Rotations. The researcher created a digital version of the pre-test with corresponding answer fields. The digital version of the pre-test was distributed through curriculum management software.

The software allowed the participants to access the pre-test, using a computer in the room, and answer the questions using the multiple-choice fields. The participants could enter, alter, and review any answer before submitting their final answers to a database. Once the final answers were submitted, the participant could no longer access the pre-test. Only the researcher had access to the database of results. The database archived all of the answers submitted.

During the pre-test portion of the experiment, the participants were instructed to turn on their computers and log in. Once everyone was logged in, the researcher instructed the participants on how to access the pre-test using the curriculum management software. Once all of the participants accessed the pre-test, the researcher read the directions of the test out loud for all of the students to hear, while projecting the written directions as an image onto a screen. After reading the directions and reviewing the provided examples, the researcher informed the students that they had 50 minutes to complete the pre-test. The participants began.

All participants completed the test in the allowable time. Most of the participants finished within 20 to 30 minutes from the start of the pre-test. No participant needed the full amount of time to complete the pre-test. The last pre-test was submitted with at least ten minutes remaining. Once all of the pre-tests were complete, the researcher collected and sorted the resulting data.

were complete, the participants were asked to properly label each individual rotating part of the gripper design with arrows that show the direction each part would rotate in order to open the robotic gripper. Size, scale, and units were not a factor. The participants were able to freely design within the limitations applied to either the control or experimental group.

All participants were supplied with the materials needed to create the designs. Both the control and experimental groups were given the same time constraints of three 55-minute sessions in order to complete the tasks. All completed designs were analyzed by the researcher for rotational accuracy only. The quality of the images was not a factor, as long as they represented the robotic gripper.

For the treatment portion of the study, the control and experimental groups had different limitations of how the participants could create the designs of the robotic gripper. The control group was limited to creating designs, through sketching, by using #2 pencils, 8½" x 11" white bond paper, erasers, measuring tools, triangles, a drawing table, and drafting tape. The control group could use as many of the materials as needed to complete the task. At no time was the control group allowed to ask questions or consult with other participants. All tasks were performed individually. An example sketch of the components and assembly can be found respectively in Figures 7 and 8.

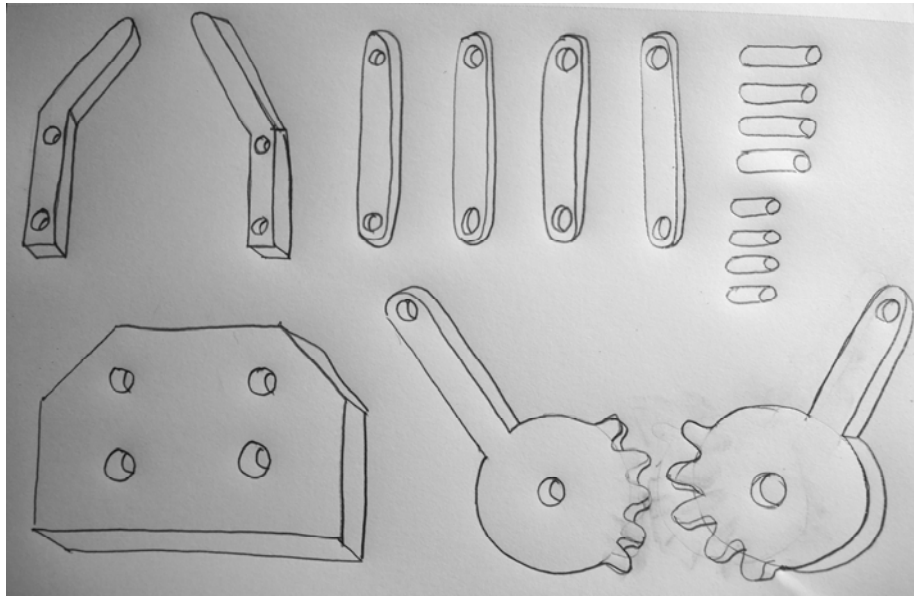


Figure 7. Sketch of components (Control)

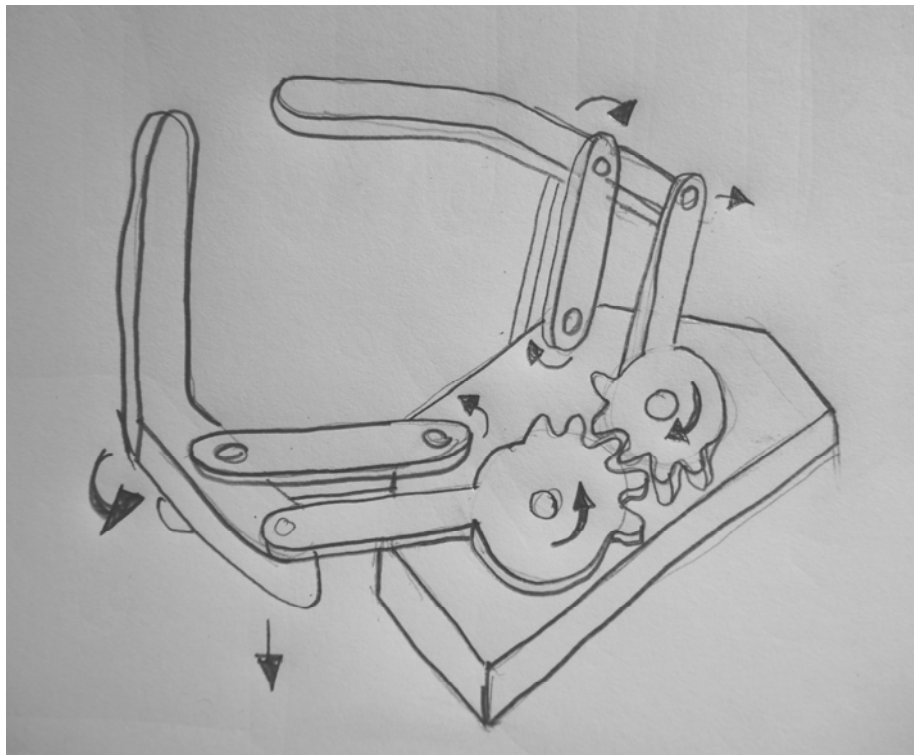


Figure 8. Sketch of assembly (Control)

The majority of the participants in the control group created the designs on two sheets of paper, while some required up to four sheets. One sheet depicted all of the separate components, as sketches, that were included in the robotic gripper model. The other sheet depicted a sketch of the robotic gripper as an assembly with the arrows labeled on the drawing, showing the rotational direction required to open the robotic gripper. All of the control group completed the designs and labeled the arrows showing rotational direction. Thirty of the participants completed the tasks by the second day.

The experimental group was limited to creating designs through the use of CAD modeling by using three-dimensional CAD modeling software and a computer with a mouse, keyboard, and monitor. In addition, the participants in the experimental group had access to graphics editing software as well as a black and white printer. The experimental group had the option of labeling the arrows using graphics editing software or a pen. The printers were required to submit the final designs to the researcher. The experimental group could create their designs within the limitations of the software. At no time was the experimental group allowed to ask questions or consult with other participants. All tasks were performed individually. An example model of the components and assembly can be found respectively in Figures 9 and 10.

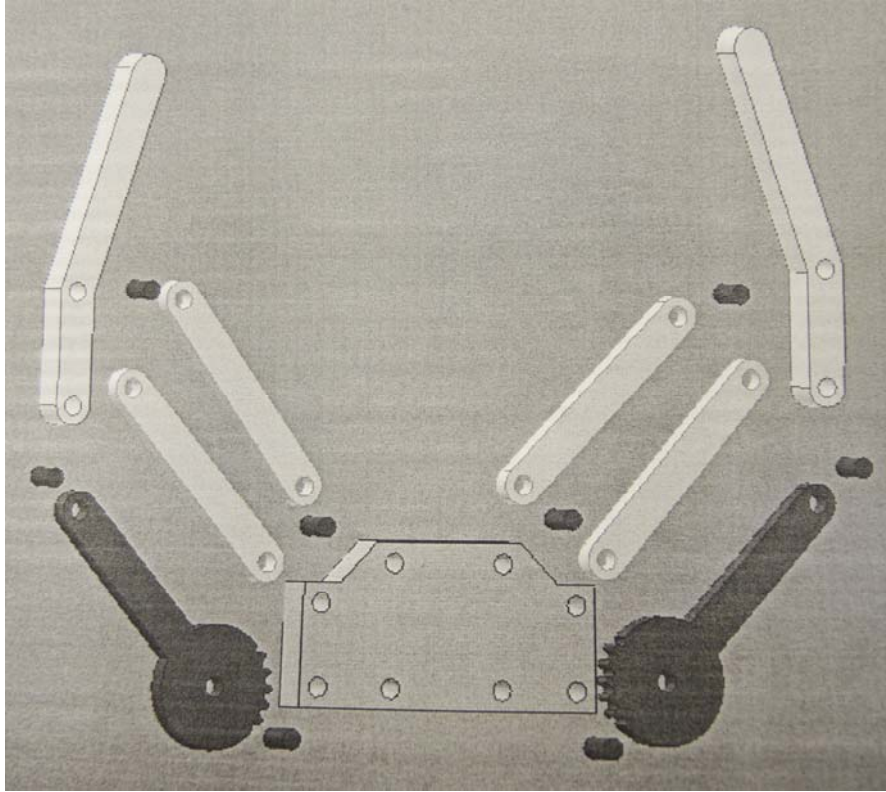


Figure 9. Model of components (Experimental)

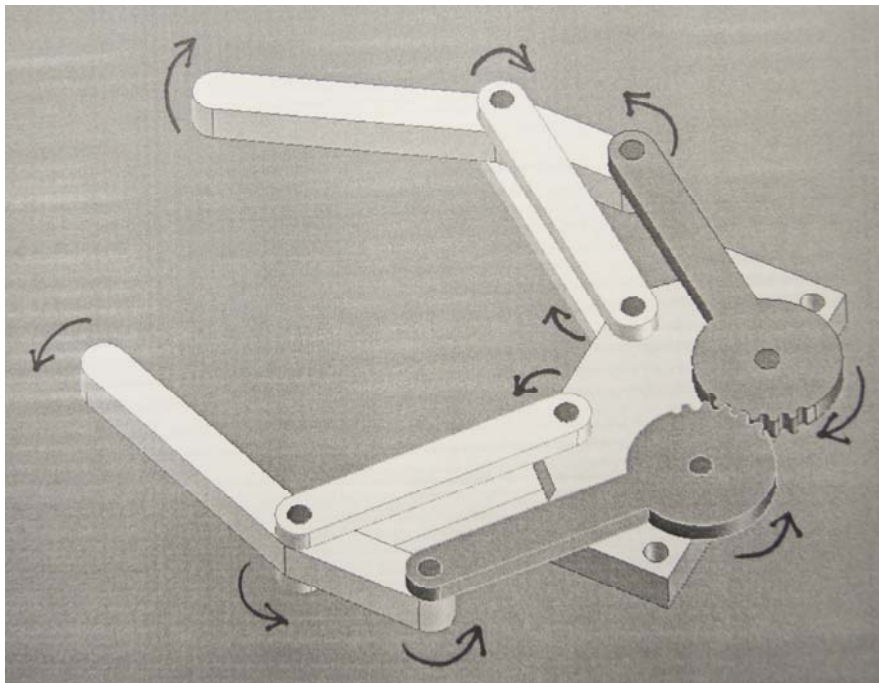


Figure 10. Sketch of assembly (Experimental)

All of the participants in the experimental group completed the designs on two sheets of printer paper. One sheet depicted all of the separate components, as CAD models, that were included in the robotic gripper model. The other sheet depicted a CAD model of the robotic gripper as an assembly. The arrows showing the rotational direction required to open the robotic gripper were either drawn on the printout with a pen or drawn before the print was made, using graphics editing software. All of the experimental group completed the designs and labeled the arrows showing rotational direction. All 34 of the participants in the experimental group required all three days of the test to complete the design tasks.

On the fifth and final day of the study, the participants took the post-test. The procedure was exactly the same as the pre-test. Both groups took the post-test in the form of the Purdue Spatial Visualization Test of Rotations. The participants once again had 50 minutes to complete the pre-test. All participants from both groups completed the post-test within the allowable time. After all of the test answers were submitted, the researcher archived the resulting data and thanked the subjects for participating in the study. Once the study was complete, the researcher analyzed the data generated from the study.

Timeline

The pre-test portion of the study was administered in one 55-minute class period. All of the participants had the same amount of time to take the pre-test. The design problem treatment portion of the study took place over the course of three 55-minute periods (165 minutes in total). The post-test portion was similar to the pre-test and was administered in one 55-minute class period. The entire study was completed in one week.

Budget

This study required a great deal of technological resources in order to administer proper execution. These included (but are not limited to) computers, CAD design software, virtual testing software, data analysis software, drawing materials, and general classroom materials. Fortunately, the majority of the materials needed for the study were readily available to the researcher. The majority of the costs associated with this study resulted from the prototype materials costs. It is estimated that it cost up to \$500.

Chapter 4: Data Analysis

The original population consisted of 70 participants. Two groups of 35 participants (a total of 70) participated in the study. The population was eventually reduced to 68 because two of the participants were absent for the majority of the design project portion of the study. Although these participants did complete the pre- and post-test portions of the study, the incomplete testing segment makes the resulting data invalid.

The design problem test produced 23 correctly labeled arrow directions and 11 incorrect labels by the control group. The experimental group produced 28 correctly labeled arrow directions and six incorrect labels. Once the design problem test was complete, all participants once again completed the Purdue Spatial Visualization Test of Rotations as a post-test. This allowed for a comparison of the data between the test and pre-test portion of the study, to determine whether any significant changes occurred.

Phase 1: Pre-Test Results Analysis

The results of the 30 questions, Purdue Spatial Visualization Test of Rotations, pre-test produced a range of results. The mean score for the 34 participants in the control group was 24.31, with a standard deviation of 5.95. The median pre-test score for the control group was 22. The mode pre-test score of the control group was 28. The mean score for the 34 participants in the experimental group was slightly less than the control group, at 23.72, with a standard deviation of 6.56. The median pre-test score for the experimental group was 21. The mode pre-test score of the experimental group was 27.

When all of the pre-test scores were looked at from both the control and experimental groups combined, the results changed slightly. The mean score for the Purdue Spatial Visualization Test of Rotations pre-test for all of the 68 participants was 24.04, with a

standard deviation of 6.22. The median pre-test score for all of the participants was 21. The mode pre-test score of all participants combined was 21. The results of the pre-test can be found in Table 2.

Table 2. Pre-test results

	Control	Experimental	All Participants
Mean Score	24.31	23.72	24.02
Standard Deviation	5.95	6.56	6.22
Median	22	21	21
Mode	28	27	21

A few questions on the Purdue Spatial Visualization Test of Rotations pre-test consistently produced incorrect answers. In the control group, Question #30 resulted in 25 incorrect answers and only nine correct answers. This question had the highest number of incorrect answers from the control group. Question #13 produced many incorrect answers from the control group as well, resulting in 19 incorrect answers and 15 correct answers. Question #22 also resulted in many incorrect responses from the control group, with 22 incorrect answers and 12 correct answers. The control group did not produce any perfect pre-test scores where a participant answered all 30 questions correctly.

In the experimental group, the pre-test question that yielded the greatest number of incorrect responses was Question #30, with 26 incorrect answers and only eight correct answers. Question #26 produced 23 incorrect and 11 correct answers from the experimental group. Question #29 followed closely behind, with 21 incorrect answers and 13 correct answers. The experimental group produced two perfect scores where two participants answered all of the 30 questions correctly.

When looking at all of 68 pre-test results including the control and experimental groups

combined, the question with the most incorrect answers was Question #30, with 51 incorrect answers and 17 correct answers. Question #26 had the second highest number of incorrect responses overall, with 39 incorrect answers and 29 correct answers. Question #29 followed closely, with 38 incorrect answers and 30 correct answers overall. When comparing the overall pre-test results with the control and experimental group results, Questions #30, #29, #26, #22, #13 proved to be the most difficult.

Phase 2: Treatment Results Analysis

The design problem test portion was assessed based on the correct labeling of arrows showing the rotational directions to make the grip open. Although all participants completed the designs through either sketching or parametric modeling, accuracy and scale were not factors determining the test outcome. These factors were not included in order for the participants to focus on the overall design concept and imagery rather than specific details of scale and size. The control group was limited to using only traditional forms of sketching with pencil and paper to create their design concept.

The experimental group was limited to using three-dimensional CAD software loaded on a computer to create their design solutions. Only correct solutions were considered as successful working solutions. A successful design solution was defined as an assembly image of the robotic gripper, created by the participant, which correctly depicted the opening motion of the robotic gripper showing the arrows indicating rotation.

Phase 3: Post-Test Results Analysis

The 30-question post-test, given in the form of the Purdue Spatial Visualization Test of Rotations, produced a slightly different range of results than the pre-test. The post-test mean score for the 34 participants in the control group was 24.62, with a standard deviation of 6.79.

The mean increased from the pre-test mean of 24.31 by a difference of 0.31. The standard deviation also increased from 5.95 by a difference of 0.84. The median post-test score for the control group was 22. This number matched the pre-test median score of 22. The mode post-test score of the control group was 23. The mode decreased by a difference of five from the pre-test mode of 28.

The mean post-test score of the 34 participants in the experimental group was still slightly less than the control group at 24.52, with a standard deviation of 6.71. However, the post-test mean increased by 0.80 from the 23.72 pre-test mean. The experimental group showed a slightly better improvement of 0.49. The standard deviation also increased slightly from the pre-test by 0.15. The median post-test score for the experimental group was 22. This was a slight increase of one from the pre-test median of 21. The mode post-test score of the experimental group was 30. This was an increase of three from the pre-test mode score of 27.

When all of the post-test scores were looked at from both the control and experimental groups combined, the results changed slightly. The mean score for the Purdue Spatial Visualization Test of Rotations pre-test for all of the 68 participants was 24.57. This is an increase of 0.55 from the overall pre-test mean of 24.02. The post-test standard deviation was 6.76, which increased by 0.54 from the pre-test standard deviation of 6.22. The median post-test score for all of the participants was 22. This is a slight increase of one from the pre-test median of 21. The mode pre-test score of all participants combined was 30. This is an increased difference of 9 from the pre-test mode of 21. The results of the post-test can be found in Table 3.

Table 3. Post-test results

	Control	Experimental	All Participants
Mean Score	24.62	24.52	24.57
Standard Deviation	6.79	6.71	6.76
Median	22	22	22
Mode	23	30	30

A few questions on the Purdue Spatial Visualization Test of Rotations post-test consistently produced incorrect answers. In the control group, Question #30 resulted in 23 incorrect answers and only 11 correct answers. This question still had the highest number of incorrect answers from the control group, but the number of incorrect answers for Question #30 decreased from the pre-test by two. Question #29 produced many incorrect answers from the control group as well, resulting with 18 incorrect answers and 16 correct answers. When the post-test results of Question #29 were compared to the pre-test results, the number of incorrect responses decreased by a difference of one, from 19 incorrect responses that were given in the pre-test. Question #26 also resulted in many incorrect responses from the control group, with 26 incorrect answers and 18 correct answers. The results for Question #26 are the same in the pre-test. The control group produced three perfect post-test scores where three participants answered all 30 questions correctly.

In the experimental group, the post-test question that yielded the greatest number of incorrect responses was still Question #30, with 22 incorrect answers and only 12 correct answers. This is a decrease of four from the pre-test results of 26 incorrect answers to Question #30. Question #26 produced 19 incorrect and 15 correct answers from the experimental group. This is also a decrease of four from the pre-test results of 23 incorrect answers to Question #26. Again, Question #29 followed closely behind, with 17 incorrect answers and 13 correct answers. This change is a decrease, as well, of four from the pre-test results of 21 incorrect answers to

Question #29. The experimental group produced three perfect scores where three participants answered all of the 30 questions correctly. This is an increase of one from the pre-test results.

When looking at all of 68 post-test results including the control and experimental groups combined, the question with the most incorrect answers was Question #30, with 45 incorrect answers and 23 correct answers. This is a decrease of six from the pre-test results of 51 incorrect answers to Question #30 overall. Question #26 had the second highest number of incorrect responses overall, with 35 incorrect answers and 33 correct answers. This is a decrease of four from the pre-test results of 26 incorrect answers to Question #26 overall. Question #29 resulted in a tie with Question #26 for incorrect answers. Question #29 had 35 incorrect answers and 33 correct answers overall. This is a decrease of three from the pre-test results of 38 incorrect answers to Question #29. When comparing the overall pre-test results with the control and experimental group results, Questions #30, #29, #26 proved to be the most difficult.

Subjects

The study included 10 females (or 15%) and 58 males (or 85%). Among the participants, 22 were freshmen (or 32%), 20 were sophomores (or 29%), 14 were juniors (or 21%), and 12 were seniors (or 18%). The study also included nine students who have academic accommodations based on a previous professional school analysis that showed the students to be struggling learners. The demographics of study sample are presented in Table 2.

Table 4. Study Demographics

Median Age:		16	
Gender:			
	Female	<i>n</i> = 10	15%
	Male	<i>n</i> = 58	85%
Grade:			
	Freshman	<i>n</i> = 22	32%
	Sophomores	<i>n</i> = 20	29%
	Juniors	<i>n</i> = 14	21%
	Seniors	<i>n</i> = 12	18%
Students with academic accommodations		<i>n</i> = 9	13%

The participants of this study ranged in age from 14 to 18. The study included 19 freshmen (or 28%), 16 sophomores (or 24%), 18 juniors (or 26%), and 15 seniors (or 22%). Among all of the subjects, ten participants were female (or 15.0%), and 58 were male (or 85.0%). The control group included four female participants (or 12.0%). The experimental group included six female participants (or 18.0%). The study also included nine participants (or 13%) who were students with academic accommodations. The control group included four participants who were students with academic accommodations (or 12.0%). The experimental group included five participants who were students with academic accommodations (or 15.0%). This information is shown in Table 3.

Table 5. Study Data

Struggling learner participants	Control		Experimental	
	Pre-test	Post-test	Pre-test	Post-test
Mean	10	9	11	11.8
Median	10	10	11	12
Mode	10	11	11	12
Treatment	<i>Pass: 0</i>	<i>Fail: 4</i>	<i>Pass: 3</i>	<i>Fail: 2</i>
Female participants	Control		Experimental	
	Pre-test	Post-test	Pre-test	Post-test
Mean	17.5	18.5	18.5	19.3
Median	17	18	18	18.5
Mode	17	18	18	18
Treatment	<i>Pass: 2</i>	<i>Fail: 2</i>	<i>Pass: 4</i>	<i>Fail: 2</i>
Male participants	Control		Experimental	
	Pre-test	Post-test	Pre-test	Post-test
Mean	22	21.3	21	21.25
Median	21	23	22	23
Mode	28	23	27	30
Treatment	<i>Pass: 22</i>	<i>Fail: 4</i>	<i>Pass: 20</i>	<i>Fail: 3</i>

Results

In the study, the participants were randomly assigned to either the control or experimental group. The scores from the study were analyzed using analysis of variance (ANOVA) to ensure that the spatial abilities of the participants were not significantly different between the groups. The data showed that that there were no significant differences between the control and experimental groups, $F = 1.317, p = .263, SD = .27$, indicating that the two groups were similar with regard to spatial visualization skills. The results of the study are represented in Table 4.

Table 6. Control and Experimental Group Results

Group	<u>Pre-test</u>			<u>Treatment (test)</u>		<u>Post-test</u>		
	N	M	SD	Successful	Unsuccessful	N	M	SD
Control	34	24.31	5.95	24	10	34	24.62	6.79
Experimental	34	23.72	6.56	27	7	34	24.52	6.71

The successful design scores generated from the treatment as well as the pre- and post-test visualization scores were analyzed in order to determine whether any statistical differences exist between the control and experimental groups and whether there was any relationship between the design method used and the scores that resulted from the pre- and post-tests. This relationship was examined in order to determine whether the hypothesized use of parametric modeling software had any affect on the visualization skills of the participants.

The control group had a mean p re-test score of 24.31. Of the robotic gripper designs, 24 were successful and 10 were unsuccessful. Overall, 71% of the control group created successful designs. The post-test mean of the control group was 24.62, with a difference of .31 between the pre- and post-tests. The experimental group had a mean pre-test score of 23.72. Of the robotic gripper designs, 27 were successful and seven were unsuccessful. Overall, 79% of the experimental group created successful designs. The post-test mean of the experimental group was 24.52, with a difference of 0.8 between the pre- and post-tests. The results can be found in Table 5.

Table 7. Pre and Post-test and Mean Comparison

Group	<u>Pre-test</u>		<u>Post-test</u>		Mean Difference
	N	M	N	M	
Control	34	24.31	34	24.62	0.31
Experimental	34	23.72	34	24.52	0.8

The first area analyzed in this study was to investigate any correlation between struggling learners who used parametric modeling software and improved scores on the post-test, as defined in Ho1. When comparing the pre- and post-test mean scores of the struggling students from the control group, there is a slight decrease in the score from 10 to 9, a decrease of one. When comparing the pre- and post-test mean scores of the struggling students from the experimental group, there is a slight increase in the score from 11 to 11.8, an increase of .8.

An independent t-test was performed, comparing the study results of struggling learners between the control and experimental groups. Using an alpha level of .05, the control group t-test results were found to be statistically insignificant, with a p-value of .067. The experimental group t-test results were also found to be statistically insignificant, with a p-value of .083. The results can be found in Table 6.

Table 8. Struggling Learners T-test

Group	t	df	P
Control	1.52	3	0.067
Experimental	1.87	4	0.083

The resulting data showed that there was no statistical significance between the results of the struggling students’ pre- and post-test scores in either the control or experimental groups. Therefore, the null hypothesis (Ho1) was found to be true, and no correlation exists between struggling learners who used parametric modeling software and improved scores on the post-test.

Regarding the treatment phase of the study, the researcher investigated whether there was any correlation between the use of parametric modeling software and the success of the final

technical design, determined by the correctly labeled arrows showing the rotational direction of the components designed in the problem, as defined in Ho2. The control group showed that 24 successful designs were created, while the experimental group produced 27 successful designs. The experimental group was able to create three additional successful designs as a result of the parametric modeling software during the treatment. An independent t-test was performed, comparing the treatment results of the control group to the results of the experimental group.

The results of the design problem treatment of the study can be found in Table 7.

Table 9. Treatment Results

Group	Successful Technical Designs	Unsuccessful Technical Designs
Control	24	10
Experimental	27	7

When comparing the results of the successful technical designs, 71% of the control group produced successful designs, while 79% of the experimental group produced successful designs. The experimental group showed a slight increase of 9% success over the control group. An independent t-test was performed, comparing the treatment results between the control and experimental groups. Using an alpha level of .05, the control group t-test results were found to be statistically insignificant, with a p-value of .0145. The experimental group t-test results were also found to be statistically insignificant, with a p-value of .074.

Table 10. Treatment T-test

Group	T	df	p
Control	2.79	33	0.145
Experimental	2.57	33	0.074

Although the experimental group did show a slight increase in the successful designs produced, the resulting data showed that there was no statistical significance between the results of the struggling students' pre- and post-test scores in either the control or experimental groups. Therefore, the null hypothesis (Ho2) was found to be true, and no correlation exists between the use of parametric modeling software and the success of the final technical design, determined by the correctly labeled arrows showing the rotational direction of the components designed in the problem.

The final area investigated in this study was to determine whether a correlation exists between the visualization skills of students, as measured by the Purdue Spatial Visualization Test of Rotations, and the use of parametric modeling software, as defined in Ho3. To determine whether a correlation exists, the overall pre-test results were compared with the overall post-test results. The mean of the control group pre-test was 24.31 and the post-test was 24.62, with an increased difference of .31. The mean of the experimental group pre-test was 23.72 and the post-test was 24.52, with an increased difference of .8. An independent t-test was performed, comparing the study results of the overall pre- and post-tests between the control and experimental groups. Using an alpha level of .05, the control group t-test results were found to be statistically insignificant, with a p-value of .096. The experimental group t-test results were also found to be statistically insignificant, with a p-value of .0102. The results can be found in Table 9.

Table 11. Control and Experimental Group T-test

Group	T	df	p
Control	1.66	33	0.096
Experimental	2.02	33	0.102

Although the resulting data showed a slight increase between the experimental pre- and post-test results, the t-test showed that there was no statistical significance between the two. Therefore, the null hypothesis (Ho3) was found to be true, and no correlation exists between the visualization skills of students, as measured by the Purdue Spatial Visualization Test of Rotations and the use of parametric modeling software.

With regard to gender, determining the differences in the study results between genders was not a primary purpose of this study. However, gender comparison within a particular study is common in the literature. When comparing the pre- and post-test scores of females from the control group, we saw that females had a mean score of 17.5 on the pre-test and 18.5 on the post-test (an improvement of 1.0). When comparing the pre- and post-test scores of females from the experimental group, we saw that they had a mean score of 18.5 on the pre-test and 19.3 on the post-test (an improvement of .8).

When comparing the pre- and post-test scores of males from the control group, we saw that males had a mean score of 22.0 on the pre-test and 21.3 on the post-test (a decline of .07). When comparing the pre and post-test scores of males from the experimental group, we saw that males had a mean score of 21.0 on the pre-test and 21.25 on the post-test (an improvement of .25). The scores from the study were analyzed using ANOVA to compare the visualization skills of the female and male participants. The data showed that that there were no significant differences in visualization skills between the female and male participants, $F = 3.24, p = .067$,

SD = .027, indicating that the two groups were similar with regard to spatial visualization skills. It is worth mentioning that the males did report a slightly higher overall mean score of 21.4, compared to the overall female mean score of 18.5.

Limitations

This study had several limitations. One of the most significant limitations was the sample size of the participants. It would be much more desirable to have included a larger population, but the researcher was limited to the sample used in this particular study. A more diverse sample of the participants would also be more desirable in order to obtain more statistical data regarding the diversity of a population.

The facility in which the study held was not intended as a controlled research facility but rather a working high school with the potential for outside events that could disrupt the study. No such events occurred, but a change in facility may be a consideration for future research. The study was also limited to the researcher and lacked other researchers who could additionally conduct the study in the attempt to compare any differences in the way the study was executed.

The tests used in the study were limited to the informative data that they generated from the participants. The time allowed for the study to take place was also a limiting factor. In addition, the participants were limited to the design of the study and the guidelines imposed on both the control and experimental groups. Ultimately, the participants were limited to the materials and confines of the study itself.

Conclusion

Ho1: In order to determine if struggling learners showed any improvement as a result of using parametric modeling software, a t-test was performed that compared the results of the struggling students' pre-test with the results of the post-test. This comparison resulted in no

significant differences between the pre and post-tests. Therefore, this hypothesis was supported.

Ho2: The results of the treatment were analyzed to determine if the use of parametric modeling had any impact on the success of the final technical design. The results were analyzed by performing a t-test that compared the success of the treatment from the control and experimental groups. The resulting data showed that there was no statistical significance between the results of the treatment and the method used in the design. Therefore, this hypothesis was supported.

Ho3: To measure whether parametric modeling had any impact on the visualization skills of all of the participants, a t-test was performed that compared the results all of the results from the pre- and post-tests from the control and experimental groups. This comparison resulted in no significant differences between the pre and post-tests. Therefore, this hypothesis was supported.

In addition, gender seemed to not be a significant factor in this study when comparing males and females using an ANOVA. However, males had slightly better scores when compared to females.

Results of the Hypothesis after Analyses

Result	Hypothesis
Supported	Ho1: Struggling learners, defined by students who require academic curriculum accommodations, as measured by the Purdue Spatial Visualization Test of Rotations, will show no improvement in visualization skills after using parametric modeling software.
Supported	Ho2: There will not be any correlation between the integration of visual literacy skills through the use of parametric modeling and the success of the final technical design. The success of the design is determined by the

correctly labeled arrows showing the rotational direction of the technical design components.

Supported

Ho3: The visualization skills of the participants, as measured by the Purdue Spatial Visualization Test of Rotations, will not increase as a result of using parametric modeling software.

Chapter 5: Discussion and Implications of Research

Summary of Research

This quasi-experimental research study was designed to investigate the effects of integrating parametric modeling software as a form of visual literacy in a technical drawing, problem-based curriculum. The study analyzed the potential correlation between struggling learners and their visualization skills after using parametric modeling software, the potential correlation between the use of parametric modeling software and the success of the technical design treatment, and the potential correlation between the use of parametric modeling software and the visualization skills of the participants. The study took place in March 2013 at a Midwest high school. The study was limited to 70 high school students but was later reduced to 68 due to incomplete data.

The participants were randomly assigned to one of two groups after the researcher was granted permission to conduct the study by the Human Subjects Review Committee at Eastern Michigan University, the high school principal, the instructor of the students, the parents of the students, and the participants themselves. The two groups consisted of a control and experimental group. The two groups were found to be statistically similar with regard to the population size, gender, demographics, and ability. All of the participants were enrolled in a high school technical design course that introduced the students to the basic elements of technical design, sketching, and three-dimensional CAD modeling.

The study itself took place over the course of one regular school week, or five days. Each day of the study lasted 55 minutes, or a total of 275 minutes for all five days. On the first day, all of the participants took the pre-test portion of the study. On the second, third, and fourth days, the participants performed the treatment portion of the study. The treatment was given in the

form of a technical design problem that the participants had to create. The control group was limited to creating their designs using traditional forms of technical sketching, while the experimental group was limited to creating their designs using parametric modeling software. On the fifth day, the participants took the post-test, which completed the study. All of the resulting data collected from the study were categorized and analyzed by the researcher.

The first part of the study that was analyzed by the researcher focused on the results comparing the pre- and post-tests of the struggling learners with the use of parametric modeling software in order to determine if any correlation existed. A t-test showed that there was not a significant difference between the pre- and post-tests, and therefore the use of parametric modeling did not seem to have any affect on struggling learners as a result. Although the data suggest that there was no correlation between the use of parametric modeling software and the visualization skills of struggling learners, it is worth mentioning that the mean scores of the experimental group produced an overall improved score of 0.8, while the mean score of the control group declined by 1.0.

The second area of the study that was analyzed by the researcher focused on the results comparing the success of the treatment of all the participants with those who used parametric modeling software to determine whether any correlation existed. A t-test showed that there was not a significant difference between the success of the treatment regardless of the method used to construct the design, and therefore the use of parametric modeling did not seem to have any affect on the success of the treatment itself. Although the data suggest that there was no correlation between the use of parametric modeling software and outcome of the treatment, it is worthwhile to mention that the mean scores of the experimental group produced more successful designs, overall, when compared to the control group. It is also worth mentioning that the

struggling learners in the experimental group generated more successful designs than the control group that did not create any successful designs.

The third part of the study that was analyzed by the researcher focused on the results comparing the use of parametric modeling software with the pre- and post-tests of all of the participants in order to determine whether any correlation existed. A t-test showed that there was not a significant difference between the pre- and post-tests, and therefore the use of parametric modeling did not seem to have any affect. Although the data suggest that there was no correlation between the use of parametric modeling software and the visualization skills of the participants, it is worth mentioning that the mean scores of the experimental group improved by 0.8, while the control group improved by only .31.

One final area that was investigated by the researcher focused on how male and female participants performed on the pre- and post-tests. The scores of the male and female participants were compared using ANOVA. The data showed that there were no significant differences between the female and male participants. However, it is worth mentioning that the males did report a slightly higher overall mean score of 21.4 than the overall female mean score of 18.5.

Implications of Study

The results of this study did not show a strong relationship between the use of parametric modeling software and an improvement in the visualization skills of the participants. However, caution must be used when generalizing the results of this study to other research because it consisted of only two groups of randomly assigned high school technical design students. The participants were selected due to their similar knowledge of drafting, design, and solid modeling. A t-test of the two groups revealed no significant differences in their spatial visualization abilities.

The test of the first hypothesis indicated that the use of parametric modeling software had no effect over how struggling learners performed on the post-test. There are a few factors that should be considered when analyzing these results. One aspect that made it difficult to get a true reflection of the treatment was the small size of the population. Another factor would be that the treatment might not have been shown to have an effect since all of the participants had been exposed to solid modeling prior to the study. These issues, combined with the short span of time in which the study took place, may have contributed to the failure to show a correlation.

The test of the second hypothesis also indicated that parametric modeling showed no influence over the success of the final technical designs. Prior training to the study could have been altered in a way that one group was only exposed to technical sketching and the other exposed to only solid modeling. The results may have shown that a proper correlation does exist between the method used and the success of the technical design. Furthermore, the technical design itself could be altered in a way to show more varying outcomes.

The test of the third hypothesis indicated that parametric modeling showed no correlation between the method used during the treatment and the post-test results. Using parametric modeling to design a solution to the design problem did not offset any differences in spatial visualization scores or provide the participants any significant advantage over sketching. Again, like the other areas investigated in the study, the size of the population, time, and the design of the treatment may have contributed to the outcome.

Although examining gender differences related to spatial visualization and problem solving was not a primary purpose of this study, the results of this study were similar to those of the study conducted by Devon et al. (1994) in which the male participants did not show a significant difference. This may be due to the sample size of female participants who were used

in the study, and possibly the past experiences and interests of the female participants, related to engineering and technology. Other studies that examined more diverse populations often found that males had significantly higher visualization scores (Branoff, 2000). Further research is needed that focuses on gender differences in visualization skills and solving technical design problems.

The results of this study suggest that solid modeling did not provide an advantage in solving this particular technical design problem. Other factors may have influenced the outcome of the success of the participants. For example, the participants may have not fully understood the requirements of the design problem or might not have taken the pre- and post-tests seriously.

Suggested Research

The continued research of visual literacy and the use of parametric modeling in the problem-based curriculum is both warranted and needed. This study suggests that there are areas relating to technology and visualization that can be further explored. There are many areas that were not addressed specifically in this study that could be points of interest for further related research. Again, having access to a much larger sample could produce differing results. This particular study was limited to the sample size used, yet using a larger population is worthy of investigating for future research.

Time was also a limiting factor in this study. A potential area worth exploring for future research would be to investigate the sample over the course of a semester in order to track any potential influence that parametric modeling has over the sample group. Due to the limited time constraints of this study, it was difficult to determine if any type of correlation truly exists.

Other testing methods should be investigated for future studies. The Purdue Spatial Visualization Test of Rotations is an excellent tool that can be used to measure spatial-

visualization skills. However, similar tests currently exist that should be considered for future research in this area, as well as the potential to develop new tests that result in more information about the subject.

The results of the study may have come to a different conclusion if the study was conducted at the beginning of the school semester. The students may have had too much previous knowledge when participating in the study so the results do not necessarily reflect the treatment used but rather the previous knowledge of the participant. By starting the study at the beginning of the semester, the participants will have very little previous knowledge of the topic and therefore the results will not be affected by their previous knowledge. The treatment could be simplified to basic shapes in order to prevent the time needed to train the participants to use more complex modeling software.

One final area that could be addressed for future research would be to conduct the study including demographics from different areas in order to analyze a wide variety of trends. These could include cultural background, ethnicity, lower-income and higher-income districts, geographic location, and graduation rates. This information could be used to help further explore the subject of visual literacy and ultimately help to improve the overall effectiveness of how curriculum is being communicated to students.

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Appendix A. Treatment Procedures

Treatment Procedures

For this technical design problem, you will be creating the designs described in part 1, part 2, and part 3. Please make sure to include all of the details required from all parts described below. You will only be able to use the materials that are provided to create the designs. An example is also provided (for another technical design problem) to show you what the layout of the final sketches could look like.

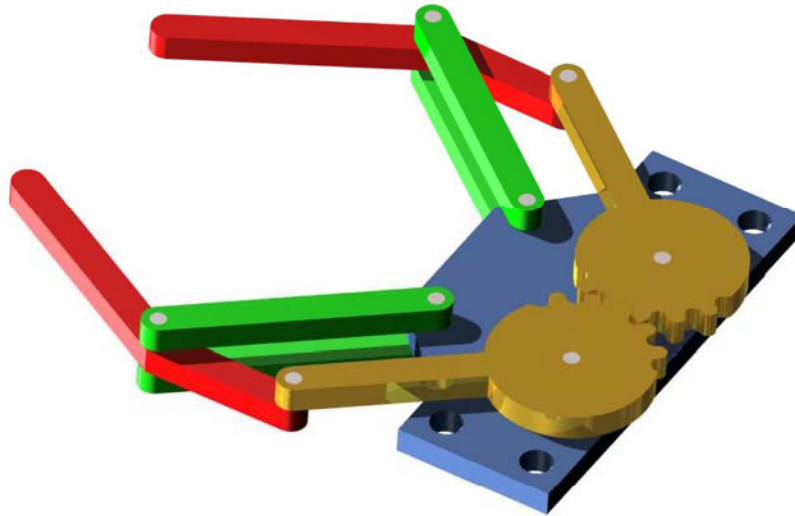


Figure 1. Robotic gripper

Image Created by: Matt Assenmacher using Autodesk Inventor

Part 1:

Using the assembly image of the robotic gripper seen in figure 1 create a sketch of each individual part that makes up the entire assembly.

Part 2:

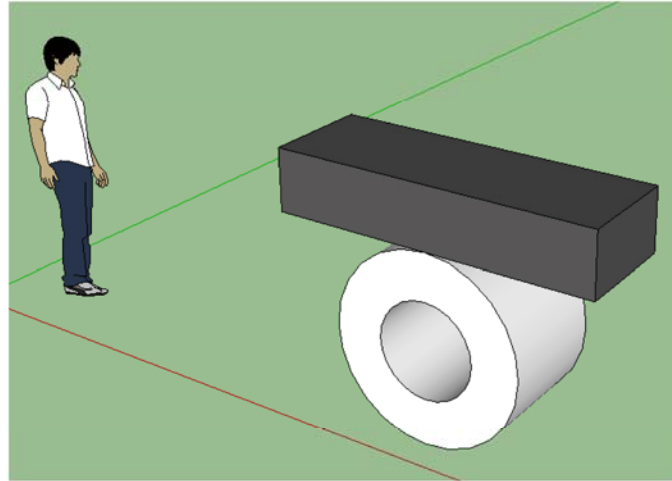
Using the assembly image of the robotic gripper seen in figure create a sketch of the entire assembly (as shown).

Part 3:

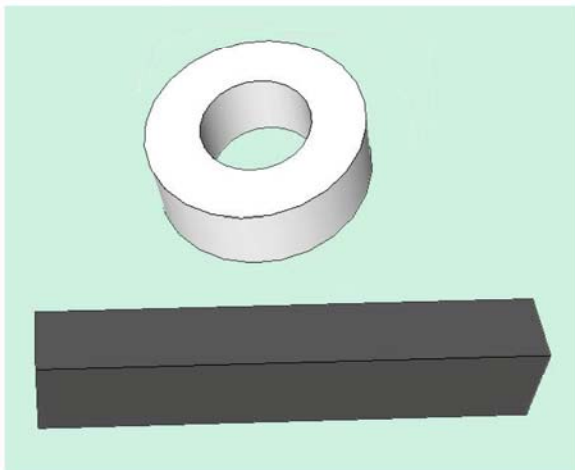
Using the assembly sketch that you created in part 2, draw arrows on the rotational axis of every part showing the rotational direction that will allow the robotic gripper to open.

EXAMPLE:

The following images are not what you will be designing. It is a similar design problem that provides an example for how the sketches could be presented. In this problem, the wheel must rotate in order to move the box towards the person.

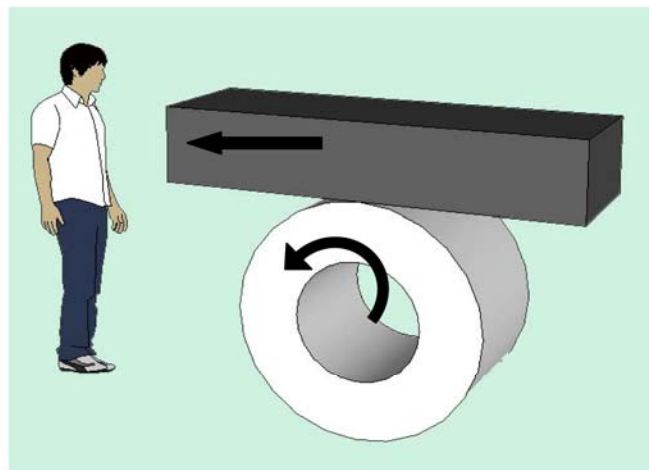


Part 1: (EXAMPLE)



The Part 1 EXAMPLE shows a sketch of each individual part that makes up the assembly.

Part 2 and 3: (EXAMPLE)



The Part 2 and 3 EXAMPLE shows a sketch of the entire assembly, labeled with arrows showing the rotational direction required to move the block towards the person.

Appendix B: Human Subjects Approval Letter



February 15, 2013

UHSRC
Application Determination

EXPEDITED APPROVAL

To: Mr. Matthew Assenmacher
College of Technology

Re: UHSRC #130113
Approval Date:

Category: Approved Expedited Research Project
February 14, 2013

Title: Visual Literacy and the Integration of Parametric Modeling in the Problem-Based Curriculum

The Eastern Michigan University Human Subjects Review Committee (UHSRC) has completed their review of your project. I am pleased to advise you that **your expedited research has been approved** in accordance with federal regulations.

Renewals: Expedited protocols need to be renewed annually. If the project is continuing, please submit the **Human Subjects Continuation Form** prior to the approval expiration. If the project is completed, please submit the **Human Subjects Study Completion Form** (both forms are found on the UHSRC website).

Revisions: Expedited protocols do require revisions. If changes are made to a protocol, please submit a **Human Subjects Minor Modification Form** or new **Human Subjects Approval Request Form** (if major changes) for review (see website for forms).

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to human subjects and change the category of review, notify the UHSRC office within 24 hours. Any complaints from participants regarding the risk and benefits of the project must be reported to the UHSRC.

Follow-up: If your expedited research project is not completed and closed after three years, the UHSRC office will require a new **Human Subjects Approval Request Form** prior to approving a continuation beyond three years.

Please use the UHSRC number listed above on any forms submitted that relate to this project, or on any correspondence with the UHSRC office.

Good luck in your research. If we can be of further assistance, please contact us at 734-487-0042 or via e-mail at gs_human_subjects@emich.edu. Thank you for your cooperation.

Sincerely,

Dr. Jennifer Kellman Fritz
Administrative Chair
University Human Subjects Review Committee

Appendix C: Participation Letter

DATE: March 4, 2013
TO: Parent/Guardian and participants
FROM: Matt Assenmacher – Drafting Instructor
RE: Student participation in doctoral research study

Dear parents/guardians and participants,

During the week of March 11- 15th, Mr. Matt Assenmacher (CAD Instructor) will be conducting a doctoral research study that will investigate problem-based learning through the use of 3-Dimensional modeling. This research study will help to better understand how high school students can use this form of technology to learn new concepts. Although the benefits of this research study are unknown at this time, it is hypothesized that the model used will enhance learning.

Your child is invited to participate in this research study due to their current involvement in a high school CAD program. Participation in this study is voluntary and your child is in no way required to take part. All information obtained will remain strictly confidential. At no time will a participant's actual name be used or any other identifiable characteristics. All of the participants will be randomly assigned a unique number in order to properly analyze the resulting data while preserving anonymity. This research study has no foreseeable risks to the participants and any volunteer can exit the research study for any reason at any time without any negative consequences.

The research study will consist of 3 parts; a multiple-choice pre-test that analyzes a participant's current ability to visualize a 3-Dimensional object, a design activity that requires the participant to solve a technical design problem involving a 3-Dimensional modeled assembly, and a multiple-choice post-test that will be compared with the pre-test to determine if any changes or patterns occurred. Participants will be randomly assigned to either a control or experimental group that will either involve the use or absence of CAD software. The results of the study will be made available to any participant upon request. No actual names will be used in the study in order to protect the anonymity of the participants. Non-participation or participation in this research study will not have any impact on the student's academic grade.

The entire research study will take approximately 5 school periods (one regular school week) to complete. Please feel free to contact me if you have any additional questions regarding this study.

Sincerely,

Mr. Matt Assenmacher
Hartland High School
Engineering Design Technology
810-626-2286
matthewassenmacher@hartlandschools.us

Please sign and return the participation form attached below.

Participant:

I have read and understand the above description of this study and I agree to

participate in this research study willingly. _____ DATE _____
(Participant's Signature)

Parent/Guardian:

As legal parent or guardian, I am allowing _____
(Participant's Name)
to participate in the research study described on this form above.

Parent or guardian permission for above student to participate in this research study.

SIGNED _____ DATE _____
(Parent/Guardian's Signature)

This research protocol and informed consent document has been reviewed and approved by the Eastern Michigan University Human Subjects Review Committee (UHSRC) for use from 3-4-13 to 3-8-13 (date). If you have any questions about the approval process, please contact the UHSRC at human.subjects@emich.edu or call 734-487-0042.