SLOAN, MARISSA MARIE. A Study of Physical Learning and Virtual Learning in Technology, Engineering, and Design Education. (Under the direction of T. Branoff and V.W. DeLuca.)

The purpose of this research study was to determine if physical learning or virtual learning was more effective for Technology, Engineering, and Design Education students in the post-secondary level. A pretest - posttest research design was used to measure the amount of knowledge gained within both settings.

A sample of 44 undergraduate students enrolled in introductory Technology, Engineering, and Design courses at North Carolina State University during the 2013 spring semester was selected. Twenty-one students completed a structures activity that including reading, quizzes, and modeling a bridge virtually using a software program called Whitebox learning. Twenty-three students completed the same structures activity physically using balsa wood to model their bridges. Both groups were given a pretest and a posttest to measure knowledge gained throughout the study.

The data implied there was a significant relationship between pretest and posttest scores when looking at the groups on an individual basis. However, when comparing the gain scores across or between the groups there was no significant relationship to note. Analyses of examining the posttest scores between or across groups indicated there is a significant difference between virtual learning and physical learning.
Technology, Engineering, and Design educators at the post-secondary level should make sure to look into the different learning types and the most effective methods to educate their students. The conclusions reached by the researcher suggest several areas of future research. First, a larger random sample should be used for the same study to compare and confirm results. Secondly, a larger sample that includes more females should be conducted to examine any gender differences that could be present. Lastly, the final two areas of research would be, a study related just to virtual learning to examine how multiple iterations affect the learning curve, and a study related to both physical and virtual learning in a mixed methods approach to students.
A Study of Physical Learning and Virtual Learning in Technology, Engineering, and Design Education

by

Marissa Marie Sloan

A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the degree of Master of Science Technology Education

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2013

APPROVED BY:

___________________________________________
V. William DeLuca

___________________________________________
Aaron C. Clark

___________________________________________
Theodore J. Branoff
Committee Chair
Marissa Marie Sloan was born in San Jose, California on October 5, 1988. She graduated from Leesville Road High School in 2006 and completed a Bachelor of Science in Technology, Engineering, and Design Education from North Carolina State University in 2010.

Marissa taught middle school in Richmond, Virginia at Fairfield Middle School before returning to North Carolina State University in 2011 to pursue her Masters of Science degree in Technology Education. Marissa is a member of the honorary society Epsilon Pi Tau. Her current academic interests include physical hands-on learning, virtual learning, and special education.
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CHAPTER 1: INTRODUCTION

The pros and cons of physical learning and virtual learning has been the interest of many people in the field of education. Learning treatments and learning types are constantly being looked at and changed to better suit the needs of students. Most recently, virtual learning has seemed to start to take over the field of education and the learning treatments within it. Administrators, teachers, and students are all being trained to think in a technologically advanced manner. Student’s assignments are changing from paper and pencil, to computers and cloud space. Although, many studies have been done on both physical and virtual learning separately, research looking at both comparatively is very scarce. Little is known about the effectiveness of virtual learning environments compared to traditional classroom education in the context of Technology, Engineering, and Design Education (Piccoli, Ahmad, & Ives, 2001).

It is believed students are able to combine intellectual stimulation through hands-on learning with activities that expand learning (Cardon, 2000). This applies to the past, industrial arts, and the present, Technology, Engineering, and Design Education. Physical learning is learning by doing to demand the students to interact with their environment. Physical learning is not simply about manipulating objects. It is engaging in in-depth investigations with products, materials, and ideas to draw knowledge and understanding from those experiences (Haury & Rillero, 1995). To
learn from an experience allows for a more rich understanding of the content being examined (Fox-Turnbull & Snape, 2011).

Virtual learning allows students to participate in a non-traditional form of hands-on education through the use of computers, extending hands-on learning to minds-on skills (Haury & Rillero, 1995). Computer-aided three-dimensional design is a technological equivalent to traditional hands-on methodology (Smith, 2003). Three dimensional computer aided design is able to teach students advanced mathematics and physics concepts, through different software and programs available. Virtual learning environments allow interaction and different encounters with the participant in order to provide a wide range of learning capabilities (Piccoli, Ahmad, & Ives, 2001). Students are able to use these programs to experiment with different scenarios, problem solving, and decision making with little risk and without wasting resources. Virtual learning is often popular due to convenience and flexibility factors, however, its effectiveness remain an open question (Chou & Liu, 2005).

Purpose of the Study

The purpose of this study is to determine if students comprehend more by completing a physical learning task or a virtual learning task. Students will be examined in both learning settings to determine if a learning difference is present or not.
Research Questions and Hypotheses

Research Question: Is there a significant difference between virtual learning and physical learning in the classroom for Technology, Engineering, and Design Education students? The research hypotheses related to the research question are as follows:

H01: There will be no significant difference in the knowledge gain scores between the virtual learning group and the physical learning group, at the p=0.05 level.

H02: There will be no significant difference between the post-test scores between the virtual learning group and the physical learning group, at the p=0.05 level.

H03: There will be a significant difference between the pretest and post-test scores for the virtual learning group, at the p=0.05 level.

H04: There will be a significant difference between the pretest and post-test scores for the physical learning group, at the p=0.05 level.

Assumptions

The following assumptions were made for the study:

1. With the population of interest being late adolescence and early adulthood, it is assumed the students in the Technology through Engineering and Design 1 and the students in the Materials and Processes Technology classes will fall into this category.

2. It will be assumed all students will have the required knowledge to operate a computer, mouse, and keyboard.
3. Since the sample will be taken from introductory courses, it is assumed all of the students will have relatively no experience with structures or bridges.

4. It will be assumed the conditions for completing the study will be consistent for all individuals involved.

5. It will be assumed each student completing the pre-assessment and post assessment will complete it to the best of his/her ability.

Limitations

1. With the study being completed over a multi-week period, it is possible the conditions when completing the project for some students may not be the same for others.

2. It is possible some students may not complete the required assessments to the best of their abilities.

3. Since the study will be done in a Technology through Engineering and Design 1 class and two sections of Materials and Processes Technology classes, the sample is limited in size and participants.

4. A percentage of the students may have background knowledge on the topic of structures before the study.

5. The sample is limited to students at North Carolina State University; therefore the results cannot be generalized to students in post-secondary institutions located in all areas of the country.
Definition of Key Terms

The purpose of this section is to provide various background information and/or definitions used in this study.

*Learning Treatments* - The different tactics of how individuals can learn and process information: by seeing and hearing, reflecting and acting, reasoning logically and intuitively, or analyzing and visualizing (Felder, 2012).

*Physical Learning (hands-on learning)* - A traditional way of teaching, in which the students are physically working with materials and tools to build a representation or final product. The students are learning by doing (Haury & Rillero, 1995).

*Post-test/assessment* – A test administered after completion of an instructional period, in conjunction with a pretest, to measure knowledge gained and achievement.

*Pre-test/assessment* – A test administered to determine a baseline of knowledge for educational purposes.

*Structures* - A body or combination of bodies that has been constructed or built of many parts and held or put together in a particular way (International Technology Education Association, 2002).

*Technology* – Human innovation in action that involves knowledge and processes to develop systems to solve problems and extend human capabilities. The innovation, change, or modification of the natural environment to satisfy wants or needs (International Technology Education Association, 2002).
Technology Education - A study of technology. Provides an opportunity for students to learn about the processes and knowledge related to technologies that are needed to solve problems and extend human capabilities (International Technology Education Association, 2002).

Three-Dimensional - To be able to give the illusion of depth or varying distances, when using an image or pictorial representation on a two-dimensional plane. A model can take many forms, including graphic, mathematical, and physical (International Technology Education Association, 2002).

Virtual Learning - A new teaching method allowing learners to perceive the environment, assess situations and performance, perform actions and process through experiences and lessons using various software on the computer (Pimentel, 1999).

Summary
This study examines the effectiveness and efficiency of both physical learning and virtual learning. The goal of the study is not to compare directly but to identify which learning group allowed students to comprehend more when completing a task. Specifically, the data collected looks at if the physical treatment group or virtual treatment group gains more comprehension, understanding, and knowledge on the topic of structures. Chapter 1 discussed the significance and purpose of the study, chapter 2 presents a relevant literature review and its findings, chapter 3 discusses the methodology used for the study, chapter 4 explains the data and findings of the
research, and chapter 5 discusses the findings in relation to the research goals and conclusions.
CHAPTER 2: REVIEW OF LITERATURE

Introduction

This chapter begins with an examination into engineering design activities within Technology, Engineering, and Design Education. Engineering design activities are constantly used and incorporated within technology education courses. This research looks into the reasoning behind these projects and the benefits they can provide. Next, research looking into both physical learning and virtual learning is examined. Both of these fields of learning have had numerous studies conducted to look into what constitutes each type of learning. The background, negative effects, benefits, and implementations are discussed from through a review of research literature. Lastly, a review of the constructivist learning theory is looked at in its regards to technology education.

Technology, Engineering, and Design Education and Engineering Design Activities

The field of Technology, Engineering, and Design Education has undergone a vast amount of changes in its curriculum, scope, missions, and principles throughout its history. In order to meet the demands of the ever-changing technological society and industrial innovation, Technology, Engineering, and Design Education has transitioned through philosophical and methodological changes. The most recent opportunity to change and develop within the Technology, Engineering, and Design Education field
stems from an alignment and closer relationship with the engineering community (Dearing & Daugherty, 2004). Both engineering and engineering design are included in the Standards for Technological Literacy (International Technology Education Association, 2002). A student’s task understanding is related to their planning and cognitive strategies within an engineering design activity (Lawanto, 2011).

Mentzer (2011) states, “Technology Education has a successful track record in providing hands-on experiences, but may strengthen its ties to an integrative STEM education approach by leveraging natural connections that exist” (p. 131). By aligning engineering design activities, such as building model bridges or rockets, it allows “students to understand the impacts of engineering development and become literate about the technological world around them” (Dearing & Daugherty, 2004, p. 8). Technological literacy is a vital educational goal, and the ability to make meaningful decisions in relation to society and technology is essential. By utilizing tools specific to engineering in conjunction with technology education’s experiential approach helps to expand and facilitate a student’s technological literacy (Mentzer, 2011). Just to be able to understand the problem is an important step and design activity for students (Lawanto, 2011). Engineering design projects are an excellent way to allow students the opportunity to relate to the real world through classroom activities but on a level that can still be structured, supervised, and explained. As Lawanto (2011) states, “solving an engineering design problem is a structured and staged process” (p. 4). Engineering design challenges apply engineering principles to solve real-world
problems by using an active, hands-on methodology through practical application (Mentzer, 2011). Not only do successful engineering and classroom projects help students to understand real-world applications, but also do natural catastrophes or engineering failures. Educators embrace studies of engineering failures as a means for a pedagogical strategy that teaches students’ different learning standards and how to design within realistic constraints (Rose & Hunt, 2012).

Technology, Engineering, and Design Education involves the process of creativity. In order, to develop creative thinking it is vital to practice activities that help to promote design and innovation. The development of design and technology curricula is premised on the importance of designing and the worth of the contingent action of creative thinking (Middleton, 2005). Technology, Engineering, and Design Education is an avenue for developing general problem solving skills, modeling and prototyping skills, creative thinking, and analytical reasoning (Dearing & Daugherty, 2004). Engineering and invention show promising tactics for how to apply creativity in design and technology education classes (Middleton, 2005). Promoting creative thinking is one of the major reasons for including design and technology programs within school curricula, it is an important concept for students to learn and evolve. Engineering design challenges bridge the divide between technology education and engineering because of the opportunity they provide to think creatively, focus efforts on a design project, all while applying engineering principles (Mentzer, 2011).
Physical Learning

Physical or hands-on learning has always been a large component of Technology, Engineering, and Design Education. Historically, Technology, Engineering, and Design Education has been the window through which students are able to apply their knowledge in a relevant, hands-on fashion (Mentzer, 2011). Technology, Engineering, and Design Education originates from industrial education, which was used to teach students trade arts for industry. Hands-on learning was an implicit aspect of industrial education. It was understood if someone wants to learn to repair an automobile, an automobile to repair must be present (Haury & Rillero, 1995). Dewey believed students could combine intellectual stimulation through hands-on learning with activities that expanded learning (Cardon, 2000). This applies to the past, industrial arts, and the present, Technology, Engineering, and Design Education. The hands-on learning approach demands that students interact with their learning environment. Physical learning is learning by doing (Haury & Rillero, 1995). The hands-on learning theory’s premise is students learn as a result of doing or experiencing, and learning happens when mental activity is combined with physical activity (Cardon, 2000). It involves the child in a total learning experience allowing an enhancement of the ability to think critically. Hands-on learning enables the students to be critical thinkers and apply not only what they have learned but also, the process of learning to various situations (Haury & Rillero, 1995). Concepts that are hard to master on paper can often be achieved through kinesthetic learning. Students indicate they learn better through
hands-on learning methods rather than lecture or bookwork, and their success in Technology, Engineering, and Design Education through hands-on learning has a direct correlation to their school attendance (Cardon, 2000). Schools that offer physical learning programs reveal higher graduation rates than those focusing on lecture and examination subjects. The heart of what stimulates the minds of young students is finding out how things operate through designing, building, and testing (Smith, 2003). Being able to use tools and machines clarifies for students that one problem can have many different possible solutions (Luna, 1998). Students are able to comprehend some problems may have multiple solutions, with some that work better than others, instead of seeing everything in black and white with right or wrong answers and solutions. Students who are exposed to the physical components of a project become interested in it, and interested students learn more (Glaze, 1999). Physical learning is not simply about manipulating objects, it is engaging in in-depth investigations with products, materials, and ideas to draw knowledge and understanding from those experiences (Haury & Rillero, 1995). Observing and doing stimulates a want to know more about the mechanics and how a product operates. Students become more involved and invest more time when fully immersed within a project they are able to understand. A nice photograph of a sunset does not compare nor captures the true essence of seeing in person the shifting of the hues; this is similar to the hands-on process in a technology classroom (Glaze, 1999). A student may be able to design and draw a catapult on a piece of paper, but it does not compare to being able to design, build, and manipulate a
model catapult. An experiential approach allows and requires the participants to become active learners instead of passive learners through lectures (Haury & Rillero, 1995).

Virtual Learning

Virtual learning is a new component in Technology, Engineering, and Design Education with a number of advantages in terms of convenience and flexibility, however, the effectiveness has yet to be determined (Piccoli, Ahmad & Ives, 2001). Online technology has a gripping impact on teaching and learning (Chou & Liu, 2005). Virtual learning allows students to participate in a non-traditional form of hands-on education through the use of computers, extending hands-on learning to minds-on skills (Haury & Rillero, 1995). Piccoli, Ahmad & Ives (2001) state, “Internet technologies are having a significant impact on the learning industry” (p. 401). Virtual learning allows interactions and the sharing of knowledge with other participants and provides a broad range of resources. The open system of virtual learning allows participant interaction through synchronous and asynchronous communication. As a result, students have a larger chance to express and articulate their knowledge and understanding (Chou & Liu, 2005).

A computer, a product of technology, is a machine students should become familiar with and feel comfortable using to solve problems (Luna, 1998). It is another tool in our arsenal of tools humans are able to use in order to extend human
capabilities. Computer-aided three-dimensional design is a technological equivalent to traditional hands-on methodology. Three dimensional computer aided design is able to teach students advanced mathematics and physics concepts, through different software and programs available. Simple machines, mechanical advantage, related mathematics, and problem solving are all examples of integration of mathematics and sciences in technology virtual learning software (Smith, 2003). By using three-dimensional computer-aided design software students are able to use the computer to make a representation of any physical object. Along with three-dimensional software programs, computers use simulation software in conjunction. Simulations allow students to see how various functions are interrelated and help contribute to success (Lamoureux, 2009). Virtual learning environments allow interaction and different encounters with the participant in order to provide a wide range of learning capabilities (Piccoli, Ahmad, & Ives, 2001). Students are able to use these programs to experiment with different scenarios, problem solving, and decision making with little risk and without wasting resources.

Virtual learning also provides benefits to the student consisting of time and place independents. It allows for flexibility of access, multi-sensory experiences, interactivity via email, chat, or video conferencing, and affordability due to the little to no cost for resources (Deal, 2002). The emphasis of virtual learning is on self-control, to diffuse thinking models, vary viewpoints, and instill self-sufficient thinking. Thus, from a performance point of view, it is reasonable to propose virtual learning is beneficial
(Chou & Liu, 2005). Additionally, virtual learning is efficient, technology-based training takes much less time to complete relative classroom instruction (Deal, 2002). Along with all of its benefits, virtual learning environments also include drawbacks. Much of literature involving technology highlights both the potential value and the setbacks of feelings of isolation, frustration, anxiety, and confusion (Piccoli, Ahmad, & Ives, 2001). Lack of interest or reduced interest in the subject or learning effectiveness can also be a setback with virtual learning (Chou & Liu, 2005). Factors of the effect of virtual learning mainly deal with technology itself. The quality and reliability of technology, along with the easy access to appropriate hardware and software equipment, are important determinants of learning effectiveness. Hardware and software compatibility, along with connectivity and technology skills, are common problems when it comes to virtual learning success (Deal, 2002).

Virtual learning helps to promote self-efficacy. Implications show that higher learner control allows students to feel proud they have the capability to use learning tools and learn independently, in turn leading to higher self-efficacy (Chou & Liu, 2005). Virtual learning is able to provide a way to merge the best features of real-world information navigation. Online navigation paired with the memory of places or visual cues permit quick searches, sorting, and swift cross-referencing (Bouras, Philopoulos & Tsiatsos, 2001).
Constructivism – An Educational Learning Theory

Constructivism, as a learning theory, can have many different meanings or versions. A ‘mild’ version of constructivism, originating from the work of Piaget, states knowledge is not passively transmitted by the instructor, but actively constructed by the learner. Furthermore, a ‘radical’ version of constructivism, originating from von Glasersfeld, states knowledge and cognition is considered adaptive based on and constantly modified by a learner’s experiences (Boudourides, 2003). However, as a whole, constructivism claims “people construct knowledge through interaction with others in the sociocultural environment” (Fox-Turnbull & Snape, 2011, p. 45) and obtain knowledge “by the experience surrounding the learning, which assigns meaning to what is learned” (Jonassen Davidson, Collins, Campbell & Haag, 1995, p. 8). Through the constructivist theory learners are to become active by engaging, grappling, and seeking to make sense of the world and environments around them (Perkins, 1992). Constructivist believe the mind is the instrument of thinking which interpret events, objects, and perspectives, and our personal world, which is constructed in our minds, define personal realities. Using these tactics, our mind is able to create knowledge as a function from how individuals apply meaning from an experience; therefore, each person conceives external reality somewhat differently (Jonassen, et al., 1995).

As Fox-Turnbull & Snape (2011) state, “Technology is a holistic and practically based curriculum, which is ideally suited to constructivist approaches to teaching and learning” (p. 45). Constructivist theorists claim people construct understanding and
knowledge through communication and interaction with others in the sociocultural surroundings (Fox-Turnbull, 2010). This relates and holds true when being applied to technology and technology education since “technological knowledge is socially constructed because the social and cultural values of particular groups of people influence the technological advances made at any one time” (Fox-Turnbull, 2010, p. 25). Meaning is assigned to what is learned by the student from the experiences that surround the learning; as a result, the process of solving real-world problems is much better and more deeply understood (Jonassen, et al., 1995). Based on the constructivist principles, practical activity successfully leads to the growth of students and teachers understanding of technological practice and technology education. Students are able to gather a rich understanding of theory linked to technological practice and other relevant links to learning within the classroom (Fox-Turnbull & Snape, 2011). The interaction between teachers and learners and peers is vital for the development of superiority technology in schools according to the practical nature and constructivist foundation of technology education (Fox-Turnbull, 2010). Constructivist educators strive to create active learning environments, where learning is participating and interacting rather than listening and mirroring (Jonassen, et al., 1995).

Constructivism holds that knowledge is something that is personally obtained by individuals in an active way as they try to understand and give significance to socially accepted and shared notions (Boudourides, 2003). A constructivist curriculum strives to promote a teaching process or way of learning to help lead students towards an
autonomous way of thinking and reasoning (Fox-Turnbull, 2010). Instructors serve as guides for students because in constructivism there is no absolute determination, there is always more than one solution to a problem and depending on the different perspectives used to approach it, it can have different solutions (Boudourides, 2003). Educators and instructors use a collaborative approach, instead of a dictating approaching to teaching. This collaborative approach helps students to take ownership of their learning and technological outcomes, which in turn, situates a quality technology education program (Fox-Turnbull, 2010). The principles of constructivists provide principles that help to guide designers and teachers to create learner-centered, collaborative environments that support experiential and reflective processes (Jonassen, et al., 1995). Learners do not just take in information that is fed to them to store, but make interpretations of experiences and use those to elaborate and test those interpretations (Perkins, 1992). Students are able to make connections and demonstrate a high level of engagement to real and authentic needs, issues, and technological practices within society through activity and reflection in the classroom (Fox-Turnbull & Snape, 2011).

Summary

This literature review covers engineering design activities through Technology, Engineering, and Design Education, physical learning, virtual learning, and the constructivist learning theory. The major conclusions of this literature review are
engineering design activities are a popular way to allow students to explore real-world problems in an engaging way to become more technologically literate and both physical and virtual learning are important ways for students to gather information, although, both include positive and negatives. In this chapter, links between the connections of the constructivist theory and technology education were explored and confirmed through how technology education should be taught and the content of the curriculum.
CHAPTER 3: METHODOLOGY

Introduction

It is believed students will gain a deeper understanding of content when actively participating within a hands-on physical activity. However, it is also believed students will take more pride, self-efficacy, and responsibility when moving at a self-motivated pace when completing virtual activities. The review of literature led to believe there could be components of both physical and virtual learning that has not been examined yet. One component included the comparison between the two learning treatments, physical and virtual, with respect to which is more effective for Technology, Engineering, and Design Education students.

Purpose of the Study

The purpose of this study is to determine if students comprehend more by completing a physical learning task or a virtual learning task. Students will be examined in both learning settings to determine if a learning difference is present or not.
Research Questions and Hypotheses

Is there a significant difference between virtual learning and physical learning in the classroom for Technology, Engineering, and Design Education students is the main research question involved with the study?

The research hypotheses relating to the research question; which will guide the sample selection, testing instrumentation, data collected, and the analysis of the data; are as follows:

H01: There will be no significant difference in the knowledge gain scores between the virtual learning group and the physical learning group, at the p=0.05 level.

H02: There will be no significant difference between the post-test scores between the virtual learning group and the physical learning group, at the p=0.05 level.

H03: There will be a significant difference between the pretest and post-test scores for the virtual learning group, at the p=0.05 level.

H04: There will be a significant difference between the pretest and post-test scores for the physical learning group, at the p=0.05 level.

Null Hypotheses

Null Hypothesis #1. There will be no significant difference between the gain scores for the virtual learning group and the physical learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables \(v\text{gain}\) for the virtual learning group and \(p\text{gain}\) for the physical learning group.
Null Hypothesis #2. There will be no significant difference between the scores on the posttest for the virtual learning group and the scores on the posttest for the physical learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables vscore2 for the virtual learning group and pscore2 for the physical learning group.

Null Hypothesis #3. For the virtual learning group, there will be no significant difference between the scores on the posttest and the pretest. A non-parametric Wilcoxon Signed Rank statistical test will be used to determine if differences exist between the variables vscore1 and vscore2 for the virtual learning group.

Null Hypothesis #4. For the physical learning group, there will be no significant difference between the scores on the posttest and the pretest. A non-parametric Wilcoxon Signed Rank statistical test will be used to determine if differences exist between the variables pscore1 and pscore2 for the physical learning group.

Research Design

The research design for this particular study will follow a pretest-posttest design (see Table 3.1). The study is comparing two different participant groups by methods of learning, while trying to control the extraneous variables. The purpose of selecting this design is to show how the study will measure the degree of change occurring as a result of the two groups, physical learning and virtual learning. The particular pretest posttest design that will be used is a two-group control design. The principle behind
this design is relatively simple; subjects are assigned a group depending upon their enrollment within an introductory Technology, Engineering, and Design Education course, a physical learning and a virtual learning group (Shuttleworth, 2009). Both groups are administered the pre and post-test, with the ultimate difference being one group is in an alternative environment, this allows a number of distinct analyses. The study is not trying to explain a relationship between the two types of learning, but trying to distinguish which learning type allows the students to learn the best and most efficiently.

Table 3.1. Research Design

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Treatment</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Learning Group</td>
<td>R</td>
<td>O₁</td>
<td>X</td>
</tr>
<tr>
<td>Physical Learning Group</td>
<td>R</td>
<td>O₁</td>
<td>Y</td>
</tr>
</tbody>
</table>

R: Assignment of the subject to either the physical learning group or the virtual learning group by enrollment status

O₁: A test on the knowledge of the components and elements on structures.

O₂: An equivalent form of the test on the knowledge of the components and elements on structures.

X: Students will be using Whitebox Learning to create a virtual model of their structure.

Y: Students will be in the traditional setting of building a physical structure.
Target Population

The intent of the study is to examine which form of learning is the most efficient and effective within a college course. The target population for this study will be individuals in late adolescence and early adulthood enrolled in a post-secondary institution. This population is of interest to teachers in the Technology, Engineering, and Design Education courses at the post-secondary level.

Sample

A convenience sample of undergraduate students enrolled in introductory Technology, Engineering, and Design Education courses at North Carolina State University during the 2013 Spring semester was selected and used. The class rolls of TDE 131 - Technology through Engineering and Design 1 and two sections of TDE 110 – Materials and Processes Technology were used as the sampling frame. The complete population of all three courses was used for the study.

Instrumentation

For this study, the measurement instruments implemented were both a pre-assessment (see Appendix C) and a post-assessment test (see Appendix D). All students involved in the study completed the same pre-test before being broken into the two different environments. After the pre-test, the students were split into groups depending upon their enrollment within an introductory Technology, Engineering, and
Design Education course, and each completed the project within their own type of environment, either physical or virtual. After completing the project within their environments, all the students then completed a post-test to measure the amount of knowledge and comprehension about the subject gained in the separate environments. The post and pre-tests were compared, then grouped and compared to look at each group and the different environments collectively.

Since the main interest for this study was the comparative knowledge learned between the physical learning and virtual learning groups, a pre and post assessment to test the knowledge of the components and elements on structures were created and used. Both the pre and post assessments were developed according to the main concepts and content of the structures project. In order to ensure content validity, the assessments were given to various experts in the field to assure the knowledge tested was applicable and valid. The experts used were two Technology, Engineering, and Design Education professors of North Carolina State University. Both professors have experience teaching either structures or technology through engineering courses. The experts commented and validated the assessment for content validity. The assessments were administered and used to measure the amount of knowledge gained between the posttest and pretest. Both the pretest and the posttest were 30 minute timed tests, administered to all individuals within the study, regardless of their group to ensure the same information was tested and accounted for. The assessments were measured for
reliability using the Kuder-Richardson Formula 20 (KR-20) test. The KR-20 values for the pretest and posttest were 0.827 and 0.699, respectively.

Procedure

To begin, the subjects within the study were the students of the undergraduate Technology, Engineering, and Design Education courses TDE 110-001, TDE 110-002, and TDE 131 at North Carolina State University. The students were both female and male who were 18 years or older. They had some background knowledge in Technology, Engineering, and Design Education, but were not masters of the subject or the activity planned. The three classes were broken up into two groups, a physical learning group and a virtual learning group which were the independent variables, to create as even as a sample as possible. The course TDE110-001 (13 students) and TDE131 (8 students) were both assigned to the virtual learning group to create one group with a total of 21 students, and TDE110-002 (23 students) was the physical learning group with a total of 23 students. To avoid cross contamination of the groups within the study, each class as a whole was assigned to a specific grouping. The separating of the groups from each class was decided by allowing the most even numbers possible to participate within each learning treatment without breaking up the classes. The complete population of each class was used, and since each class as a whole conducted the same treatment there was no cross-contamination of information.
All students involved signed an informed consent form (see Appendix A) and were aware of the study being conducted.

The students were given a structures design project sheet (see Appendix B) to outline the contents of what was going to be asked of them and inform the students of the time limitations for each step of the process. Both groups in the class took a pre-test of the information that was going to be learned through the project to check each students beginning knowledge. The pre-test was a 30 minute timed test that showed previous knowledge carried over into the project by the students, such as mathematics formulas and physical attributes; it also acted as a section of the dependent variable and measurement instrument. The students were given a project on structures; the physical learning group was given readings and informal quizzes on paper, and supplies to build a model bridge. Whereas, the virtual learning group completed readings, informal quizzes, and a virtual model online through software called Whitebox Learning. The virtual learning group completed their online modeling in a classroom equipped with computers, while the physical learning group completed their physical modeling in an attached separate laboratory. Participants were given 1.5 hours to complete the readings and quizzes and 2 hours to plan and complete the modeling, regardless of the group to which they were assigned.

Once all of the students completed their projects in both groups, the students then completed a post-assessment test. The posttest was also a 30 minute timed test and was equivalent to the pre-test. This allowed for direct comparison on the
differences from the pre-test to the post-test. Once the results were recorded, an
analysis was completed on the differences between the knowledge gained and
comprehension for the subject for each of the two groups. The data was turned into
quantitative data in order to carry out the statistical tests to look at the spreads and
significance tests. The statistical tests used for this study were non-parametric tests,
consisting of the Wilcoxon Signed Rank test and the Mann Whitney test.

Figure 3.1 shows the procedure in a quick list format. The courses and number
of participants per group is listed, as well as each step of the study is named, along with
the amount of time tied to each activity.

- TDE 110-001 and TDE 131 = Virtual Learning Group (21 students)
- TDE 110-002 = Physical Learning Group (23 students)
  - 1. Consent Form Signed
  - 2. Structures Design Sheet
    - Outline of process and assignment
  - 3. Pretest – 30 minutes
  - 4. Given assignment in respective groups – 1.5 hours
    - Readings and informal quizzes
  - 5. Given project in respective groups – 2 hours
    - Designing and modeling a bridge structure
  - Posttest – 30 minutes

Figure 3.1 Procedure – Quick View

Analysis of Data

This study can be characterized as quantitative research. Data collect from the
pretests and posttest were summarized and analyzed. In order to produce reliable
results that can be verified and validated, inferential statistical analyses were
conducted. The data was analyzed using the SPSS statistical analysis program to run the Mann Whitney test in order to analyze the pretest and posttest scores within the groups. Additionally, the data was analyzed using the JMP statistical analysis program to run the Wilcoxon Signed Rank test in order to analyze the pretest and posttest scores between the two groups. The study aimed to provide reliable, consistent, and accurate statistical analyses.

**Dependent Variables**

The dependent variables of the study are the gain scores in each learning environment of the post-test and the pre-tests, which were given to the students. Four dependent variables were examined: the difference between \textit{vscore1} (score of the virtual learning group for the pretest) and \textit{pscore1} (score of the physical learning group for the pretest) – \textit{diff1}, the difference between \textit{vscore2} (score of the virtual learning group for the posttest) and \textit{pscore2} (score of the virtual learning group for the posttest) – \textit{diff2}, the difference between \textit{vscore2} and \textit{vscore1} – \textit{vgain}, and the difference between \textit{pscore2} and \textit{pscore1} – \textit{pgain}. All participants received the same treatment when \textit{vscore1} and \textit{pscore1} were collected. For \textit{vscore2} and \textit{pscore2}, although the test group and control group received different treatments throughout the project, all the participants received the same treatment when these values were collected.
**Independent Variables**

Within the study, the independent variables were the two different learning environments, physical learning and virtual learning. The purpose of the study was to examine which learning environment creates a more effective and efficient version of learning.

**Control Variables**

The control variables within the study are the students and the class in which the study is given, TDE 110-001, TDE 110-002, and TDE 131.

**Variables**

- **group** – 1-virtual learning group, 2-physical learning group
- **vscore1** – Score of the virtual learning group for the pretest
- **pscore1** – Score of the physical learning group for the pretest
- **diff1** – Difference between **vscore1** and **pscore1**
- **vscore2** – Score of the virtual learning group for the posttest
- **pscore2** – Score of the physical learning group for the posttest
- **diff2** – Difference between **vscore2** and **pscore2**
- **vgain** – Difference between **vscore2** and **vscore1**
- **pgain** – Difference between **pscore2** and **pscore1**
The analyses used to test each research hypothesis are listed in Table 3.2.

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Dependent Variable(s)</th>
<th>Independent Variable</th>
<th>Data Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>vgain, pgain</td>
<td>group</td>
<td>Mann Whitney</td>
</tr>
<tr>
<td>2</td>
<td>diff2</td>
<td>group</td>
<td>Mann Whitney</td>
</tr>
<tr>
<td>3</td>
<td>vgain</td>
<td>Group – virtual learning</td>
<td>Wilcoxon Signed Rank</td>
</tr>
<tr>
<td>4</td>
<td>pgain</td>
<td>Group – physical learning</td>
<td>Wilcoxon Signed Rank</td>
</tr>
</tbody>
</table>

Summary

This chapter has described the method and research design used to execute the purpose of the study and test the research hypotheses. The study used a pretest-posttest design. The test instruments used were a structural pre-assessment and an equivalent form as a structural post-assessment. The target population was individuals in late adolescence and early adulthood. The sample was of undergraduate students enrolled in introductory Technology, Engineering, and Design Education courses during the spring semester of 2013 at North Carolina State University. Two statistical analysis programs, SPSS and JMP, were used to analyze the data. Each section discussed outlined the aims, scope, and strategy for this study.
CHAPTER 4: RESULTS

Introduction

The purpose of this study was to explore the comparison of physical learning versus virtual learning in Technology, Engineering, and Design Education at the post-secondary level. The results from all students enrolled in introductory classes TDE110-001, TDE110-002, and TDE131 (n=44) were investigated, in regards to which learning group was most efficient and effective. This chapter presents the data relevant to physical learning and virtual learning within Technology, Engineering, and Design Education introductory courses.

The target population for this study consisted of 44 students currently enrolled in introductory Technology, Engineering, and Design Education courses, TDE110-001, TDE110-002, and TDE131. Participants were acquired and informed through each of these courses, at which they then signed an informed consent letter. Usable responses were collected from the full population of 44 students who responded and participated within the learning activities and assessments (response rate 100%).

This chapter is divided into three sections. The first section exhibits the demographic data on the participants. Participation in the study is broken down by gender, classification, major, course enrolled, and treatment group. The second section in this chapter exhibits data related to scores on the pretest and posttest contained within each treatment grouping. Each pretest and posttest assessment consisted of 31 questions, with the posttest being an equivalent form of the pretest. The questions
covered a wide range about structures and the calculations behind how to correct build a structural sound bridge. Research hypotheses 3 and 4 are tested and the results are reported to whether the findings were statistically significant. The third section in this chapter exhibits data related to scores on the pretest and posttest compared between treatment groups. Research hypotheses 1 and 2 are tested and the results are reported to whether the findings were statistically significant. The chapter concludes with an overall summary of the findings.

*Description of the Participants*

Table 4.1 displays data on the participants in the study by gender.

<table>
<thead>
<tr>
<th>Gender</th>
<th>No. of participants</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>34</td>
<td>77.0</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
<td>23.0</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Of the 44 participants males were the predominant gender at 77.0%. There were approximately three times as many males as females participating in the study. This is probably due to the fact that majors requiring Technology, Engineering, and Design Education courses (from which the sample was drawn) attract considerably more male students than female students.
Table 4.2 displays the classification demographics of the participants within the study.

Table 4.2. Classification Demographics of the Participants (N=44)

<table>
<thead>
<tr>
<th>Class</th>
<th>No. of participants</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>1</td>
<td>2.3</td>
</tr>
<tr>
<td>Sophomore</td>
<td>16</td>
<td>36.4</td>
</tr>
<tr>
<td>Junior</td>
<td>14</td>
<td>31.8</td>
</tr>
<tr>
<td>Senior</td>
<td>13</td>
<td>29.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Within the sample (N=44), the spread of classification through school ranking all participants except for one outlier were classified as a sophomore, junior, or senior. This could be due to the fact that is an introductory course and showing up early in their curricular display for sophomores (36.4%), and perhaps major changes for juniors (31.8%) or seniors (29.5%).

Table 4.3 displays the major demographics of the participants within the study.
Table 4.3. Major demographics of the participants (N=44)

<table>
<thead>
<tr>
<th>Major</th>
<th>No. of Participants</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture &amp; Life Sciences</td>
<td>9</td>
<td>20.5%</td>
</tr>
<tr>
<td>Education</td>
<td>10</td>
<td>22.7%</td>
</tr>
<tr>
<td>Engineering</td>
<td>10</td>
<td>22.7%</td>
</tr>
<tr>
<td>Natural Resources</td>
<td>11</td>
<td>25.0%</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>9.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

When considering the major each participant was currently enrolled in, participants were almost evenly spread across the board for Agriculture & Life Sciences (20.5%), Education (22.7%), Engineering (22.7%), and Natural Resources (25.0%). These colleges most likely require students in the different curricula to take the involved introductory courses.

Table 4.4 displays the breakdown of participant enrollment in the two courses.

Table 4.4. Participant Enrollment of Involved Courses (N=44)

<table>
<thead>
<tr>
<th>Course</th>
<th>No. of Participants</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDE110 – Materials &amp; Processes Technology</td>
<td>36</td>
<td>81.8%</td>
</tr>
<tr>
<td>TDE131 – Technology Through Engineering &amp; Design 1</td>
<td>8</td>
<td>18.2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>44</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>
The study involved two different Technology, Engineering, and Design Education introductory courses. The class rolls of two sections of TDE 110 – Materials and Processes Technology (81.8%) and TDE 131 - Technology through Engineering and Design 1 (18.2%) were used as the sampling frame.

Table 4.5 shows the breakdown of participants for each treatment group.

Table 4.5. Treatment Groups (N=44)

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of Participants</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Learning</td>
<td>23</td>
<td>52.3</td>
</tr>
<tr>
<td>Virtual Learning</td>
<td>21</td>
<td>47.7</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Students were assigned to two treatment groups, physical learning or virtual learning. Courses TDE 131-001 and TDE110-001 were assigned virtual learning, while course TDE110-002 was assigned to physical learning. Twenty-one students (47.7%) were assigned to the virtual learning group and twenty-three students (52.3%) were assigned to the physical learning group.

Analysis of Scores within Treatment Groups

Table 4.6 looks at the scores attained on the pretest and posttest for both the physical learning and virtual learning groups. It displays the mean and standard deviation for each group.
Table 4.6. Scores for Pretest and Posttest by Treatment Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Pretest Standard Deviation</th>
<th>Posttest Mean</th>
<th>Posttest Standard Deviation</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Learning Group</td>
<td>group1</td>
<td>21</td>
<td>69.3</td>
<td>13.2</td>
<td>82.0</td>
<td>10.7</td>
</tr>
<tr>
<td>Physical Learning Group</td>
<td>group2</td>
<td>23</td>
<td>75.3</td>
<td>17.5</td>
<td>88.1</td>
<td>8.9</td>
</tr>
</tbody>
</table>

The data was analyzed using the JMP statistical analysis program. The table shows the variable vscore1 = 69.3, vscore2 = 82.0, pscore1 = 75.3, and pscore2=88.1. The mean difference is discussed as variables, vgain (12.7) and pgain (12.8).

Table 4.6 shows that the virtual learning group started with a mean score of 69.3 and ended with a mean score of 82.0, this was a mean difference of 12.7 points. Meanwhile, the physical learning group started with a mean score of 75.3 and ended with a mean score of 88.1, this was a mean difference of 12.8 points. Even though the physical learning group had a higher mean for both the pretest and the posttest scores, the gain or mean difference within both groups was about equal.

Table 4.7 displays the results for the Wilcoxon Signed Rank statistical test for the virtual learning group (group1), while table 4.8 displays the results for the physical learning group (group2). The data was analyzed using the JMP statistical analysis program. This test is a non-parametric statistical hypothesis test. It is used when comparing two related samples or matched samples, such as the pretest and posttest for this study.
Table 4.7. Wilcoxon Signed Rank Test Results for Virtual Learning Group (group1)

| Posttest - Pretest | Test Statistic S | Prob>||S| | Prob>|S| | Prob<|S| |
|--------------------|-----------------|-----------------|-----------------|-----------------|
|                    | 109.500         | <.0001*         | <.0001*         | 1.0000          |

*Significant at α = 0.05.

Table 4.8. Wilcoxon Signed Rank Test Results for Physical Learning Group (group2)

| Posttest - Pretest | Test Statistic S | Prob>||S| | Prob>|S| | Prob<|S| |
|--------------------|-----------------|-----------------|-----------------|-----------------|
|                    | 123.000         | <.0001*         | <.0001*         | 1.0000          |

*Significant at α = 0.05.

The p-value for both the virtual learning group (group1) and the physical learning group (group2) is p=0.0001, meaning it is significant. This shows that for both groups the amount of knowledge content learned between the time of the pretest and the time of the posttest, vgain and pgain, was significant.

Null Hypothesis #3. For the virtual learning group, there will be no significant difference between the scores on the posttest and the pretest. A non-parametric
Wilcoxon Signed Rank statistical test was used to determine if differences existed between the variables $\text{vscore1}$ and $\text{vscore2}$ for the virtual learning group.

The analysis indicated a significant difference for the variable $\text{vgain}$, the difference between $\text{vscore2}$ and $\text{vscore1}$ at $\alpha = 0.05$. The findings support Research Hypothesis 03.

**Null Hypothesis #4.** For the physical learning group, there will be no significant difference between the scores on the posttest and the pretest. A non-parametric Wilcoxon Signed Rank statistical test was used to determine if differences existed between the variables $\text{pscore1}$ and $\text{pscore2}$ for the physical learning group.

The analysis indicated a significant difference for the variable $\text{pgain}$, the difference between $\text{pscore2}$ and $\text{pscore1}$ at $\alpha = 0.05$. The findings support Research Hypothesis 04.

**Analysis of Scores between Treatment Groups**

Table 4.9 and table 4.10 display the results for the Mann Whitney statistical test for the gain scores, $\text{vgain}$ and $\text{pgain}$. The data was analyzed using the SPSS statistical analysis program. This test is a non-parametric statistical test of the null hypothesis. It is used when two populations are the same against an alternative hypothesis; it is used across two groups of data, such as the virtual learning group and the physical learning group within this study.
Table 4.9. Mann Whitney Results for Gain Scores – Ranks

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Learning Group</td>
<td>21</td>
<td>23.52</td>
<td>494.00</td>
</tr>
<tr>
<td>Physical Learning Group</td>
<td>23</td>
<td>21.57</td>
<td>496.00</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.10. Mann Whitney Results for Gain Scores – Test Statistics

<table>
<thead>
<tr>
<th>Gain</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann Whitney</td>
<td>220.00</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>496.00</td>
</tr>
<tr>
<td>Z</td>
<td>-0.507</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>0.612</td>
</tr>
</tbody>
</table>

The p-value for the gain scores across the virtual learning group and the physical learning group is p=0.612, meaning it is not significant. This shows the difference in the gain scores across the virtual learning and physical learning groups was not significant.

*Null Hypothesis #1.* There will be no significant difference between the gain scores for the virtual learning group and the physical learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables \(\text{vgain}\) for the virtual learning group and \(\text{pgain}\) for the physical learning group.
The analysis indicated there was not a significant difference for the differences between the variables \( v_{gain} \) and \( p_{gain} \) at \( \alpha = 0.05 \). The findings support Research Hypothesis 01.

Table 4.11 and table 4.12 display the results for the Mann Whitney statistical test for variable \( \text{diff2} \), the difference in the posttest scores of the virtual learning group (\( v_{score2} \)) and the physical learning group (\( p_{score2} \)). The data was analyzed using the SPSS statistical analysis program.

Table 4.11. Mann Whitney Results for Differences between Posttest Scores – Ranks

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Learning Group</td>
<td>21</td>
<td>18.55</td>
<td>389.50</td>
</tr>
<tr>
<td>Physical Learning Group</td>
<td>23</td>
<td>26.11</td>
<td>600.50</td>
</tr>
<tr>
<td>Total</td>
<td>44</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.12. Mann Whitney Results for Differences between Posttest Scores – Test Statistics

<table>
<thead>
<tr>
<th>Posttest</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann Whitney</td>
<td>158.50</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>389.50</td>
</tr>
<tr>
<td>( Z )</td>
<td>-1.963</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>0.05</td>
</tr>
</tbody>
</table>
The p-value for the difference in the posttest scores across the virtual learning group and the physical learning group is p=0.05, meaning it is significant. This shows the difference in the posttest scores across the virtual learning and physical learning groups was significant.

Null Hypothesis #2. There will be no significant difference between the scores on the posttest for the virtual learning group and the scores on the posttest for the physical learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables vscore2 for the virtual learning group and pscore2 for the physical learning group.

The analysis indicated there was a significant difference for diff2, the differences between the variables vscore2 and pscore2, at α = 0.05. The findings do not support Research Hypothesis 02.

Summary

This chapter presented the demographics data on the participants, presented means and gain scores, and has tested the four research hypotheses and reported the results. Several significant relationships were identified after running the analysis of the data in this chapter. When analyzing the pretest and posttest scores within the virtual learning and physical learning groups, significant differences exist. The p-value for both the virtual learning group (group1) and the physical learning group (group2) is p=0.0001, meaning it is significant. However, there was no significant difference when
looking across the groups at the gain scores (p=0.612), but when looking across the
groups at just the posttest scores, a significant difference did exist (p=0.05).
CHAPTER 5: DISCUSSION

Introduction

In this chapter major findings between physical and virtual learning are discussed. The findings of this study were based on the data collected in the form of the pretest-posttest research design. Using this form of instrumentation, the comparative analyses between physical learning and virtual learning was explored. This discussion seeks to achieve an interpretation of empirical analysis of the data and compare the results of the research with the literature review or with the views of other researchers. The chapter also gives guidance and suggestions for future studies relating to physical learning versus virtual learning, and concluding with lessons learned about the research from the perspective of the researcher.

Summary of Findings

There have been many discussions of physical learning versus virtual learning in the Technology, Engineering, and Design Education field. These discussions go back and forth to what it the best method to teach students within the field. Many instructors believe it is important to maintain the hands-on approach to technology education. They believe students gain more knowledge by experience and manipulation (Haury & Rillero, 1995). While, others believe virtual learning is a more conducive
approach. Not only is there a convenience factor, but it also offers affordability, flexibility, and self-sufficient thinking (Piccoli, Ahmad, & Ives, 2001).

This study carried out analyses of data collected from students currently enrolled in two different introductory Technology, Engineering, and Design Education courses, TDE110 – Materials and Processes Technology and TDE131 – Technology through Engineering and Design 1. Of the two courses, a total of three sections were offered in the spring semester of 2013, TDE110-001, TDE110-002, and TDE131-001. The pretests and posttests were used to gather quantitative data from the complete population of all 44 students of the three classes. Of the students, 77% were male and 23% were female. The students ranged almost evenly between majors of Agriculture and Life Science (20.5%), Education (22.7%), Engineering (22.7%), and Natural Resources (25.0%).

One of the biggest challenges in technology education, today, is the battle between maintaining a hands-on atmosphere, changing to virtual learning, and finding a nice balance of the two different styles. The literature review noted several pros and cons related to both physical learning and virtual learning. As such, the purpose of this quantitative study was not to document more positive and negative but to expand upon this knowledge to look into which learning treatment is more effective and efficient within a Technology, Engineering, and Design Education classroom at the post-secondary level.
Research Questions and Summary of the Findings

The major research question set up for this study was: Is there a significant difference between virtual learning and physical learning in the classroom for Technology, Engineering, and Design Education students?

The following research hypotheses guided the study, sample selection, testing instrumentation, data collection, and the analysis of the data:

\[ H01: \text{There will be no significant difference in the knowledge gain scores between the virtual learning group and the physical learning group, at the } p=0.05 \text{ level.} \]

Both the virtual learning group and the physical learning group had a raise in scores between the pretest mean scores and the posttest mean scores, when looking within the contents of each group. However, even though each group jumped in mean scores individually, when looking at the gain scores between or across the groups, there was no significant difference in the gain scores. The virtual learning group had a mean difference of 12.7, while the physical learning group had a difference of 12.8. When analyzing the gain scores across groups the p-value=0.612, stating there is not a significant relationship. The findings support Research Hypothesis 01.

\[ H02: \text{There will be no significant difference between the post-test scores between the virtual learning group and the physical learning group, at the } p=0.05 \text{ level.} \]

The mean of the posttest scores in the virtual learning group (82.0) was lower than the mean in the physical learning group (88.1). The mean score in the physical
learning group was significantly higher than the mean score for the virtual learning group. With a p-value of 0.05, the findings do not support Research Hypothesis 02.

**H03:** *There will be a significant difference between the pretest and post-test scores for the virtual learning group, at the p=0.05 level.*

When calculating the mean pretest and posttest scores for the virtual learning group, the scores were significantly different. The posttest mean (82.0) was significantly higher than the pretest mean (69.3). With a p-value of <0.0001, the findings support Research Hypothesis 03. There was significant knowledge gain from the pretest to the posttest.

**H04:** *There will be a significant difference between the pretest and post-test scores for the physical learning group, at the p=0.05 level.*

The scores of the pretest mean and posttest mean were, also, significantly different when calculating for the physical learning group. The posttest mean (88.1) was significantly higher than the pretest mean (75.3). Again, with a p-value of <0.0001, the findings support Research Hypothesis 04. There was significant knowledge gain from the pretest to the posttest.
Conclusions and Discussion

The purpose of the study was to determine whether students comprehended more by completing a virtual learning task or a physical learning task in Technology, Engineering, and Design Education. It appears the physical learning group had an overall better performance on both the pretest and the posttests. The physical learning group scored higher on both assessments than the virtual learning group. Both groups, however, made significant gains between the pretest and posttest. This indicates a gain in knowledge from the beginning of the assignment to the end.

Although the physical learning group scored higher on both assessments, the mean difference or gain scores were almost equal for each group individually. The result was no significant difference between the gain scores. Both groups had mean increases of about 12.7 between the pretest and posttest. This demonstrates that both groups did learn and take away content knowledge from the activity. Both of the learning treatments were equally effective for the students participating in the study when looking at each group individually. By examining the learning methods together and focusing on the posttest scores, there is a significant difference in the scores causing a conclusion that physical learning is a more effective and efficient way of learning within the Technology, Engineering, and Design Education classroom at the post-secondary level. This can be backed-up by the literature review on the constructivist theory. The constructivist theory explores that learning by doing is the best method of educating a person (Fox-Turnbull, 2010). A student deepens their
understanding of a subject when interacting and experiencing throughout the content of the lesson (Jonassen, et al., 1995). Although constructivists can learn through interactions virtually as well, the physical learning group was able to apply their content knowledge and construct their bridges through experience with a learning by doing approach.

When examining the pretest scores, there was no significant difference between the groups (p=0.08). There was a significant difference between the groups when analyzing the posttest scores (p=0.05). Due to the extreme proximity of the two p-values for the pretest and the posttest, it could easily be inferred that the groups might not have been equivalent. A convenience sample was used in this study. Random assignment of participants was not possible since it would have required modifying students’ schedules. Random assignment would have allowed for randomization of students previous skill sets, majors, and content knowledge to be applied to the study.

An additional component of the study that needs a closer look is why the physical learning group scored higher on the pretest than the virtual learning group. Upon taking a more scrutinized look at the demographics of the classes, table 5.1 shows that group 2, the physical learning group, consisted of more natural resource majors and physical majors (located in the other category). When discussing with students in the classes, some of the students in the physical learning group majoring in natural resources were enrolled in a Bridge Dynamics course. The basis of the bridge course the students were enrolled in were the same as the structures activity the students
participated in for the study. Therefore, these students had more proceeding knowledge of the material than expected. Again, this could be avoided by using a larger simple random sampling rather than a complete population convenience sampling. A note, however, is even though these students had more preceding knowledge and caused the curve in the mean of the pretests and posttest to be higher, as stated before, the gain was still on the same level as the virtual learning group.

Table 5.1. Major Demographics: Number of Participants by Treatment Groups

<table>
<thead>
<tr>
<th></th>
<th>Virtual Learning Group</th>
<th>Physical Learning Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture &amp; Life Sciences</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Education</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Engineering</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Natural Resources</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21</strong></td>
<td><strong>23</strong></td>
</tr>
</tbody>
</table>

It is important to look closely at how each group completed their activities and understand the different criteria each had to undergo. Both groups completed the readings and quizzes under the same criteria, although in different conditions (computer versus on paper). However, when actually modeling a bridge, there was a major difference between virtual learning and physical learning. The virtual learning students were able to build multiple iterations or many different types of bridges in
order to see what worked best to try to make their bridge as efficient as possible. While, the physical learning group, since they built their bridges by hand out of balsa wood then tested, they were only able to build one iteration of a bridge within the same amount of time. An advantage of the virtual learning group was the fact that they were able to test multiple bridges, however, it could also be seen as a negative since it allows a 'guess-and-check' tactic. If a student is fully focused and trying to create the best bridge possible, multiple iterations can deepen their understanding for the subject. However, if they are using a guess-and-check tactic then they are not focused on the content and their knowledge base does not broaden as richly. The physical learning group, since they are only allowed one iteration, must do a more in depth planning process and be completely sure of their design before actually building it. It allows the students to be fully engaged in the activity and intensify their learning curve.

Figure 5.1 displays a learning curve for one of the virtual learning students. The student completed five different iterations. It is easy to see, even though there is a bit of variability, the student successfully gained knowledge by increasing their efficiency throughout the activity. The student began with a 18.37 efficiency rate, and by the end of the activity was able to increase their efficiency to 34.41.
Figure 5.1. Virtual Student Example: Engineering Results

Recommendations for Further Research

This study examined the effectiveness of both physical and virtual learning within a Technology, Engineering, and Design Education course on the post-secondary level. The conclusions reached by the researcher suggest several areas of further future research.

1. A larger sample with simple random sampling should be examined to confirm results revealed in this study.

2. A larger sample that includes more females should be examined to look into any gender differences that could possibly occur within the study.
3. The study needs to be replicated at other post-secondary institutions with similar populations to allow generalizations to be made about the data and analyses of the study.

4. A replicated study with the addition of a beginning survey. This survey would gather information consisting of the participants' backgrounds and previous knowledge of the material. Additionally, the survey would ask questions toward the participants' sense of comfort and capability within virtual learning and physical learning treatments.

5. Further study needs to examine virtual learning individually.

6. A study relating to the content learning curve regarding number of iterations made and number of successful iterations should be conducted. This study would look into the guess-and-check factor versus the fully exploring the content factors to allow an explanation of how students work and what is the best way to fully engage them in a virtual learning lesson. It would focus more on the planning and designing aspects of virtual learning, instead of the complete process. Participants would be examined by collecting data on each iteration made, the amount of time spent on it, and the planning process for it.

7. A study relating to a mixture of learning methods. Instead of looking at individually which learning treatment is best in the Technology, Engineering, and Design Education curriculum, examine what is the best combination of virtual learning and physical learning treatments. The study could consist of two
groups, one that would complete the background information (readings, assignments, and quizzes) virtually then switch to a physical modeling activity, and the other group would complete the background information in the traditional method (pen/pencil and paper) then would switch to a virtual modeling activity. The study would examine the different aspects of physical and virtual learning treatments in a mixed methods approach to see which resonates with students at a higher learning content level.
REFERENCES


APPENDIX A: INFORMED CONSENT FORM

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

What are some general things you should know about research studies?
You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?
The purpose of this study is to examine different learning environments for a structures activity in a Technology, Engineering, & Design Education class.

What will happen if you take part in the study?
The research will take place within normal class time. It will take two class durations, the first being for the pre-test, reading, and quiz assignments, and the second being for the construction of your bridge structure. These activities are all required course assignments, regardless of the study. If you choose to participate in the study, your pre/post quizzes will become part of the data used within the study.

Risks
There are no potential risks associated with the proposed procedures.

Benefits
The benefit of this study is to allow instructors to see what type of learning is most effective and efficient for students within Technology, Engineering, and Design Education introductory courses.

Confidentiality
The information in the study records will be kept confidential to the full extent allowed by law. Data, including both the pre and posttests, will be stored securely in a locked office at NCSU and/or on a password protected external hard drive. These records will also either be locked in an office at NCSU, or stored electronically through pictures on a secure server. No reference will be made in oral or written reports, which could link you to the study. Data in the reports will only be looked at in aggregate terms and confidentiality of the students will not be broken.

Compensation
There is no compensation for participating in this study.

What if you are a NCSU student?
Participation in this study is not a course requirement and your participation or lack thereof will not affect your course standing or grades at NC State.

What if you have questions about this study?
If you have questions at any time about the study or the procedures, you may contact the researcher, Marissa Sloan, at mmsloan@ncsu.edu, or 919-414-5248.

What if you have questions about your rights as a research participant?
If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (910/515-4514)
**Consent To Participate**

“I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.”

Subject's signature __________________________ Date ______________

Investigator's signature __________________________ Date ______________
APPENDIX B: STRUCTURES PROJECT DESIGN SHEET

STRUCTURES
Project Design Brief

For the next few class periods, you will be learning, exploring, and constructing a bridge structure.

Directions: (Make sure to follow each step without getting ahead of the class or skipping around)

1. Complete Structures Pre-test.
2. Read thoroughly through ALL of the structures information sheets. Complete the questions/quizzes as they arise in the readings. It is important to actually work through the mini-quizzes as they occur and not skip through them.
3. As a class, we will move onto the construction portion. Everyone will design a bridge, and then test them as a class against other students.

Schedule: (You must abide by these time-constraints, no extra time will be allowed. Use your time wisely.)

- Pre-Test: 30 Minutes
- Readings and Questions/quizzes: 1.5 hours
- Building and Testing: 2 hours
- Post-Test: 30 Minutes
APPENDIX C: PRETEST

Name: __________________________
Date: __________________________

STRUCTURAL PRE-TEST

Directions: Read through each question and circle the best answer choice.

1. An engineer is designing a manufacturing facility that will need to support 20,000 pounds of machinery. In order to ensure a safe design, the engineer designs for a safety factor of 1.5. How much weight is the engineer actually designing the building to hold?
   a. 13,333 pounds
   b. 20,000 pounds
   c. 30,000 pounds
   d. 35,000 pounds

2. Determine the external forces acting on the truss.
   a. \( F_1 = 75 \text{ N}; F_2 = 75 \text{ N} \)
   b. \( F_1 = 150 \text{ N}; F_2 = 0 \text{ N} \)
   c. \( F_1 = 0 \text{ N}; F_2 = 150 \text{ N} \)
   d. \( F_1 = 150 \text{ N}; F_2 = 150 \text{ N} \)

3. Written descriptions of the size, shape, and material of a manufactured part are known as:
   a. Dimensions
   b. Materials
   c. Specifications
   d. Tolerances

4. In the following diagram, what additional force is needed for the block to remain static?
   a. 6 N pointing down
   b. 6 N pointing up
   c. 12 N pointing down
   d. 12 N pointing up
5. The maximum weight a bridge can hold is known as:
   a. Capacity
   b. Efficiency
   c. Factor of Safety
   d. Stress

6. In the following diagram, what is the value of Force A for the block to remain static?
   a. 5 N
   b. 7 N
   c. 12 N
   d. 19 N

7. The forces that try and twist bridge members are known as:
   a. Compression
   b. Shear
   c. Tension
   d. Torsion

8. What is the stress on a piece of balsa wood if a 20 pound force is applied over an area that is 1/8" x 1/8"?
   a. 0.3125 psi
   b. 2.5 psi
   c. 160 psi
   d. 1280 psi

9. A truss that has too many joints and not enough web members is known as:
   a. Statically determinate
   b. Statically indeterminate
   c. Structural
   d. Unstable

10. The truss in the following diagram is:
    a. Statically determinate
    b. Statically indeterminate
    c. Structural
    d. Unstable
11. An engineer is designing a bridge that will need to support 50,000 pounds of traffic at any one time. In order to ensure a safe design, the engineer designs for a safety factor of 2.5. How much weight is the engineer actually designing the building to hold?

a. 20,000 pounds  
b. 50,000 pounds  
c. 100,000 pounds  
d. 125,000 pounds

12. Which type of shape is the most stable when used in construction?

a. Rectangle  
b. Square  
c. Trapezoid  
d. Triangle

13. The differences in the minimum and maximum dimensions that are allowed when manufacturing a part are known as:

a. Materials  
b. Measurements  
c. Specifications  
d. Tolerances

14. The truss in the following diagram is:

a. Statically determinate  
b. Statically indeterminate  
c. Structural  
d. Unstable

15. For a truss to be static, the sum of the external forces acting on the truss must be:

a. Equal to the internal forces  
b. Greater than zero  
c. Less than zero  
d. Zero

16. In the following diagram, what is the value of Force A for the block to remain static?

a. 5 N  
b. 10 N  
c. 15 N  
d. 25 N

A

10 N
17. A bridge member will fail when:
   a. The stress to yield ratio is greater than one
   b. The stress to yield ratio is less than one
   c. Both A & B
   d. None of the above

18. What is the stress on a piece of balsa wood if a 15 pound force is applied over an area that is 1/4” x 1/4”?
   a. 0.9375 psi
   b. 3.75 psi
   c. 60 psi
   d. 240 psi

19. In the following diagram, what additional force is needed for the block to remain static?
   a. 10 N pointing down
   b. 10 N pointing up
   c. 20 N pointing down
   d. 20 N pointing up

20. The forces that try and pull bridge members apart are known as:
   a. Compression
   b. Shear
   c. Tension
   d. Torsion

21. In the following diagram, what additional force is needed for the block to remain static?
   a. 20 N pointing down
   b. 20 N pointing left
   c. 20 N pointing right
   d. 20 N pointing up
22. Determine the external forces acting on the truss.
   a. F1 = 50 N; F2 = 50 N
   b. F1 = 50 N; F2 = 0 N
   c. F1 = 25 N; F2 = 25 N
   d. F1 = 0 N; F2 = 50 N

23. If a bridge member breaks at a load of 7,500 pounds, and a load of 5,000 is applied to the member, what is the member's stress to yield ratio?
   a. 0.67
   b. 1.00
   c. 1.33
   d. 1.50

24. What is the horizontal (x) component of the force acting on the block?
   a. 12.8 N
   b. 24.0 N
   c. 15.4 N
   d. 11.2

25. In the following diagram, what is the value of Force A for the block to remain static?
   a. 5 N
   b. 8 N
   c. 10 N
   d. 20 N

26. Determine the external forces acting on the truss.
   a. F1 = 100 N; F2 = 100 N
   b. F1 = 50 N; F2 = 50 N
   c. F1 = 150 N; F2 = 50 N
   d. F1 = 75 N; F2 = 75 N
27. A bridge member will fail when:
   a. The stress is greater than the yield strength
   b. The yield strength is greater than the stress
   c. Both A & B
   d. None of the above

28. In the following diagram, what is the value of Force A for the block to remain static?
   a. 3 N
   b. 4 N
   c. 7 N
   d. 10 N

29. If a bridge member breaks at a load of 10,000 pounds, and a load of 8,000 is applied to the member, what is the member's stress to yield ratio?
   a. 0.50
   b. 0.80
   c. 1.00
   d. 1.25

30. A truss that has the proper combination of joints and web members is known as:
   d. Statically determinate
   e. Statically indeterminate
   f. Structural
   g. Unstable

31. What is the horizontal (x) component of the force acting on the block?
   a. 26.1N
   b. 29.1N
   c. -26.1N
   d. 7.8N
APPENDIX D: POSTTEST

Name: _______________________
Date: _______________________

STRUCTURAL POST-TEST

Directions: Read through each question and circle the best answer choice.

1. The differences in the minimum and maximum dimensions that are allowed when manufacturing a part are known as:
   a. Materials
   b. Specifications
   c. Tolerances
   d. Measurements

2. The forces that try and break a members cross-ways are known as:
   a. Compression
   b. Shear
   c. Tension
   d. Torsion

3. Specifications of a manufactured part are written descriptions of:
   a. The size, shape, and material
   b. The size and shape
   c. The shape and material
   d. The material and size

4. In the following diagram, what additional force is needed for the block to remain static?
   a. 5 N pointing left
   b. 5 N pointing right
   c. 8 N pointing right
   d. 13 N pointing left

5. The weight a bridge can hold compared to the weight of a bridge is known as:
   a. Capacity
   b. Efficiency
   c. Stress
   d. Yield
6. In the following diagram, what is the value of Force A for the block to remain static?
   a. 5 N
   b. 10 N
   c. 14 N
   d. 24 N

7. What is the horizontal (x) component of the force acting on the block?
   a. 26.1N
   b. -26.1N
   c. 7.8N
   d. 29.1N

8. A truss that has too many web members and not enough joints is known as:
   a. Statically determinate
   b. Statically indeterminate
   c. Structural
   d. Unstable

9. The truss in the following diagram is:
   a. Statically determinate
   b. Statically indeterminate
   c. Structural
   d. Unstable

10. What is the stress on a piece of balsa wood if a 30 pound force is applied over an area that is 1/4” x 1/4”?
    a. 1.875 psi
    b. 7.5 psi
    c. 120 psi
    d. 480 psi

11. If a bridge member breaks at a load of 6,000 pounds, and a load of 9,000 is applied to the member, what is the member's stress to yield ratio?
    a. 0.67
    b. 1.00
    c. 1.33
    d. 1.50
12. The truss in the following diagram is:
   a. Statically determinate
   b. Unstable
   c. Statically indeterminate
   d. Structural

13. An engineer is designing a library that will need to support 10,000 pounds of machinery. In order to ensure a safe design, the engineer designs for a safety factor of 2.0. How much weight is the engineer actually designing the building to hold?
   a. 7,500 pounds
   b. 20,000 pounds
   c. 30,000 pounds
   d. 35,000 pounds

14. What is the most stable shape when used in construction?
   a. Rectangle
   b. Square
   c. Trapezoid
   d. Triangle

15. The sum of the external forces acting on the truss must be zero for the truss to be:
   a. Stable
   b. Static
   c. Structural
   d. Unstable

16. In the following diagram, what is the value of Force A for the block to remain static?
   a. 10 N
   b. 15 N
   c. 25 N
   d. 35 N

17. Determine the external forces acting on the truss.
   a. $F_1 = 100 \text{ N}; F_2 = 100 \text{ N}$
   b. $F_1 = 50 \text{ N}; F_2 = 50 \text{ N}$
   c. $F_1 = 150 \text{ N}; F_2 = 50 \text{ N}$
   d. $F_1 = 75 \text{ N}; F_2 = 75 \text{ N}$
18. A bridge member will not fail when:
   a. The stress to yield ratio is greater than one
   b. The stress to yield ratio is less than one
   c. Both A & B
   d. None of the above

19. In the following diagram, what additional force is needed for the block to remain static?

   3 N pointing down
   10 N pointing up

   a. 3 N pointing down
   b. 7 N pointing down
   c. 7 N pointing up
   d. 10 N pointing up

20. The forces that try and push bridge members together are known as:
   a. Compression
   b. Shear
   c. Tension
   d. Torsion

21. An unstable truss has:
   a. Only web members
   b. Too many joints and not enough web members
   c. Too many joints and too many web members
   d. Too many web members and not enough joints

22. In the following diagram, what additional force is needed for the block to remain static?

   15 N pointing down

   a. 15 N pointing down
   b. 15 N pointing up
   c. 25 N pointing down
   d. 25 N pointing up
23. Determine the external forces acting on the truss.

   a. \( F_1 = 50 \text{ N}; F_2 = 50 \text{ N} \)
   b. \( F_1 = 50 \text{ N}; F_2 = 100 \text{ N} \)
   c. \( F_1 = 100 \text{ N}; F_2 = 100 \text{ N} \)
   d. \( F_1 = 100 \text{ N}; F_2 = 50 \text{ N} \)

24. A bridge member will fail when:

   a. The stress is greater than the yield strength
   b. The yield strength is greater than the stress
   c. Both A & B
   d. None of the above

25. What is the stress on a piece of balsa wood if a 20 pound force is applied over an area that is 1/8" x 1/8"?

   a. 0.3125 psi
   b. 2.5 psi
   c. 1280 psi
   d. 1620 psi

26. If a bridge member breaks at a load of 7,500 pounds, and a load of 5,000 is applied to the member, what is the member's stress to yield ratio?

   a. 0.43
   b. 0.67
   c. 1.33
   d. 1.50

27. In the following diagram, what is the value of Force A for the block to remain static?

   a. 4 N
   b. 12 N
   c. 16 N
   d. 20 N
28. What is the horizontal (y) component of the force acting on the block?

a. 12.8 N  
b. 24.0 N  
c. 15.4 N  
d. 11.2

29. An engineer is designing a bridge that will need to support 50,000 pounds of traffic at any one time. In order to ensure a safe design, the engineer designs for a safety factor of 2.5. How much weight is the engineer actually designing the building to hold?

a. 25,000 pounds  
b. 50,000 pounds  
c. 125,000 pounds  
d. 150,000 pounds

30. Determine the external forces acting on the truss.

a. F1 = 100 N; F2 = 100 N  
b. F1 = 50 N; F2 = 50 N  
c. F1 = 25 N; F2 = 75 N  
d. F1 = 75 N; F2 = 25 N

31. In the following diagram, what is the value of Force A for the block to remain static?

a. 2 N  
b. 3 N  
c. 10 N  
d. 12 N  
   12 N  
   A  
   9 N