EFFECTS OF A SELECTED COMPUTER SIMULATION ON HIGH SCHOOL STUDENTS' ACADEMIC PERFORMANCE IN TECHNOLOGY EDUCATION

by

HONG FENG

(Under the Direction of Jay W. Rojewski)

ABSTRACT

Instructional technology has been an important element in recently initiated educational reforms. Computer simulations are very suitable for developing learners' problem-solving skills. In technology education, though computer simulation has been increasingly used, there is a dearth of studies conducted on its effects.

This quasi-experimental study examined the effects of a selected computer simulation on the academic performance of high school students in a technology education. The research question asked, "Does involvement in a selected computer simulation improve high school students' basic knowledge of truss bridge building in secondary technology education classes?" The basic knowledge of truss bridge building was measured by a pre- and post-test.

Situated cognition theory guided this study. The theory holds that learning is a combination of activity, context and culture, and the learning environment should be as authentic as possible.

Eighty students participated in the study and were recruited from 7 different courses offered by a Career-Technical Education (CTE) academy. There were 42 students in the treatment group and 38 students in the control group.

ANOVA test showed no statistically significant difference between learning through computer simulation and traditional method. Bootstrapping method was used to validate the result.

This finding implies that computer simulation may be an alternative to traditional teaching that produces comparable results. This research adds more knowledge to existing literature on integrating computer simulation into (technology) education. Recommendations are made.

INDEX WORDS: Technology Education, Computer Simulation, Situated Cognition, Quantitative Research, Quasi-experimental Research, ANOVA, Bootstrapping

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DEDICATION

This dissertation is dedicated to my husband Jianwu Wang for your love and constant encouragement; to my son for bringing me so much joy and happiness; to my father Diwang Feng, my mother Banghua Liu, and my brother Bo Feng for all of your heartwarming love and assistance.

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INTRODUCTION

Rationale

Many students, including secondary technology education students, learn best in real-life contexts solving real-world problems (Milrad, Spector, &Davidsen, 2000). The International Technology Education Association ([ITEA], 2000), asserted that “recent research on learning finds that many students learn best in experimental ways—by doing, rather than only by seeing or hearing—and the study of technology emphasizes and capitalizes on such active learning“ (p. 5). Cardon (2000) pointed out that activities encouraging problem-solving are a very important part of Technology Education (TE) curricula. However, “the legacy of behaviorist, teacher-centered, whole-class teaching, with teacher as expert and student as passive recipient of knowledge, seems, however, to remain the dominant orthodoxy in technology classrooms today” (Dakers, 2005, p.75).

According to Lunce (2004), instructional technology has been an important element in recently initiated educational reforms. Some researchers argue that computer simulations are very suitable for the solution of real-life problems as a form of discovery learning (De Jong & Van Joolingen, 1998). Computer simulation can provide authentic, yet controlled, experiences, learning by doing, and interactive learning environments (Chen & Levinson, 2006; May, 1997). Computer simulations also provide *interactive practice*, which allows students to respond to changing information in a simulated environment (Berge, 2002). When compared with physical experiments, computer simulation can provide environments where parameters can be changed, and more accurate results can be obtained (Marshall& Young, 2006). As a result, students are able to test hypotheses more deliberately and systematically in computer simulation environments. They can also reach more robust conclusions, which is especially the case for solving complex problems.

Computer simulations have been identified as possible alternatives to physical laboratories in terms of easy transportability and cost-effectiveness(Gorrell, 1992; Thomas & Hooper, 1991). Many studies show that computer simulation is more effective than lab experiments in facilitating students' conceptual change. (e.g., Khoo & Koh, 1998; Stratford, 1997; Veenman & Elshout, 1995; Zirkel & Zirkel, 1997). For instance, White (1993) found that six graders using computer simulation *ThinkingTools* scored higher on a test of conceptual physics knowledge than high school students in traditional physics classrooms. Computer simulations may be equally effective whether used at a distance or in person. According to Hensgens, van Rosmalen, and Hanu (1998) and Khoo and Koh, computer simulation is chosen when real lab experiments are too time-consuming or occur quickly, when they are dangerous or too expensive, or when visualization through computer can help better observe and understand certain phenomena. For instance, in science education, through a computer simulation, students are able to safely observe a phenomenon, such as a chemical reaction process, within a desired time period (Khoo & Koh).

Simulation software has been successfully used to stimulate students' interest, bring about conceptual change, and improve problem-solving and higher-order thinking (Strangman & Hall, 2003). Computer simulations can also give learners timely feedback throughout the learning process (Granland, Bergland, & Eriksson, 2000; Lunce). Because of flexibility, computer simulations help learners reach desired learning goals (Gibbons, Fairweather, Anderson, & Merrill, 1997; Lunce, 2004). Computer simulation has also become an important tool in science education as it allows students to explore hypothetical scenarios and test hypothesis (Forinash & Wisman, 2001; Lunce,).

Many studies have been conducted on the effects of emerging technologies on preK–12 learning during the past decades. Meta-analyses find that students who use computers perform slightly better in academic achievement than those who do not use computers (Lunce, 2004). A great majority of research on computer simulations has been conducted in areas of science and math education. These studies have focused on the effectiveness of computer simulations when compared to other instructional methods (e.g., Akpan& Andrew, 2000; Gaddis, 2001). The effects of computer simulation were measured mostly through comparing students' post-test scores between a treatment group and a control group in an experimental or quasi-experimental study. There have been inconsistent results among these studies. Some research indicate that computer simulation is better than traditional lab in improving students' academic performance as measured by post-test scores, while others do not find any difference.

In secondary technology education, though computer simulation has been increasingly integrated into instruction, little research has been conducted on its effectiveness. Even in engineering education, which shares similarities with technology education, there is a scarcity of studies investigating the effects of information technologies including computer simulation (Wiesner & Lan, 2004). Therefore, this research seeks to examine the effects of computer simulation by comparing the academic performance of computer simulation students to their counterparts in traditional technology laboratories. Students' academic background, relevant prior experiences and knowledge, and computer proficiency also affect their academic performance (Chen & Levinson, 2006).

Statement of Purpose

The purpose of this quasi-experimental study was to examine the effects of a computer simulation on the academic performance of high school students in technology education classes.

The independent variable was the instructional strategies (learning with [*WPBD*] or without computer simulation). The dependent variable was the academic performance (conceptual knowledge) of students after implementing the instructional strategies through post-test scores. Academic performance was represented by the basic knowledge involved in truss bridge building, which was measured by a pre- and post-test. The research question asked, "Does involvement in a selected computer simulation improve high school students' basic knowledge of truss bridge building in secondary technology education classes?" The basic knowledge of truss bridge building was measured by a pre- and post-test.

Theoretical Framework

Situated cognition theory guided this study. This theory holds that learning is a combination of activity, context and culture (Lave, 1988). In contrast with current educational practice, which holds that there is cross-situational cognitive continuity, situated cognition maintains that there are many skills and strategies, such as arithmetic, which are often not effectively learned through traditional instruction methods such as lecture (Lintern, 1995). Lave compares the task of learning math in public schools with learning math in simulated shops. She presented research participants with two questions, which contained the same arithmetic concepts in different forms. She found that participants performed very well (93% correct) in an applied math question, but when being asked to answer questions based on rote memory, the same participants performed much worse (59% correct).

Situated learning environments should be as authentic as possible with appropriate levels of support. However, contemporary high schools often prevent students from learning in real-world settings. For this study, the assumptions of Schell (2001) and Winn et al. (2005) will be used to view situated environments as either physical or virtual environments that simulate the real world. This assertion is a compromise that acknowledges the importance of authentic contexts but also recognizes the practical limitations of public schools (Herrington & Oliver, 2000; McLellan, 1996). Schell (2007) described the relationship between context and reality through a continuum. On one end of the continuum, students are confined to classrooms and learn through traditional instruction without opportunities to apply knowledge in real-world situations. At the other end of the continnum, students learn and explore in authentic contexts. The closer the learning context is to the right end of the continnum, the more authentic the learning context will be and the higher the likelihood for successful learning. Based on this perspective, computer simulation occupies a place in the middle of these two extremes Several scholars have pointed out that research in operational training, such as learning to fly airplanes, indicates that the higher the instructional fidelity, the better the learning transfer from the training environment to the real world

(Caird, 1996; Winn et al., 2005). Teachers' scaffolding is very important for achieving the optimal authentic learning environment.

Computer simulations differ from other instructional tools in that simulations need an underlying model. "Designers must learn about the real phenomenon (usually to a more sophisticated degree than they must learn content for a tutorial or drill), must create and refine a computer model to simulate it, and must then incorporate that model into an educational program" (Alessi & Trollip, 2001, p. 260). Some may argue that social and cultural factors play very little role in computer-based instruction, because the main interaction is between computer and individual learner (Wilson & Myers, 2000). However, Greeno (1997) argued,

> The situative view assumes that all instruction occurs in complex social environments. For example, a student studying along with a textbook or a computer tutor may not have other people in the same room at the time, but the student's activity is certainly shaped by the social arrangements that produced the textbook or the computer program, led to the student's being enrolled in the class where the text or program was assigned, and provided the setting in which the student's learning will make a difference in how the student participates in some social activity, such as a class discussion or a test. (pp. 9-10)

Constructivists often believe computer simulations are simulated real-life scenario displayed through the computer (Wilson, Jonassen, & Cole, 1993). In a computer-simulated environment, students play an authentic roll and learn complex skills through carrying out complicated tasks (Harper, Squires, & McDougall, 2000). A good computer simulation may teach abstract concepts better than direct experience. This is especially the case when the simulation shows phenomena that cannot be easily observed in the real world (Winn et al, 2005). From the theories discussed, it appears that a well-designed computer simulation should be more effective than traditional instruction, which can include both lectures and hands-on practice.

Significance of the Study

With the rapid development of science and technology, the world is ever progressing (Friedman, 2005). Meanwhile, skills required in the emerging workplace will require employees who are capable of quickly adapting to new demands. This capability improves work efficiency and enhances an organization's competitive power(Friedman). Career and technical education (CTE) is highly responsible for training qualified students to quickly adapt to emergent jobs in the workplace. An effective way to achieve the goal of developing workers capable of higher-order thinking and problem solving is to relate course content in everyday school classrooms to real-world practice (Brown, Collins, & Duguid, 1998). However, in today's accountability-based public education, learning in a real-world setting can be perceived to have limited practicality. As a response to these circumstances, computer simulations can provide an acceptable imitation of learning in real-world settings and contexts and they are increasingly implemented in education. As bandwidth gradually becomes less of a constraint for learners, educators can expand their utilization of instructional technologies such as computer simulations. Related research has demonstrated both the effectiveness and ineffectiveness of computer simulation. This study explores the effects of selected computer simulation on high-school students' academic performance in technology education. It will serve as a reference for teachers both in TE and other majors when utilizing computer simulation and other computer technologies in their classroom. It will also be very useful for school administrators when making decisions whether to purchase computer simulation software or lab equipment. In addition, it will contribute to research related to the use of computer simulations in classrooms.

CHAPTER 2

REVIEW OF LITERATURE

This section reviews literature in the areas of situated cognition theory. In addition, key literature related to learning transfer is also introduced. Finally, a review of the research conducted on conceptual change and computer simulation is presented.

Situated Cognition

Situated learning is a general theory that deals with the acquisition of knowledge. Situated learning is a theory on the nature of learning (Atlib, 2002) and has been widely researched in recent years. In some cases, situated cognition has been applied in technology-based learning activities in schools to develop students' problem-solving skills (Cognition & Technology Group at Vanderbilt, 1993). According to Kearsley (2005), situated learning theory can be traced back to the work of Gibson and Vygotsky. Gibson (1979) believed that instruction should include real-world situations to facilitate learning, learners should not be controlled by the learning environment, and teachers should try to stimulate students to bring about their conceptual change. Vygotsky's (1978) social-learning view holds that social interaction is required to have complete cognitive development. Vygotsky believed that "Every function in the child's cultural development develops twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological)" (p. 57). According to Lauzon (1999), situational cognition is one of many constructivist approaches. Constructivism's five major principles are: there is no pre-specified knowledge; learning occurs a in real-world settings; knowledge is socially constructed; dialogue and collaboration are tools for knowledge construction; learners evaluate their own learning (Vanden, 1998). This constructivist view has been confirmed by the research in some fields in education. For instance, in science education classrooms, research indicated that experience, language, and socialization are all vital factors that directly impacts how well an individual learns. In addition, "scientific knowledge is both symbolic in nature and also socially negotiated" (Scalise, Claesgens, Wilson, & Stacy, 2006, p. 172). "Socially negotiated" means that "scientific entities and ideas are unlikely to be discovered by individual students through their own empirical enquiry, so learning science needs to join the scientific community to grasp scientific ideas and practices" (p. 173).

Proponents of situated cognition believe that in standard education, programs and instructions are not contextualized. Learning activities deliver knowledge that is abstract, decontextualized, and not connected with the real world (Fullera, 2005; Lave, 1988). Learners are thought of as receptors of knowledge. The traditional learning model cannot explain how people learn new knowledge and skills without formal education or training (Fullera, 2005). According to Lave , learning is a combination of activity, context, and culture. Situated instruction is effective because new learning is based upon existing knowledge and mental models. The activities through which knowledge is gained are connected to learning and cognition. Situated cognition theory also holds that activities and perceptions precede conceptualization (Brown et al., 1989). Situated learning also acknowledges the importance of social interaction.

Lave and Wenger (1991) claimed that situated cognition is applicable to schooling and all other areas of social practice. They described situated learning in five situations: Yucatec midwives, tailors, navy quartermasters, meat cutters and alcoholics. In each of these five circumstances, beginners gradually acquire knowledge from experts through everyday activities. Stein (2006) summarized situated cognition's four premises: (a) learning is grounded in the actions of everyday situations; (b) knowledge is acquired situationally and transfers only to similar situations; (c) learning is the result of a social process, encompassing ways of thinking, perceiving, problem solving, and interacting in addition to declarative and procedural knowledge; and (d) learning is not separated from the world of action but exists in robust and complex social environments made up of actors, actions, and situations. (¶ 3)

Based on a review of literature, Herrington and Oliver (2000) summarized nine design elements for instructional design based on the situated learning theory. These include authentic context, authentic activities, collaborative construction of knowledge, reflection, articulation, coaching and scaffolding and authentic assessment.

Ormrod (2004) defined authentic activities as "tasks that are identical or similar to those that students will eventually encounter in the outside world" (p. 396). By participating in the authentic activities in the classroom, the learners find the relationship among concepts under context and transfer learning to similar situations and settings. Lebow and Wager (1994) list characteristics of real-life problem-solving tasks that are important for designing learning environments. Some of the characteristics are: conditions are frequently ill-structured and problems are ill-formulated; there are clear goals for learning activities; projects frequently have depth, complexity, and duration;

people work on solving problems not having known solutions. Simulations are “open-ended evolving situations with many interacting variables” (Gredler, 2004, p. 571). They can provide an authentic learning environment containing ill-defined problems with many variables (Winn et al., 2005).

In contrast to current educational practices maintaining that there is cross-situational cognitive continuity, situated cognition holds that there are many skills and strategies, such as arithmetic, which cannot be effectively learned at school (Lintern, 1995). One important idea of situated cognition is that learning will be ineffective if learning does not occur in the context in which the skills are used. However, some scholars, like Lintern, believe that this idea is inconsistent with many practices in education and cognition. They believe that skills do not have to be learned in the context in which they are applied. Though Herrington and Oliver (2000) believe that situated learning environments should be authentic, the authentic environment can be either a physical or a virtual environment that is similar to the real world with real-world complexity and limitations. In addition, it should carry the choices and possibilities existing in real situations. Similarly, Brown et al. (1989) argues that learners can acquire skills through instruction in environments similar to real situations. McLellan (1996) also stated that the context for learning can be the actual working environment or a highly realistic or “virtual” substitute for the real-work setting. In educational technology, situated cognition theory has been used as a framework for using technology to facilitate teaching and learning (Hansman & Wilson, 2002). According to McLellan, technology plays an important role in situated learning. Computers and virtual reality devices can be used to facilitate learning using situated cognition as a framework.

Another important idea of situated cognition is that people self-organize their behavior to adjust to their surroundings (Lave, 1988). Street vendors, weight watchers, and grocery shoppers all organize their actions to adapt to their environment. External support such as workplace and teacher instruction should also be flexible to facilitate learning. Otherwise, it will result in inert knowledge and skills (Lintern, 1995).

Some scholars believe there are different degrees of situated learning (Lunce, 2006). Schell (2001) described the relationship between context and reality through a continuum. At the left end of the continuum, students are confined to classroom learning without opportunities to understand how knowledge can be applied in real world. At the right end of the continuum, students can learn in authentic context and explore. The closer the learning context is to the right end of the continuum, the more authentic the learning context will be, resulting in better learning outcomes.

Computer simulation replicating real world phenomena or objects occupy the middle section in the continuum. As a result, a well designed computer simulation should be more effective than traditional instruction which may include both lectures and hands-on practice/activities. Since the learning environments created by computer simulation are in the middle of the continuum, they are only partially situated and authentic. Under this partially situated environment, teachers' scaffolding is very important to ensure students' best learning outcome. According to Schell (2007),

> Skillful teachers often provide the learner with a scaffold or bridge to other related information by performing some of the more difficult tasks for the student. At a later time, students will be able to perform this part of the hard

> tasks for themselves as the teacher fades from the direct instructional role (p. 267).

This indicates teachers should support students to make sure they can handle learning through computer simulation. For instance, in this study, the computer simulation group teacher could give a general introduction to the project and demonstrate how to run the software.

Winn et al. (2005) shares some similar thoughts with Schell. Winn points out that the closer the simulated experience is to the real-world experience, the better the students will learn. They point out that the idea that students learn some things better through direct experience has existed for a long time. For example, Dewey (1990) argued that a map is an abstraction of a journey. Successful education in geography requires that students have direct experience of the journey and experience of the map. Hung and Chen (2001) put situated learning on a continuum of instructional contexts ranging from authenticity to generalizability.They define the authenticity as the number of controllable variables. Generalizability refers to a de-contextualized approach in traditional instruction. They argue that computer simulations are in the middle range of this continuum and provide real-world problem-based learning. However, to create a situated learning context, there should be enough scaffolding and variables that can be manipulated in computer simulation. For instance, in computer simulation *Sim City*, learners can choose different types of buildings and facilities, and frequencies of natural disasters, etc. Students can begin with manipulating two variables (e.g., building houses and roads) and observe the outcome. After they have understood how the two variables interact with each other and the outcome, more variables (e.g., utility companies and supermarkets) are added into the simulation. In this way, students gradually move towards the authenticity end of the continuum. Hung and Chen believe both authenticity and genaralizability are necessary for students' learning. Computer simulation can help students move from generalizability to authenticity or from authenticity to generalizability. Computer simulations with *staging* capabilities (controlling of variables) can support students to move from generalizability to authenticity. Computer simulations with experimentation capabilities can assist students to move from authenticity to generalizability.

Some scholars hold different views concerning the issue of authenticity of learning environment. For example, some claim that the more students feel present in a computer-created environment (believing that they are in the simulated world, not the real one), the more they learn (Winn, Windschitl, Fruland, & Lee, 2002; Witmer & Singer, 1998; Zeltzer, 1991). Simulations that try to re-create real-world experiences often do not directly help students discover general principles. Caird (1996) found that too much emphasis on fidelity to reality in computer simulations can have adverse effects on students' learning. Alessi (1988) pointed out that this is especially true for beginning students. Many scientific models created through computer simulation offer limited number of variables and simplified systems so that learners can more easily observe behavior patterns and causal relationships. Therefore, despite the importance of authentic direct experience in learning, it is also very important to arrange learning activities that provide less-than-realistic experiences. Several scholars argue that in well-designed computer simulations, the absence of some real-world experience can help learners learn better (e.g., De Jong & Van Joolingen, 1998; Winn et al., 2005). They may even prepare learners to perform better in real practice (Zacharia & Anderson, 2003). A good computer simulation can teach abstract concepts better than direct experience. This is especially the case when the simulation shows phenomena that cannot be easily observed in the real world (Winn et al.).

Despite its increasing popularity, situated cognition theory is not universally accepted. Wineburg (1989) suggested that situated cognition theory is not a brand-new theory. Both John Dewey and Jerome Bruner once proposed the idea that learning is situated in practice. Wineburg believed that teaching abstract knowledge is as effective as the situated learning method and much more easily applied in the classroom. Some researchers even feel that situated cognition theory is not suitable for computer-based education because "courseware becomes the learning environment and not the authentic situation" (Hummel, 1993, p. 15). Similarly, Tripp (1993) pointed out that environments created by computer simulations differ from real situations and that "true expertise is learned by being exposed to experts" (p. 75).Despite these negative views, scholars increasingly agree "computer-based representations and 'microworlds' do provide a powerful and acceptable vehicle for the critical characteristics of the traditional apprenticeship to be located in the classroom environment" (Herrington & Oliver, 2000, p. 24).

To overcome the difficulties of getting students engaged in authentic practice in technology education, Dakers (2005) introduced two models. The first model is adapted from Lave's (1988) theory of situated learning and Senge's (1994) idea of "'practice fields' where learning is situated in real or authentic practices that have been constituted in the world outside the school setting" (p. 83). Senge suggests setting up practice fields to make up for the deficiencies in school learning. Dakers explained practice fields are "authentic situations that have occurred and have been solved, and are now used as true representations of authentic practice rather than some decontextualised activity 'invented' by the teacher or the learner" (p. 83). Dakers' second model was based on the work of Barab and Duffy (2000). The model contains five parts:

1. Undertaking domain-related practices: "The scenarios in TE should be based upon some authentic practice that has occurred and can be replicated within the resources available in the technology classroom setting" (p. 83).
2. Ownership of the enquiry: "The pupils must have a sense of ownership of the scenario and must be given scope to develop their own solutions" (p. 84).
3. Coaching and modeling of thinking skills: "The teacher's role in this model is to question and challenge the learners and to encourage the learners to do likewise" (p. 84).
4. Ill-structured dilemmas: "The dilemmas in which learners are engaged must either be ill-defined or defined loosely enough so that students can impose their own problem frames'' (p. 32).
5. Support the dilemma rather than simplify the dilemma: "The problem presented must be a real problem. Students should not start with simplified, unrealistic problems because this would not be reflective of a practice field but rather would reflect the more traditional building blocks approach to instruction characteristic of the representational perspective''(p. 33).

Learning Transfer

An important topic related to situated learning theory is learning transfer. Detterman (1993) believed that “transfer is the degree to which a behavior will be repeated in a new situation” (p. 4). Greeno, Smith, and Moore (1993) explain that transfer means whether knowledge acquired in one context can be applied in another circumstance. To Ceci and Ruiz (1993), the idea of transfer has been in existence ever since Aristotle’s DeAnima appeared. Nonetheless, transfer is a controversial issue—some believe there is transfer, others think not. But formal scientific debate over this issue only began in the beginning of twentieth century. Learning transfer research started from Thorndike, who believed that the more two situations are alike, the more learning can be extended from one situation to the other (Lave, 1988). According to Lintern (1995), "skill learned in one context (e.g., school) can be readily applied in different but relevant contexts" (p. 337). But some think skills acquired in one context will be realized gradually and only applied to a new context when learners feel it is possible. According to Brown et al.(1989) and Lave, psychological views of learning hold that knowledge can be transferred anywhere as soon as it is acquired through a learner's thought and action. They believe this view neglects the context in which knowledge and skills are acquired.

Learning transfer is one of the most important goals and a very challenging issue in education. Quite often, it occurs without learners’ notice. This type of transfer occurs at a subconscious level when the original situation and the new situation are quite similar. For instance, if children have mastered how to tie brown cotton shoelaces, they will often know how to tie the white nylon shoelaces of another pair of shoes. But in many situations, transfer does not occur so easily. For example, even though students learn various skills at schools, this does not guarantee a successful transfer of those skills to the workplace (Moursund, 2006).

According to Detterman (1993), when people talk about transfer, they are mostly interested in far/general transfer of deep structures instead of near transfer of surface structures. Near transfer happens when two situations are similar; far transfer occurs when two situations are different. In either situation, transfer is very difficult to achieve. Quite often, transfer happens between two highly similar situations. Detterman believes there is no convincing evidence to prove that transfer occurs or that there is a way to teach how to realize transfer. He believes there is no secret to becoming an expert. What is needed is time, ability, and many opprtunities to learn though experience.

Perkins and Salomon (1992) introduced the terms low road and high road. Low road transfer occurs when stimulus conditions in the transfer context closely resembling those in the beginning context trigger semi-automatic responses. Low road transfer is similar to near transfer. High road transfer, however, differs from far transfer in that it needs deep abstraction. Although high road transfer requires time and effort, it can help far transfer occur. Perkins and Salomon believed this framework matches well with those of many other theorists. Transfer can be driven by stimulus, often occurring automatically (the low road), but sometimes transfer needs deep abstraction and it challenges learners to detect possible connections (the high road). Perkins and Salomon believed many learning situations only give learners limited examples and insufficient practice to develop important automaticity. This makes low road transfer hard. Mindful (high road) transfer requires active abstraction and exploration of possible connections. Many learning situations do not offer opportunities for developing this. Moursund (2006), who critiqued the near and far transfer theory as unuseful for teaching, feels the low road/high road transfer theory is more practical than near/far transfer theory. This is because the near/far transfer theory "does not provide a foundation or a plan for helping a person to get better at far transfer and dealing with novel and complex problems." (¶5)

Greeno, Smith and Moore (1993) think theories related to transfer can be generally classified into four types: empiricist, rationalist, sociohistorical, and ecological. Both empiricist and rationalist theorists think that learning transfer relies on what cognitive structures learners already have at the beginning of learning and are able to apply in the transfer situation. The empiricist theorists are interested in overlapping elements/components between the two situations. But the rationalist theorists focus on overlapping cognitive structures passing from the first situation to the transfer situation. The sociohistorical theorists including Lave emphasize cognitive structures created through social activities.

> Transfer, in this view, depends primarily on a person's having learned to participate in an activity in a socially constructed domain of situations that include the situation where transfer can occur. Transfer depends on structure in the situation that is primarily socially defined, and that has been included in the person's previous social experience. (Greeno et al., 1993, p. 161)

Ecological theorists are interested in cognitive structures in physical contexts. They think action is an interaction with the world and is direct perception, not through mental structure. In favor of the ecological theorist view, Greeno, Smith, and Moore argue that cognition should be interpreted both physically and socially.

According to Lave (1988), learning transfer is the central tool necessary for bringing knowledge learned in school to life after graduating from school. One good thing about situated instruction is that it forces the instructor to relate teaching material to practice. However, to best achieve learning transfer, school curriculums must be adjusted. Just as Lintern (1995) claimed, "Transfer of learning will be minimal when school curriculums focus on the development of knowledge and skills that are irrelevant to or even incompatible with practice" (p. 337).

As acknowledged by Schell and Black (1997), although it is a major issue in situated cognition, learning transfer is very controversial in the educational field. They refer to both sociological and psychological views on this. Sociologically speaking, “generalizability of acquired information to other situations is relatively rare and unpredictable.” (¶ 11)From a psychological point of view, “there is no general cognitive skill that promotes learning transfer.” (¶ 11) However, Schell and Black do not argue that transfer does not exist. As a matter of fact, they argue “teaching should promote learning in a context that is as close as possible to the one where the acquired information will be applied so that there is a better chance of it being activated when needed.”

Ormrod (2004) believed that when new settings differ much from the original environment in which learning occurs, learning transfer will probably be reduced. Therefore, learners must learn how to use and transfer the knowledge they have learned to new environments (Mayer & Wittrock, 1996). Because computer simulations are simplified versions of authentic scenarios, it helps learners focus on important variables and content, resulting in effective learning (Winn et al., 2005).

Computer Simulation

Computer simulations are "techniques which aim to provide the student with a highly simplified reproduction of part of a real or imaginary world." They are considered "one of the most effective ways to promote deep conceptual understanding of the real world" (O'Haver, 2000, ¶3). "Computer simulations are computer-generated versions of real-world objects (for example, a skyscraper or chemical molecules) or processes (for example, population growth or biological decay)" (Strangman& Hall, 2003, p.2).

According to Lunce (2006), educational simulations are generally classified into four types: (a) physical, (b) iterative, (c) procedural, (d) situational. The following is a brief discussion of Lunce's theory.

In a *physical simulation,* a learner manipulates variables in an open-ended environment and observes the results. For instance, in a global weather patterns simulation, the student can manipulate certain parameters and observe the result.

In *iterative simulations,* thestudent conducts scientific research, tests hypotheses, and observes the outcomes in a discovery learning environment. This type of simulation teaches phenomena which cannot be easily observed in real situations, such as phenomena from biology, geology, or economics.

In *procedural simulations,* the student interacts with simulated objects to learn skills required for real world practice. For example, the student manipulates simulated laboratory equipment to prepare for working in a real-world laboratory setting.

In *situational simulations,* human behavior is simulated with focus on people's attitudes Role-playing is often used in these simulations. Situational simulations are usually run several times with each participant playing a different role each time (Wilson & Cole, 1996). Situational simulation is the most difficult type of simulation.

Computer simulation, representing a new trend in computer technology, has been applied in many fields including military, medical schools, and educational institutions. Some studies have been conducted to compare the effectiveness of computer simulation with that of other forms of instructional approaches. The effectiveness of using computer simulation has been compared with that of traditional labs (e.g.,Bourque & Carlson, 1987; Choi & Gennaro, 1987; Gaddis, 2001; Kelly, 1997-1998; Khoo & Koh, 1998; Michael, 2001;Parher, 1995; Stratford, 1997; Veenman & Elshout, 1995; Woodward, Carnine, & Gersden, 1988; Zirkel & Zirkel, 1997), computer simulation in addition to hands-on practice (Akpan& Andrew, 2000). In addition, instructional sequences (Alkazemi, 2003) such as using computer simulation both before and after traditional labs have also been compared. With the rapid development of computer technology, some virtual labs have also been set up. At the same time, some studies have also been conducted to compare the effectiveness of virtual labs with physical labs (Sicker, Lookabaugh, Santos, & Barnes, 2005). The research results show that computer simulations sometimes can replace real labs. For example, the software developed by the Multiverse Project (Institute for Computer Based Learning, 1999) provides detailed explanations of lab assignments and the anticipated results of experiments. Research findings suggest that the software has met laboratory requirements to some degree. Another study, conducted by Kruper and Nelson (1991), on computer simulation Biota simulates a biology laboratory experiment (Jungck, Soderberg, Calley, Peterson, & Stewart, 1993). Biota simulates processes influencing sizes of plant and animal populations. They compared students in the traditional wet lab with the simulated lab on the development of science reasoning skills and differences in the learning environments. They found that students the Biota lab group could perform experiments several times while the wet lab group could only perform one experiment.The treatment and control groups did not differ significantly in terms of science reasoning skills.

Computer simulation allows students to observe and interact with a real-world. Computer-simulated experiment may be a good substitute for a laboratory experience in the teaching of some concepts (Winn et al., 2005). According to Mintz (1993), one of the most promising computer applications in science instruction is the use of simulations for teaching material, which cannot be taught by traditional labs. For example Choi and Gennaro (1987) compared the effectiveness of computer simulation with hands-on practice for teaching junior high school students the concept of volume displacement. They found that there were no significant differences between the two instructional methods.

Computer simulations can be used in distance education (Lara &Alfonseca, 2001). Many educators encounter the challenge to deliver the hands-on lab portion in distance-learning courses. Computer simulations may be an alternative for hands-on practice in distance learning. In addition to providing distance access, they offer pedagogic benefits for science laboratories. According to Hofstein and Lunetta (2003), “interacting with instructional simulations can help students understand a real system, process, or phenomenon” (p. 42). Computer simulations are good tools for individual learning. Distance labs not only let instructors and students have synchronizing access to lab content, but also provide constant access whenever needed by students (Forinash&Wisman, 2001).

Computer simulations have many advantages over other instructional approaches and media. A term closely related to computer simulation is fidelity. Fidelity refers to the accuracy with which the simulation models a real-world system or phenomena (Alessi & Trollip, 2001). A well-designed computer simulation can have a high degree of fidelity and facilitate learning by simplifying or omitting elements present in a real-world setting. Simulation may be superior to other learning media (such as textbooks, lectures, and tutorial courseware). This is because simulation simulates real-world experiences and may increase students' intrinsic motivation by engaging them in solving challenging problems (Akpan, 2000; Alessi&Trollip; Winn et al., 2005). In comparison to other instructional approaches, computer simulation offers learners opportunities to learn in a relatively authentic context, to perform task without stress, to systematically explore both realistic and hypothetical situations, to change the time scale of events, and to interact with simplified versions of the process or system being simulated (Alessi & Trollip; de Jong, 1991). Computer simulation provides students with opportunities to observe certain processes that happen too quickly or too slowly in real life (Akpan, 2002).Computer simulations can lead to learning transfer, which means that learned knowledge is successfully applied in real-world environments (Khoo & Koh, 1998). In addition, computer simulations are probably more efficient instructional tools for learning in some content areas. Due to ethical, safety, or cost-effective reasons, sometimes an on-the-job training may not be practical. Simulations provide students with environments that could be dangerous, expensive, or even impossible to observe in the real world situations.

(Alessi & Trollip, 1985) For example, computer simulations allow students to stretch or compress time and space (Wilson & Cole, 1996). In addition, computer simulations can accommodate different types of instructional approaches, such as scientific discovery learning, virtual reality, laboratory simulations, role-playing, and simulation gaming. (Alessi & Trollip)

Computer simulations also have disadvantages in comparison with other instructional methods. Computer simulation may be more time-consuming than other instructional strategies since many computer simulations concentrate on problem solving. Without proper coaching, scaffolding, feedback, and debriefing, the student learns little from the discovery learning through simulations (Lunce, 2006). Some argue that educational simulations oversimplify the complexities of real-life situations, giving the learner an inaccurate understanding of a real-life problem (Heinich, Molenda, Russell,&Smaldino, 1999). In addition, development of educational simulations may need a big investment of time, effort, and money (Lunce).

Most early research on computer simulations was on the effectiveness of computer simulations on students' learning (Akpan, 2002). Despite this, "the literature on computer-based instructional simulations is filled with contradictions concerning their use and effectiveness" (Thomas & Hooper, 1991, p.1). The literature has also revealed that computer simulation can help alleviate misconception, enhance learning transfer, improve such skills as problem-solving and high-order thinking skills, and develop content knowledge (Strangman & Hall, 2003).

1.<u>Alleviate misconception and enhance learning transfer</u>**.** Computer simulations "provide a potential means of providing students with experiences that facilitate conceptual development" (Akpan, 2002, p. 1). Research has indicated that computer simulations can focus on learners' misunderstanding and knowledge deficiency and enhance the transfer of learning. During their learning processes, it is unavoidable for students to often have misconceptions. Computer simulations have been found useful in helping to correct the misconceptions. This effect is especially evident in science learningwhen computer simulation is used in instruction. According to Akpan, in science education classrooms, computer simulations are often used as a scaffold to allow students to gain initial understanding of a concept and to stimulate problem solving. Strangman and Hall (2003) examined seven research studies from 1986 to 1994 on conceptual change through using computer simulation. They found that six out of seven studies were in the science domain. The other was in the mathematics area.

2. Enhance a variety of skills including problem-solving skills and high-order thinking skills. According to Magnusson and Palincsar (1995), simulations are effective tools not only for teaching content but also for improving thinking or reasoning skills. Strangman and Hall (2003) also conducted a review of researches related to the roles of computer simulations in developing learners' skills. Among 12 studies, 11 reported that using computer simulation could improve such skills as reading, math problem solving, algebra, scientific process, and several other skills. For instance, Jiang and Potter (1994) conducted an experiment through using *Chance*, (software simulating dice and spinner probabilities). They found that the group using the *Chance* simulation software made improvements in mathematics problem-solvingskills. Huppert, Lomask, and Lazarowitz (2002) discovered the effectiveness of simulation software, "The Growth Curve of Microorganisms" on improving students' problem-solving and higher-order thinking

skills, in addition to their academic improvements. In general, it appears that computer simulation's power to improve all types of skills is significant. This is especially the case in science and mathematics.

3. Enhance student's learning of content-area knowledge**.** The literature has shown that computer simulation has been used effectively to teach content knowledge such as frog dissection and chemical molecules. Strangman and Hall (2003) conducted a survey on 12 studies, eleven of which examined the influence of using computer simulation on content knowledge. The results indicated that students who worked with computer simulations performed much better in standard tests of content knowledge. Barnea and Dori (1996) examined computerized molecular modeling (CMM) software used in teaching chemistry in Israeli high schools. There were three groups in their study, with one group learning through CMM and two groups learning through traditional methods. They studied the effect of CMM on students' spatial ability, understanding of new concepts, and perception of modeling concept. They discovered that students in the experimental group performed better than those in the control groups in all three areas.

As illustrated, computer simulation has demonstrated its abilities to make conceptual change, promote various kinds of skills, and strengthen content-area knowledge.

Despite the benefits of technologies such as computer simulation, there is debate as to whether or not such technologies are really effective. Some research also indicates that there is no significant difference between computer simulation and other instructional strategies with regard to their effectiveness on students' learning. For instance, Michael (2001) examined the effect of computer simulation on product creativity in comparison with hands-on activities in TE. He found that there were no significant differences between the experimental group that used computer simulation and the control group that used hands-on activities.

The controversial characteristic of the effectiveness is not only unique to computer simulation. Alanis (2004) stated that ever since technology was applied in higher education, its effectiveness has been a hot topic. There are basically three views with regard to technology's effectiveness in higher education: (a) technology improves education; (b) technology lowers educational quality; and (c) technology-based education does not differ significantly from traditional education. Alanis also noted that for "every study that found a measurable benefit, there tends to be a counter study that found no benefit or even a negative impact" (p.13).

Almost all the research mentioned previously simply focuses on the results after using computer simulation. Hardly any considers the design of learning environments when implementing computer simulation. Joy suggested that, "instead of comparing the effectiveness of varying technologies and instructional media, efforts should be better spent in determining the optimal combinations of instructional strategies and delivery media that would best produce the best learning outcomes for a particular audience" (Greenberg, 2004). Similarly, Liu (2005) concluded that it is the design of the learning activities not the use of technology that had an impact on student learning.Some related research has been conducted investigating the outcomes of collaborative learning in using computer simulation (Blaye, Light, Joiner, & Sheldon, 1991; Howe, Tolmie, & Rodgers, 1992; Light, Foot, Colbourn, & Mcclelland, 1987; Tao, 1999). These studies indicate that work in pairs at the computer is very effective in fostering conceptual change. Goodyear, Njoo, Hijne, and van Berkum(1991) theorized that though computer simulation offers learners much freedom, learners often cannot handle the freedom. Consequently, supported learning through computer simulation is very effective. One form of instructional support is off-screen written material, such as a workbook of exercises; another form of instructional support is an individual coach who monitors and assists learners (van Berkum& de Jong, 1991).

Although computer simulation has been popularly used in TE classrooms, little research has been done on the effectiveness of computer simulation in TE. Even in engineering education, which shares some commonalities with TE, there are not many studies on the impact of simulations upon student learning either (Wiesner & Lan, 2004). A common computer simulation used in high school TE classrooms is West Point Bridge Designer, which will be used by the participants in this research and discussed later.

West Point Bridge Designer

WPBD is a computer-aided design (CAD) software. It is a stand-alone Windows application. The software was originally created by Stephen Ressler, a professor and deputy head in the Department of Civil & Mechanical Engineering at the United States Military Academy. *WPBD* was first created for a competition of high-school students interested in civil engineering and was later available at no cost. “The West Point Bridge Designer software package was developed to provide students with a realistic, hands-on introduction to engineering through the design of a steel truss bridge” (Ressler & Ressler, 2004, p. 5). It is designed to help students learn engineering concepts and to arouse their interest in engineering (Ressler, 2002). *WPBD* has been updated each year and is now used in thousands of schools in America. The following is a detailed description of *WPBD* by Ressler, Ressler, and Schweitzer (2001):

> In *WPBD* there is a very detailed Help section that integrates two parts—informing the student on how to use the software, and teaching him/her about the engineering design process.
>
> At startup, the student is presented with a choice of seven different design projects, all of which involve the design of a truss bridge to carry a two-lane highway across a river. Each project represents a set of pre-defined site constraints—span length, support conditions, maximum height, and minimum clearance over the river.
>
> Once the student has selected a project, he/she can immediately begin creating his/her design. He/She creates a *structural model* by drawing *joints* and *members* on the screen with the mouse. Templates and sample designs are available to help the new user create a stable structure. The site constraints—span, supports, and height restrictions—are built into the user interfaces for each design project. Thus it is virtually impossible to violate the design specifications. Even users with limited computer skills have little difficulty achieving successful first design iteration.
>
> Once this first attempt at a structural model is complete, the student clicks a button to initiate a simulated *load test*. During the load test, the student's bridge is subjected to the weight of the truss, the concrete bridge deck, the asphalt road surface, and a standard, code-specified truck loading (amplified by the appropriate load factors).*WPBD* automatically calculates the maximum internal force, tensile

strength, and compressive strength for every member in the structural model. Each member is then checked for structural adequacy.

As soon as these computations are complete (normally in just a few seconds), *WPBD* displays a full-color, three-dimensional animation of the load test. The student's bridge is shown deflecting, first under its own weight, then under the weight of the truck as it drives across the span. The actual computed displacements are shown, but they are exaggerated by a factor of ten. This feature helps the student see how member *deformations* result in global *displacement* of the structure. As loads are applied, the members of the truss change color—blue for tension and red for compression—and the intensity of color is directly proportional to the magnitude of each member's force-to-strength ratio. Thus the user can see vividly (1) how the truss carries load and (2) how heavily each member is loaded, just by carefully observing the variation of colors in the animation. If all members in the truss are strong enough, the truck successfully crosses the span. But if any member is inadequate, it fails at the appropriate point in the animation, and the structure collapses into the river.

Once the simulation is complete, the student returns to the "drawing board" to continue his/her design. If any members have failed the load test, their properties can be changed to increase their strength. The designer can choose from three materials (three different grades of structural steel), two cross-section types (solid bars and hollow tubes) and 35 different member sizes. After changing member properties, he/she can run the load test again to determine whether or not the changes are adequate.

Once the design passes the load test, it is *successful* but not *optimal*. To optimize his/her design, the student must *minimize the total cost*. *WPBD* automatically calculates the cost of the truss and displays it in real time. The cost algorithm is a reasonably realistic one that accounts for the contributions of material, fabrication, and construction cost.

In seeking an optimal design, the student has complete freedom to modify the shape and configuration of the truss. He/she can also run the load test at any time, to ensure that the strength is still adequate for each new design iteration. The variation of color in the load test animation provides a powerful visual tool for guiding the structural optimization process. When the color of a loaded member is intense red or blue, but the member does not fail, it is optimized (or very nearly so).

The student can work through the design process entirely in a trial-and-error mode. After gaining experience, he/she can get better results by clicking a button and viewing various numerical data—load test results, mechanical properties of members, and detailed cost calculations.

Once the student has completed the design, he/she can access a “Best Scores” web site to see how his/her performance compares with WPBD users from all over the world. If the cost of her design ranks in the top ten for any of the design projects, the student can email a copy of it to the webmaster and have his/her name posted on the scoreboard. (pp. 3-4)

Quality of *WPBD*

As pointed out by Lee (1999), one confounding variable in research on computer simulation is the quality of computer simulation used. However, very few research articles describe the quality of the simulations used. Therefore, Lee suggested further research should include the description of the quality of the simulations employed. According to Lunce (2004), a well-designed computer simulation should offer an engaging environment where a learner can manipulate variables, predict results, understand process, and stimulate critical thinking. De Laurentiis (1993) listed criteria for excellent software: (a) symbolic graphics; (b) adaptability; (c) student control; (d) the medium matched to the content; (e) relational content; (f) hierarchy of instruction; (g) thorough treatment of the content; (h) knowledge of results (feedback); and (i) predictable results. Judged by the listed criteria, *WPBD* seems to be of high quality: Graphics in *WPBD* all symbolize a true truss bridge and components; freedom to choose a design is quite adaptable to the student's levels and needs; the student controls *WPBD* to a great extent, such as selecting design and manipulating variables; the clear step-by-step style of tutorials in the Help section shows a hierarchy of instruction; the whole process of engineering design has been effectively presented in *WPBD*. Finally, the student can get immediate feedback about his/her design.

Conceptual Change

Conceptual change is "learning that changes an existing conception (belief, idea, or way of thinking)" (Davis, 2001, Conceptual Change: Definition section). This notion was developed in the early 1980s by some science-education researchers and science philosophers at Cornell University. (Posner, Strike, Hewson, & Gertzog, 1982). "The question of conceptual change has become one of the topics most investigated by cognitive and educational psychologists as well as science educators interested in the learning processes that take place during the implementation of curriculum materials" (Mason & Boscolo, 2000, p. 200).

Conceptual change was initially thought to be affected only by cognitive factors. Later, however, social constructivist and cognitive apprenticeship views influenced conceptual change theory, encouraging discussion among students and instructors. Now it is thought that affective, social, and contextual factors also affect conceptual change (Davis, 2001). Duit (1999) pointed out all of these factors must be considered in teaching or designing learning environments that foster conceptual change.

Posner et al. (1982) developed a conceptual change model, which was later modified by other scholars. According to the model, there are two types of conceptual change: assimilation and accommodation. Assimilation means "the use of existing concepts to deal with new phenomena," accommodation indicates "replacing or reorganizing the learner's central conceptions" (p. 222). This model states that in order to change their concepts, learners must be dissatisfied with their existing concepts; they must be able to understand the new concept; the new concept must seem plausible to them; and the new concept must help them understand their experiences and observations better. Only when these conditions are met will students able to achieve conceptual change.

One of the common and effective instructional strategies for fostering conceptual change is to present students with opposing events that contradict their existing conceptions (Tao, 1999). This cognitive conflict strategy derived from Piaget's constructivist view of learning (Duit, 1999). Computer simulations can be used to present opposing events to individual learners or in a group setting (Davis, 2001). Many science educators believe that the computer simulation can be used for improving teaching and learning science concepts (Akpan, 2002). Some studies indicated that computer simulation is an effective tool for fostering conceptual change. Zacharia and Anderson (2003) examined the effects of using computer-based simulations prior to laboratory experiments on students' conceptual understanding of mechanics, waves/optics, and thermal physic. They found that the use of the simulations improved the students' ability to predict and explain. The use of simulations also fostered a significant conceptual change in the physics content areas studied.

To successfully achieve conceptual change, teachers should follow "a constructivist approach in which learners take an active role in reorganizing their knowledge" (Davis, 2001, ¶ 6). In addition, the teacher and students should have some experience with cooperative learning groups.Some researchers have combined the constructivist approach with use of computer simulation. For instance, Windschitl and Andre (1998) conducted research in which one group of students used a computer simulation following prescribed guidelines another group of students used the same computer simulation following an exploratory instructional guide to make hypotheses and test possible answers. They found that the “exploratory (constructivist) simulation experience could be more effective in altering learners’ misconceptions than a confirmatory simulation experience” (p. 158). Yang, Greenbowe, and Andre (2004) conducted research on the effects of using an interactive software program (ISP) to reduce students’ misconceptions about batteries. Their results indicated that the combination of teacher mediated ISP, worksheets, and the use of cooperative learning was effective.

Johnson (1997) assumed that four elements are crucial for conceptual change. Two of the four elements are contextual learning and activity-based practice. “A rich learning environment filled with authentic problems and real situations is critical for developing intellectual skills” (p. 170). The activity involved in the learning environment “should be oriented toward the design or construction of a project or product and involve the integration of knowledge and skills” (p. 173). In a review of simulation research, Stratford (1997) found that simulations are “useful in confronting students with their misconceptions in order to promote conceptual change” (p. 16).

Literature related to concept learning and teaching in TE classrooms is quite rare (Hoepfl, 2003). In addition, despite the importance of conceptual change as an important teaching and learning goal, “a relatively small amount of research has been done on students’ understandings of design and technology concepts, or technical knowledge” (Davis, Ginns, & McRobbie, 2002, p. 36). Most research related to conceptual change in education is in science education. Planinic, Krsnik, Pecina, and Susac (2005) found through literature that there are four fundamental teaching methods to bring about conceptual change in physics education: cognitive conflict, concept substitution, bridging analogies, and Socratic dialogue. Cognitive conflict has been discussed in previous paragraphs. Concept substitution strategy "is based on the fact that the essence of some student ideas is correct, but the idea is applied to the wrong concept. If this concept is substituted with another concept, the idea may become correct" (p. 2). The strategy of anchoring conception and bridging analogies "builds on students' existing ideas by forming analogy relations between a misunderstood target case and an "anchoring example" which draws upon intuitive knowledge held by the student" (p. 3). In Socratic dialogue, a teacher encourages a student to think and guides the student to his/her own conclusion. Each of these methods has both advantages and limitations. The best way to facilitate conceptual change is to combine these methods.

CHAPTER 3

METHOD

This chapter begins with a restatement of the research purpose and questions. The balance of the chapter details the specific research design, population and sample, instrumentation, procedures, and data analysis.

Purpose of Research

The purpose of this quasi-experimental study is to examine the effects of a selected computer simulation, the West Point Bridge Designer, on the academic performance of high school students in some technology education classes. The research question asks, does involvement in a selected computer simulation significantly improve high school students' basic knowledge of truss bridge building in secondary technology education classes? The basic knowledge of truss bridge building will be measured by a pre- and post-test.

Sample

Eighty students participated in the study and were recruited from 7 courses offered by a Career-Technical Education (CTE) academy. Three courses belonged to the Manufacturing Pathway and were titled Foundations of Manufacturing andMaterials Science, Roboticsand Automatic Systems, and Production Enterprises. Two courses belonged to the Engineering Pathway and were titled Introduction to Engineering Concepts and Introduction to Drafting. Two courses, Architecture I and II, were part of the Architecture Pathway. All courses belonged to the Technical/Engineering career cluster and were offered during the same semester. Two teachers taught all participants. Each class met three times a week. Teacher A taught the three courses in Manufacturing Pathway, while Teacher B taught the two Engineering Pathwaycourses and thetwo courses intheArchitecture Pathway. There were five classes (Class 1, 2, 3,4, and 5; labeled for convenience of data analysis) in Manufacturing Pathway, three classes in Engineering Pathway (Class 6, 7, and 9; labeled for convenience), and two classes in Architecture Pathway (Class 8 and 10; labeled for convenience). Each class period lasted 75 minutes per session. Students' grade level ranged from 9th to 12th grade. There were only 9 females among the 80 participants. Demographic and class enrollment information about participants is in Table 3.1. Participants did not vary much in terms of race or gender.

Table 3.1

Demographic Information

Class	Period	Count	Ethnicity				Gender		Grade		
			White	African-American	Hispanic	Asian-American	Male	Female	10	11	12
1	3	10	3	5	1	-	10	-	1	4	5
2	4	9	2	7	-	-	9	-	3	6	-
3	5	9	6	2	-	-	8	1	2	7	-
4	6	2	1	1	-	-	2	-	1	1	-
5	7	8	3	3	1	1	5	3	1	5	2
6	3	10	-	10	-	-	10	-	4	5	1
7	4	13	4	8	1	-	10	3	5	5	3
8	5	5	1	3	1	-	5	-	-	4	1
9	6	9	1	7	1	-	7	2	9	-	-
10	7	5	1	3	1	-	5	-	1	3	1

Research Design

The design for this research is quasi-experimental. The research used a pre-test–post-test nonequivalent control group quasi-experimental design. There were a treatment group and a control group. The five intact classes (in Manufacturing Pathway) taught by teacher A was Group A, while the five intact classes (in Engineering Pathway and Architecture Pathway) taught by teacher B was Group B. Group A or Group B was randomly assigned to the experimental group, while the other group was used as the control group. Mackey and Gass (2005) stated, “Intact classes are commonly and often by necessity used in research for the sake of convenience” (p. 42). One advantage of using intact classes is that it reflects real world classrooms, where students are in class units to learn. But a disadvantage of utilizing intact classes is that individual students cannot be randomly assigned to the treatment group or the control group. Later, Iusedthe bootstrap method to validate results.

Though it is generally believed that experimental research design is the best research design to find causal relationships, education researchers have always had to face the challenge of meeting the requirement of random assignment of people. Consequently, quasi-experiments have often been used to examine causal relationships in education (Campbell & Stanley, 1963; Cook & Campbell, 1979). In this study, the samples were not randomly chosen because of logistical complications associated with class assignments and student academic programs. Since research participants were not randomly selected or assigned to treatment or control groups, the research is quasi-experimental.

There were a quasi-experimental group and a control group. Teacher A's intact classes were assigned to Group A; teacher B's intact classes were Group B. Then, Group A and Group B were randomly assigned to the experimental and comparison conditions.

Both groups were administered the pre-test at the beginning of the study. According to Tuckman (1999), giving the pre-test to both groups allows the researcher to determine if the two groups are equal with regard to the dependent variable at the beginning of the instructional program. After participants completed the pre-test, pre-test scores were put into SAS, where a one-way ANOVA procedure was conducted to determine if the two groups' initial knowledge on truss bridge building is equivalent. If no statistically significant differences existed in pre-test knowledge, post-test scores would be considered and analyzed according to established protocol. However, if initial differences existed between treatment and control groups (i.e., statistically significant differences exist between two groups on pre-test scores), pre-test scores would be used as a covariate and ANCOVA should be used to assess treatment effects.

Internal Validity of the Study

An experiment has internal design validity if results are caused only by manipulated independent variables. Simply speaking, internal validity is to examine causal relationship between the independent variable and dependent variable without the influence of other variables (Beins, 2004). Campbell and Stanley (1963) found eight threats to internal validity, including history, maturation, testing, instrumentation, statistical regression, differential selection, experimental mortality, and selection-maturation interaction. The first threat to internal validity for this research is that the control group may use the software. Since some participants took a couple of courses together in the CTE academy, participants in the control group might hear about *WPBD* from those in experimental group and play with the tool during the data collection period, the research results will probably be affected. Testing was the second threat to internal validity for this research. Pre-testing and pre-test-testing sensitization happens when the participant takes a pre- and post-test (Onwuegbuzie, 2000). This means research participants' scores might become higher after taking the post-intervention instruments as result of having taken the pre-intervention instrument no matter if an intervention had been given. Testing is more likely to threaten the research's internal validity if "(a) cognitive measures are utilized that involve the recall of factual information and (b) the time between administration is short" (p. 16). In both pre-test and post-test, there is a section on factual knowledge. In addition, the time between the two tests was only one week. As a result, the research's internal validity might be weakened. Finally, resentful demoralization of respondents receiving less desirable treatments is another threat to internal validity for this research. Subjects in the control group might make no effort, in contrast to the experimental group.Despite the risks, there are some ways to avoid them. Using a control group and random assignment can help avoid seven of the threats except experimental mortality. This research used a control group, although I was not able to randomly assign participants to either experimental or control groups. However, I tried to increase the internal validity of the research. One way was to examine pre-test scores. After participants completed the pre-test, pret-test scores was put into SAS, where a one-way ANOVA procedure was conducted to determine if the two groups' initial knowledge on truss bridge building equivalent. If no statistically significant differences exist in pre-test knowledge, then post-test scores would be considered and analyzed according to established protocol. However, if initial differences existed between treatment and control groups (i.e., statistically significant differences exist between two groups on pre-test scores), pre-test scores would be used as a covariate and ANCOVA would be used to assess treatment effects. Another way to increase the internal validity was to prepare checklists (see Appendixes E, F) to ensure the instructor followed the prescribed procedures. In addition, for each class, I followed each class period to observe and made sure the instructor followed the prescribed procedures. If it was found out that the teacher does not follow the guidance, the researcher would talk with the teachers to make sure they followed the prescribed procedures.

External Validity

External validity is "the extent to which the results of a study can be generalized to and across populations of persons, settings, times, outcomes, and treatment variations" (Johnson & Christensen, 2004, p. 242).According to Onwuegbuzie (2000), population validity is a threat to external validity of almost all educational studies because "(a) all members of the target population rarely are available for selection in a study, and (b) random samples are difficult to obtain due to practical considerations such as time, money, resources, and logistics" (p. 30). This research chose samples from a CTE academy. The samples might not be representatives of all high school technology students in America. The samples were not randomly chosen or completely randomly assigned to treatment and control groups. These factors might reduce the research's external validity. However, since participants in the technology education classes came from all high schools in the county, it was representative of most high school students in the county. The demographic information further suggests that students are almost equally distributed between the experimental group and the control group.

Extraneous Variables

Johnson and Christensen (2004) point out there are three necessary conditions that must be met if a research study intends to examine a causative relationship between variable A and variable B, no matter if the research is experimental or non-experimental. The three conditions are(a) there should be some relationship between variable A and variable B, (b) changes in variable A must occur before changes in variable B, (c) an observed relationship should not be due to alternative explanations or rival explanations.

Johnson and Christensen (2004) further state that normally it is easy to meet conditions *a* and *b*. However, there are some issues involved in meeting condition *c*. They suggest that one way to identify all alternative explanations is the method of using multiple hypotheses, which was originally proposed by Chamberlin (1965).

> The effort is to bring up into view every rational explanation of new phenomena, and to develop every tenable hypothesis respecting their causal and history. The

investigator thus becomes the parent of a family of hypotheses; and by his parental relationship to all, he is forbidden to fasten his affections unduly upon anyone. (p. 357)

One deficiency of this method is that it is difficult for a researcher to know if all alternative explanations have been found. However, they suggest that statistical control is a technique most commonly used for controlling for extraneous variables in non-experimental research. According to them, most statistical controls belong to a general linear model. One typical case of a general linear model is ANCOVA (analysis of covariance).

Instrumentation

Pre-test and Post-test

The pre-test and post-test were designed by Hausmann (2005). The two tests are very similar except that the pre-test asks the respondents in both groups to fill in some demographic information and indicate if they have any previous knowledge of truss bridges. The tests include almost all concepts from *WPBD* software. There is a labeled model of a bridge at the very beginning of the tests. The tests have six types of assessment items: definition items, rank-order items (by strength and by cost), greater-than-less-than items, multiple-choice items, and short answer question items. Definition items ask the participants to define four terms. An example of the definition items is "Compression". Rank-order (RO) items ask the participants to arrange three different types of steel in order (Carbon Steel, High-strength Low-alloy Steel, and Quenched and Tempered Steel) both by strength and by cost. Greater-than-less-than (GTLT) items require the participants to choose members that are more expensive. An example is:

“Hollow Tube (> (< Solid Bar”. Multiple - choice (MC) items ask participants to select one correct item from given four items. For instance, the first multiple - choice item begins with “As cross-sectional dimension increases, member strength ____________”. Participants need to choose one of the three given options: (a) increases (b) stays the same (c) decreases. The short answer (SA) questions asked questions about the effect of bridge configuration on strength and price. An example is: “The bridge below (Bridge A) is flawed in a significant way. What might be done to the bridge to allow it to carry a load? (Describe your modifications to the bridge).” Since short answer questions require participants to apply basic knowledge into practice, the researcher classifies the short answer questions as procedure knowledge. The rest are basic knowledge about facts and are classified by the researcher as factual knowledge.

Pre-and-Post-test Validity

To check content validity, pre-test and post-test were examined by a group of experts consisting of one TE teacher in a high school and two university professors whose specialty is in TE. These experts checked the test items and confirmed if there was an acceptable correct choice for multiple-choice items. In addition, a pilot test was conducted with a group of high school students to make sure the instruments are clear and students could understand directions and terms.

Pre-and-Post-test Reliability

For the reliability of the pre-and-post test, an item analysis was made by Hausmann (2005), who designed the pre-test and the post-test. Prior to designing the instruments, Haussmann conducted a thorough content analysis through interacting with the *WPBD*. As a result, 24 concepts came out of the analysis. These concepts were developed in two ways. First, Haussmann referred to the information contained in the companion text (Ressler, 2002) containing both conceptual and procedural knowledge for redesigning a bridge. The companion text is a handbook written by Ressler, the designer of the *WPBD*, for better understanding and application of the *WPBD*. Hausmann's content analysis was based on the text. It suggests that students first optimize member properties before optimizing the shape of the truss. When optimizing member properties, they need consider several factors, such as the strength, price, and different types of stress (*i.e.*, tension and compression). Hausmann used the software for approximately 40 hours to design the pre-test and post-test. The assessment items in the two tests were chosen from the content analysis of the simulation. Based on the item analysis, the final pre-test and post-test included the 20 items.

Cronbach's alpha is the most commonly used measure of reliability (Streiner, 2003). After converting all five of the different types of questions into scale numbers, Cronbach's alpha was calculated by me to determine pre-and-post test reliability, which is not to measure the statistical significance of group mean difference (Zimmerman & Williams, 1982). It was calculated using scores from pre-test and post-test scores. According to Cronbach (1951), reliability can be expressed in the following formula:

$$\frac{k}{k-1}\left(1-\frac{\sum \sigma_i^2}{\sigma_c^2}\right)$$

where k is the number of test items (k=160), σ_c^2 is the variance of the whole test (i.e., variance of both pre-test and post-test scores as a whole), and $\sum \sigma_i^2$ is the sum of the individual item variances (variance of pre-test score and variance of post-test score, 80 test items were used for each variance calculation). A high alpha is the result of relatively high variance of the whole test (σ_c^2) in comparison with the relatively low variances of both pre-test score and post-test score ($\sum \sigma_i^2$), and high variance means there is a wide spread of scores, indicating that respondents can easily differentiate test items. If a test has a low variance, the scores for respondents are similar and are difficult to distinguish. By convention, if Cronbach's alpha is above 0.70, a research instrument is reliable. In this study, the *Cronbach*'s alpha was 0.70. This indicates the research instrument (pretest and posttest) was reliable.

Treatment

Treatment Group

The experimental group used *WPBD* to create a bridge that is cost effective and able to pass a load test. *WPBD* is computer-aided design (CAD) software. It is a stand-alone Windows application. *WPBD* has a tutorial and a very detailed Help section that teaches the student how to use the software and present concepts of engineering design process. Before using *WPBD*, students took the pre-test. After students finished the pre-test, the instructor generally introduced *WPBD*, distribute handouts that listed the requirements of the projects (as described in *WPBD*) to the participants and demonstrated to them how to start with *WPBD*. At the very beginning, the student need to choose one of seven different design projects presented in the software. All the seven projects required students to design a truss bridge that will carry a two-lane highway across a river. Once the student had selected a project, he/she could immediately begin creating his/her design of a structural model. In order to do so, the students need todraw joints and memberson the screen with the mouse. After finishing the structural model, the student clicked a button to start a simulated load test. *WPBD* automatically calculates the maximum internal force, tensile strength, and compressive strength for every member in the structural model. Immediately after computing, *WPBD* displays a color 3-D animation of the load test. The truck successfully crosses the bridge if all members in the truss are strong enough. But if any member is weak, it fails at the corresponding point in the animation, and the bridge collapses into the river. Once the students finished the simulation, they returned to the drawing board to continue their design. Immediately after participants in the quasi-experimental group finished their projects, they took a post-test, which is quite similar to the pre-test. Participants finished their projects in 4 class periods.

Control Group

The control group also created a model truss bridge that is cost effective and able to pass a load test. The materials they used were: cardboard file folders, yellow carpenter's glue, building board (Styrofoam or cork), pins, scissors, metal ruler, hobby knife or single-edge razor blade, and rubber cement. Before starting to work, participants in the control group also took the same pre-test as the treatment group (experimental group). Next, the instructor gave the control group a PowerPoint presentation on how to use cardboard file folders to create a truss bridge that is cost effective and able to pass a load test. The PowerPoint slides were written by Prof. Stephen Ressler (2007). It gives detailed step-by-step information on building the truss bridge. The presentation handouts were also distributed to the students. Before the students started to use the materials to build bridges, the instructor gave a general introduction to the project, gave participants handouts on the requirements of the projects, and demonstrated to them how to start. Each participant in the control group refers to the PowerPoint handouts and the step-by-step procedure written out by the instructor, while using cardboard file folders to create the truss bridge. The PowerPoint presentation and step-by-step procedure written by the instructor are quite similar in content to the tutorial in *WPBD*. Immediately after participants in the control group finish their projects, they took a post-test.

Procedures

Permission to conduct the study was requested from appropriate school administrators. Approval was requested from the Institutional Review Board at the University of Georgia (IRB, Human Subjects). After gaining approval from the IRB, data collection began.

Pilot Study

A pilot study was conducted. The pilot study focused on the wording used in pre- and post-tests to ensure that research participants correctly understood and responded the test items. Four high school students were recruited to participate in the pilot study. The pilot study did not include a treatment or control group. Rather, the focus of the pilot study was to determine the validity of the test instrument.

Data Collection Process

The researcher prepared checklists of detailed step-by-step procedures for treatment and control groups to follow. I also followed each class to observe and made sure the instructor followed the prescribed procedures. Whenever finding out that the teacher does not follow the guidance, the researcher talked with the teacher to make sure he followed the prescribed procedures.

Both treatment and control groups were administered the pre-test at the very beginning of the study. Completed pre-tests were collected by the classroom instructor and graded by the researcher. Upon finishing their projects, both groups took the post-test. Completed post-tests were also collected by the instructor and graded by the researcher.

Data Analysis

Level of Significance

The level of significance is the probability of Type I error, which occurs when the researcher rejects the null hypothesis when it is true (Johnson & Christensen, 2004). Because 0.05 is popularly used in most educational research, I used 0.05 significancelevel when I conducted data analysis.

Effect Size

The effect size of each statistical analysis will be calculated by obtaining the difference of sample means divided by the sample standard deviation (Cohen, 1988).

Researchers can enhance their research findings with a discussion on effect-size in addition to a test of statistical significance (Olejnik & Algina, 2003). Vogt (1999) provided the following definitions of effect size,

> Broadly, any of several measures of association or of the strength of a relation, such as Pearson's r or eta. Effect size often is thought of as a measure of practical significance. (b) A statistic, often abbreviated D or delta, indicating the difference in outcome for the average subject who received a treatment from the average subject who did not (or who received a different level of the treatment). This statistic is often used in meta-analysis. It is calculated by taking the difference between the control and experimental groups' means and dividing that difference by the standard deviation of the control group's scores-or by the standard

> deviation of the scores of both groups combined. (c) In statistical power analysis, effect size is the degree to which the null hypothesis is false. (p. 94)

Simply speaking, an effect size indicates the extent of a research result, such as the strength of the relationship between an independent variable and a dependent variable or the amount of change caused by an intervention (StatSoft., Inc, 2004). Standardized mean difference, which is the difference between experimental and control group means divided by the standard deviation of the control group, is used to determine group differences in experimental research (Mohammad, 1998). Effect sizes are generally categorized as small (effect size = .2), medium (effect size = .5) and large (effect size =. 8) (Cohen, 1988). Olejnik (1984) pointed out that there are no universal guidelines in interpreting effect sizes. What is large in one study may be a medium effect in another study. He suggests that reviewing literature can provide some guidance for interpreting effect size. According to Liao (2007), beginning in the early 1980s, several meta-analyses on the effectiveness of computers on learning were conducted by Kulik and his colleagues (e.g., Bangert-Drowns, Kulik, &Kulik, 1985; Kulik, Kulik, & Cohen, 1980). The studies examined in the meta-analyses were done in elementary school, secondary school, college, and among adult learners. For these categories, the positive effect sizes from learning through computers were found: 0.47, 0.26, 0.36, 0.42, respectively. Starting from 1990, the effect sizes from some meta-analyses were between 0.13 and 0.8. Liao (1992) conducted a meta-analysis of 31 studies to synthesize research concerning the effects of computer-assisted instruction on cognitive outcomes. All 31 studies were done in K-12 settings. The overall grand mean of effect sizes for these studies was 0.48. I especially examined two meta-analytic studies, where discussed researches share some similarities with this research.Lee (1999) conducted a meta-analysis of 19 studies concerning the effectiveness of instructionalsimulation. The participants of these studies are college and high school students. Overall mean effect size for academic achievement is .41. Based on Yaakuband Finch's (2001) meta-analysis, the overall effect size of computer-assisted instruction in technical education was 0.35.

Based on the results of the meta-analyses from instructional simulation and technical simulation, it seems that Cohen's (1988) medium effect size of .5 seems to be too high. Therefore, I chose the average of the effect sizes from these two meta-analyses, which was .38, as a judging criterion for medium effect size for the study.

This study used one-way analysis of variance (ANOVA). One-way ANOVA compares the mean of one or more groups based on a single independent variable (Miller, 1997). One advantage of using ANOVA is that it requires fewer analyses than multiple *t*-tests do, thus reducing the probabilities of Type I errors (Field, 2005). One shortcoming of one-way ANOVA is that it compares means on only one variable.

After participants completed the pre-test, pre-test scores were put into the SAS software package, where a one-way ANOVA procedure was conducted to determine if the two groups' initial knowledge on truss bridge building equivalent. If no statistically significant differences existed in pre-test knowledge, then post-test scores would be considered and analyzed according to established protocol. However, if initial differences existed between treatment and control groups (i.e., statistically significant differences between two groups on pre-test scores), pre-test scores would have been used as a covariate and ANCOVA would be used to assess treatment effects. ANCOVA is used to statistically control pre-existing differences between treatment and control groups (Keppel & Wickens, 2004).

CHAPTER 4

ANALYSIS OF DATA AND RESULTS

This chapter begins with a restatement of the research purpose. Research design and procedures are also summarized. An introduction to ANOVA and ANCOVA is presented. Basic sample statistics are presented. Results of the ANOVA assumption tests and an outlier check are presented. To verify the ANOVA results, bootstrapping is introduced and applied.

Purpose of Research

This quasi-experimental study examined the effects of a selected computer simulation on the academic performance of high school students in a selected technology education class. The research question asked, “Does involvement in a selected computer simulation improve high school students’ basic knowledge of truss bridge building in secondary technology education classes?” The basic knowledge of truss bridge building was measured by a pre- and post-test.

Research Design and Procedures

All participants completed a pretest and were then assigned to experimental groups.Teacher A’s intact classes were assigned to Group A; teacher B’s intact classes were assigned to Group B. Group A and Group B were randomly assigned to experimental or comparison (control) conditions. After the administration of experimental treatment was completed, all students completed a post-test, which was the same academic test asthe pre-test. Students’ post-test scores (dependent variable) were measured under quasi-experimental conditions, represented by different teaching methods. The objective of this study was to determine if a statistically significant difference would exist in achievement between teaching approaches, which if observed would be attributed to the treatment effect.

Introduction to ANOVA

According to Miller (1997), analysis of variance (ANOVA) is widely used to test for significant differences between the mean scores of selected variables found in treatment and control groups. The basic concept of ANOVA is that variances can be divided, or partitioned, and can be computed as the sum of squared deviations from the overall mean divided by *n*-1. The variance is a function of sample size, *n,* and the sum of (deviation) square (SS). Table 4.1 provides a better understanding of the concept. Numbers 1, 2, 3, 9, 10, and 11 in table 4.1 are hypothetical and only used for illustrating the meaning of ANOVA.

Table 4.1

Treatment Group and Control Group Mean Scores

	Treatment Group	Control Group
Observation 1	1	9
Observation 2	2	10
Observation 3	3	11
Mean	2	10
Sum of squares (SS)	2	2
Overall mean	6	
Total sums of squares (TSS)	100	

From Table 4.1, mean scores for the treatment group and control group appear to be very different. For each group, the sum of the squared deviation from the mean (the sums of squares within each group) equals 2. If repeating these computations without differentiating group membership, an overall mean of 6 is obtained and total sums of squares equals 100, which is much larger than the previous within group sums of squares (both are 2). The variance based on the within-group variability is much smaller than what is based on the total variability. This difference is mainly caused by the large differences between means. The following are some key terms to understand ANOVA.

*SS Error***.** SS error is within-group variability (SS) and is usually referred to as error variance.

*SS Effect***.** SS effect is the between-group variabilitythat can be explained. SS effect is due to the differences in means between groups.

*F distribution***.**The F-distribution arises as the ratio of two chi-squared variates:

$$\frac{U_1/d_1}{U_2/d_2}$$

Where U_1 and U_2 have chi-square distributions with d_1 and $d_2$degrees of freedom respectively, andU_1 and U_2 are independent. The probability density function of an F (d_1, d_2) distributed random variable is given by

$$f(x) = \frac{\sqrt{\frac{(d_1\,x)^{d_1}\,\,d_2^{d_2}}{(d_1\,x+d_2)^{d_1+d_2}}}}{x\,\mathrm{B}\left(\frac{d_1}{2},\frac{d_2}{2}\right)}$$

For real $x \geq 0$, where d_1 and d_2 are positive integers, and B is the beta function.

*F test***.**TheF test is the test statistic thathas an F-distribution under the null hypothesis.

The total sums of squares (TSS) can be broken down into one component that is due to true random error (i.e., within-group SS, or SS Error) and another component that is due to differences between means (i.e., between-group SS, or SS Effect). The total SS based on the overall mean is 100, while the sum of within-group variability is only (2+2=4), and variability due to differences between means (100 – (2+2) = 96). The variance based on the within-group variability yields much smaller value than the variance based on the between-group variability. The reason for the different variances is that there is a large difference between means, and it is this difference that accounts for the difference in the SS. For testing the significance of different means, the null hypothesis states that there are no mean differences between groups. Therefore, under the null hypothesis, the variance estimated based on the within-group variability (SS Error) should be about the same as the variance due to between-group variability (SS Effect). Then the F test can be used to compare those two estimates of variance to see whether the ratio of the two variance estimates is significantly greater than one. If the F-test statistic is significantly greater than one, the null hypothesis can be rejected, meaning that the mean differences between groups are significantly different.

Sample Statistics

There were 42 students in the control group and 38 students in the treatment group. Pre-test scores for control group participants ranged from 7 to 21, while the pre-test scores for treatment group participants ranged from 2 to 20.5. The pre-test score mean for the control group (group taught through the traditional teaching method) was

12.45, while the mean score of the treatment group (group using the computer simulation) was 11.31. The posttest scores for control group participants ranged from 9 to 22, while post-test scores for treatment group participants was between 7 and 22.50. Post-test score means were 15.70 and 15.10, respectively. The standard deviation of the pre-test scores for the control group equaled 3.31, while the standard deviation of the treatment group was 2.80. Post-score standard deviations were 4.15 and 3.30, respectively.

Cronbach Alpha and ANOVA Assumption Test

Cronbach alpha for reliability test. Converting all survey questions to scale numbers, I set that

1.Eachdefinition question was given one point if correctly answered, 0 points if answered incorrectly, and .5 point if answered partially correct.

2. Each rank order questionwas given one point if correctly answered, and0 points if answered incorrectly.

3. Each greater-than-less-than questionwas given one point if correctly answered, and0 points if answered incorrectly.

4. Each multiple choice questionwas given one point if correctly answered, and 0 points if answered incorrectly.

5. Each short answer questionwasgiven one point if correctly answered, 0 points if answered incorrectly, and .5 if answered partially correct.

Full pretest/posttest score is 26. By convention, if Cronbach alpha is above 0.70, a research instrument is reliable (Nunnally, 1978). In this study, the Cronbach alpha was 0.70. This indicates the research instrument (pretest and posttest) was reliable.

ANOVA assumption test. Almost all research papers and textbooks mention assumption tests when introducing ANOVA. Olejnik (2004) and D'Alonzo (2004) summarized several assumption tests that are commonly conducted before implementing ANOVA, including homogeneity of variance, normal distribution, and the test of independence.

1.Homogeneity of variance. Homogeneity of variance assumes that variances between the treatment and control groups are identical. The SS Error is calculated by adding up the sums of squares within each group. If the variances in the two groups are different, adding the two together is not appropriate, which will not yield an estimate of the common within-group variance. In the current study, the one-way ANOVA, F (1, 78) = 1.04, MSE = 183.6, p = .31, demonstrated no statistically significant differencebetween the two groups.So, I concluded that there was no violation of the homogeneity of variance assumption.

2.Normality of sample data. Normality of sample data means that the histogram of data frequency is distributed in a bell shape around the population mean. The bell-shaped curve is symmetrical with a single central peak and its spread is controlled by the standard deviation. In fact, normal distribution can be completely specified by its mean and standard deviation. For the normality assumption test of the sample data (pre-test and post-test scores), I used the SAS procedure PROC UNIVARIATE, in which Shapiro-Wilk test, Kolmogorov-Smirnov test, Cramer-Von mises test, and Anderson-Darling test were performed by default to check the normality of the sample data. Table 4.2 and Table 4.3 show that all test statistic p-values through the 4 tests were larger than 0.05. Therefore, I concluded to accept the null hypothesis that the sample data followed normal distributions.

Table 4.2

Tests for Normality PreScore

Test	Statistic		*p* Value	
Shapiro-Wilk	W	.99	Pr< W	.60
Kolmogorov-Smirnov	D	.08	Pr> D	>.15
Cramer-Von mises	W-sq	.09	Pr> W-Sq	.16
Anderson-Darling	A-sq	.49	Pr> A-Sq	.22

Table 4.3

Tests for Normality PostScore

Test	Statistic		p Value	
Shapiro-Wilk	W	.99	Pr< W	.86
Kolmogorov-Smirnov	D	.07	Pr> D	>.15
Cramer-Von mises	W-sq	.05	Pr> W-Sq	>.25
Anderson-Darling	A-sq	.30	Pr> A-Sq	>.25

3. Independence of observations between groups. Independence of observations between groups assumes that groups do not relate to or influence each other. For the Durbin-Watson D test, a statistic value of 2 means there is no correlation between the two variables. From the SAS output for the pretest score (see Table 4.4), the test statisticDurbin-Watson D for testing correlation is around 2, which means that the observations between the two groups (traditional teaching method and computer-based method) were independent.

Table 4.4

Dubin-Watson D for Pretest

Sum of residuals	Sum of squared residuals	Sum of squared residuals - error SS	First order autocorrelation	Durbin-Watson D
-.00	1110.87	.00	-.13	2.21

From the SAS output for the posttest scores (see Table 4.5), the test statistic for the Durbin-Watson D for testing correlation is around 2, which means that the observations between the two groups (traditional teaching method and computer-based method) are independent.

Table 4.5

Dubin-Watson D for Posttest

Sum of residuals	Sum of squared residuals	Sum of squared residuals - error SS	First order autocorrelation	Durbin-Watson D
.00	736.39	.00	-.07	2.12

Findings

Pretest Analysis

To decide whether ANOVA or ANCOVA would be used, I analyzed the impact of pretest scores on posttest scores. ANOVA would not be appropriate to analyze the effectiveness of the treatment factor (different teaching methods) if the treatment group and control group differed significantly on pretest scores. This is because different posttest scores could result from initially different pretest scores rather than by different treatment effects. In this case, ANCOVA was not necessary to analyze the treatment effect given the results of a one-way ANOVA between the two groups on pre-test scores, F (1, 78) = 1.81, MSE = 1.24, p = .18, η^2 = 0.02. Results indicated no statistically significant differences between the two groups in pretest scores.

Posttest Analysis

I conductedANOVA on post-test scores to determine if the two experimental groups differed after treatment. For this one-way analysis, treatment (different teaching methods: traditional teaching method and computer simulation) was the independent variable, while the posttest score was the dependent variable. Mathematically, the following model was used:

$$\text{Posttest Score} = \beta 0 + \beta 1 * \text{TeachingMethod} + \varepsilon,$$

where TeachingMethod was either 0 (representing traditional teaching method) or 1 (representing computer simulation method), ε was an error term, which follows the normal distribution.

Results of the one-way ANOVA, F (1, 78) =. 77, MSE = 9.44, p = .38, η^2 = 0.01, demonstrated no statistically significant differences between the two groups on the posttest score. Thus, the computerized teaching method did not differ from the traditional teaching method on students' academic performance.

Unbalanced Design

In this research design, there were 38 students in the traditional teaching class and 42 students using the computer simulation. This is an unbalanced design. In this case, I also calculated the type III SS, which is for unbalanced ANOVA. Table 4.6 shows that neither SS Effect nor *p*-value changed as a result of this different statistic. This result further confirms that treatment factor was not a significant factor in student achievement.

Table 4.6

Treatment Effect in Unbalanced Design

						Noncentrality Parameter			
Source	DF	Type III SS	Mean square	F	Pr > F	Min var Unbiased estimate	Low MSE estimate	95% Confidence limits	
Teaching Method	1	7.23	7.23	.77	.38	-.25	-.25	0	8.04

Effect Size

Following Cohen's *d* calculation, the effect size for teaching method was 0.17 (mean1=15.70, mean2=15.10, std1=2.80, std2=3.30, n1=38, n2=40). This number is far below the cutoff point as a medium effect size .38, which was set by me after conducting literature review. As seen in Cohen's mapping table, this small number of effectsize indicates that the distribution of post-test scores from the traditional teaching class overlaps more than 85% of the distribution of posttest scores from the computer simulation class. The different teaching methods do not contribute enough to separate their posttest scores. Following Vogt's (1999) interpretation (effect size is the degree to which the null hypothesis is false), the small value of effect size also confirms the conclusion from the statistical *p*-value that the post-test scores between two groups are not significantly different.

Outlier Checking

There are several ways to check the undue influence of outliers. For example, in Wilcox's (2009) paper, outliers were considered by choosing the mean of location (20% trimmed mean) for comparison. This means: "Under normality, a 20% trimmed mean has nearly the same efficiency as the mean, but a 20% trimmed mean can have substantially higher efficiency when sampling from a heavily-tailed distribution where outliers tend to occur" (Wilcox, 2009, p. 428). I followed Ho and Naugher's (2000) idea to identify outliers by checking Cook's distance for each observation in the sample data. From the test result (see Figure 4.1), there is only one observation having a Cook's distance = .12 which is relatively larger than the rest, which are all below .07. After reinvestigating this observation and finding nothing abnormal, I decided to include this observation in the analysis.

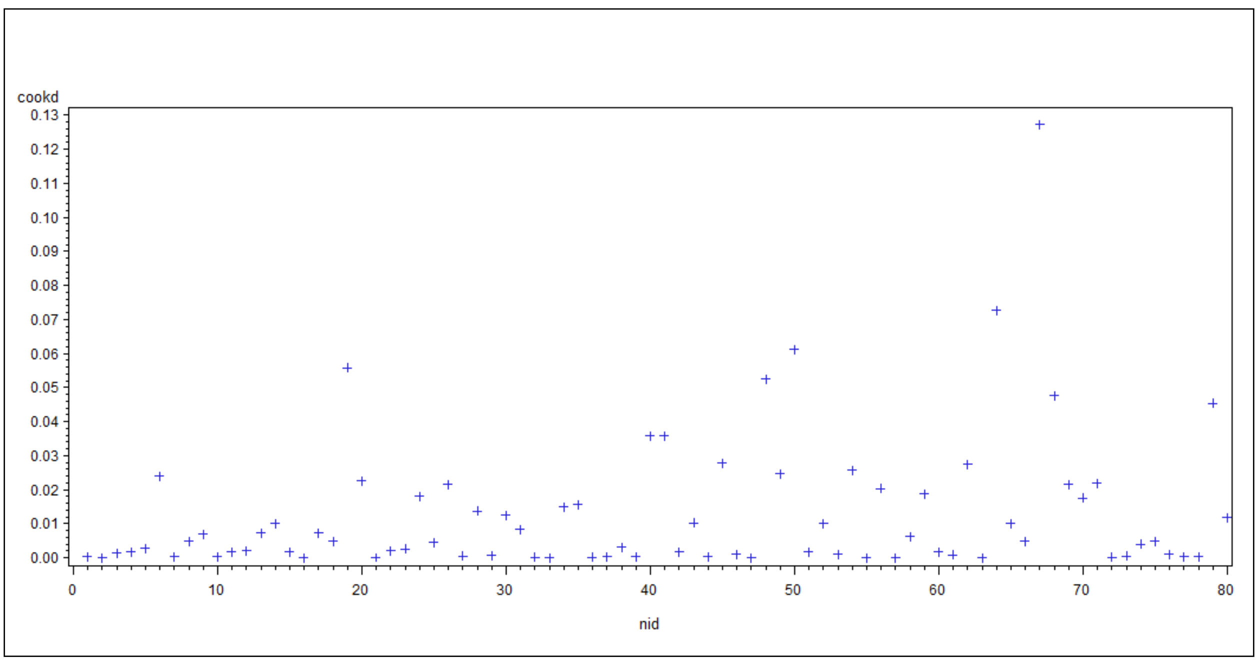

Figure 4.1 Outlier checking

Bootstrapping Test

Sampling Bias

Sampling bias refers to the difference between the sample collected for the research and the population that the collected sample represents. Bias can arise due to sample selection. It is a systematic error that can prejudice research findings. Sampling bias is an issue for all models, especially for these models based on static sampling. Some natural questions to ask are, "How significant is the effect of the sampling bias on model estimates?", "How reliable or accurate is the model to depict the true population?" To know how reasonable the estimate is, the variability of the estimator based on different samples can be calculated. However, in many cases, it's not feasible or even possible to have multiple sets of samples. "Bootstrapping was introduced in 1979 as a computationally intensive statistical technique that allows researchers to make inferences from data without making strong distributional assumption" (Haukoos & Lewis, 2005, p. 360).

Bootstrapping

Bootstrapping has been widely applied in business, medical science, statistics and education. Its application includes sampling bias correction and model validation. Medema, Koning, and Lensink (2009) applied bootstrap method to validate their business model for a decision-making. Based on bootstrap results, Mick and Ratain (1994) confirmed their model estimates from a training data set, which normally has few sample data points in a pharmaceutical study. Tong and Brennan (2004) applied bootstrapping in social science and developed a single optimal bootstrap procedure for obtaining the estimates for ANOVA-type designs. Chambers and Dorfman (2004) use bootstrapping for a model-based survey inference by calculating confidence intervals for estimates to conclude their estimates from single collected sample is the estimates of their choices. The most relevant research papers on ANOVA and bootstrapping include those by Harris and Sass (2008) and Wilcox (2009). Harris and Sass summarized the research papers with and without random sampling. Most research papers on non-random sampling introduce a covariate in the model to mitigate the sampling bias resulting from the non-random assignment of observation. Next, they used bootstrapping to calculate standard deviation of their model estimates.

Bootstrapping is a random sampling with replacement process to estimate a statistic's sampling distribution. Stine (1989) explained its procedure. For each random sample, a new data set is generated from a given sample data set through random picking of observations. The new data set has exactly the same number of observations as the original sample. Which observation to be included in the new data set is totally random. With the replacement feature, same observation can be selected as many times as the number of original sample size. The replacement here does not mean to change the data information in the original sample data set. Neither will it delete the selected observation from the original data set. Instead, the selected observation will be put back into the original sample file. As a result, this observation could be the next draw again. The next step is to calculate statistics based on new sampled data set. After repeating the same procedure a significant number of times (such as 1000 times, which also is known as bootstrap samples), 1000 research statistics are ready for statistical analysis including confidence interval calculation.

Estimating confidence levels using the bootstrapping follows the following steps, which are illustrated in Figure 4.2:

(1) Using random sampling with replacement to generate a new sample with the same size as the original data set. For example, if the original data set has five observations with IDs 1, 2,3,4,5, each sampled data set will also have five observations. During the selection of these five observations, each observation has the same possibility to be selected in the new sample. Meanwhile, same observation could be selected many times.

The followings are a couple of feasible sets:

IDs: 1,1,1,1,1; IDs: 2,2,2,2,2; IDs: 1,1,2,3,4; IDs: 1,1,1,5,5; IDs: 1,2,3,4,5

The followings are some examples not applicable:

IDs: 1,2,3,4 (only four observations, the original one has five observations)

IDs: 1, 2,3,5,6 (though this one has the same size, IDs 6 does not belong to the original data set)

(2) Calculating statistic (which is the p-value of the significance of different teaching methods) based on the data created from (1).

(3) Repeating (1) and (2) as many times as needed, then calculating the confidence level of p-value.

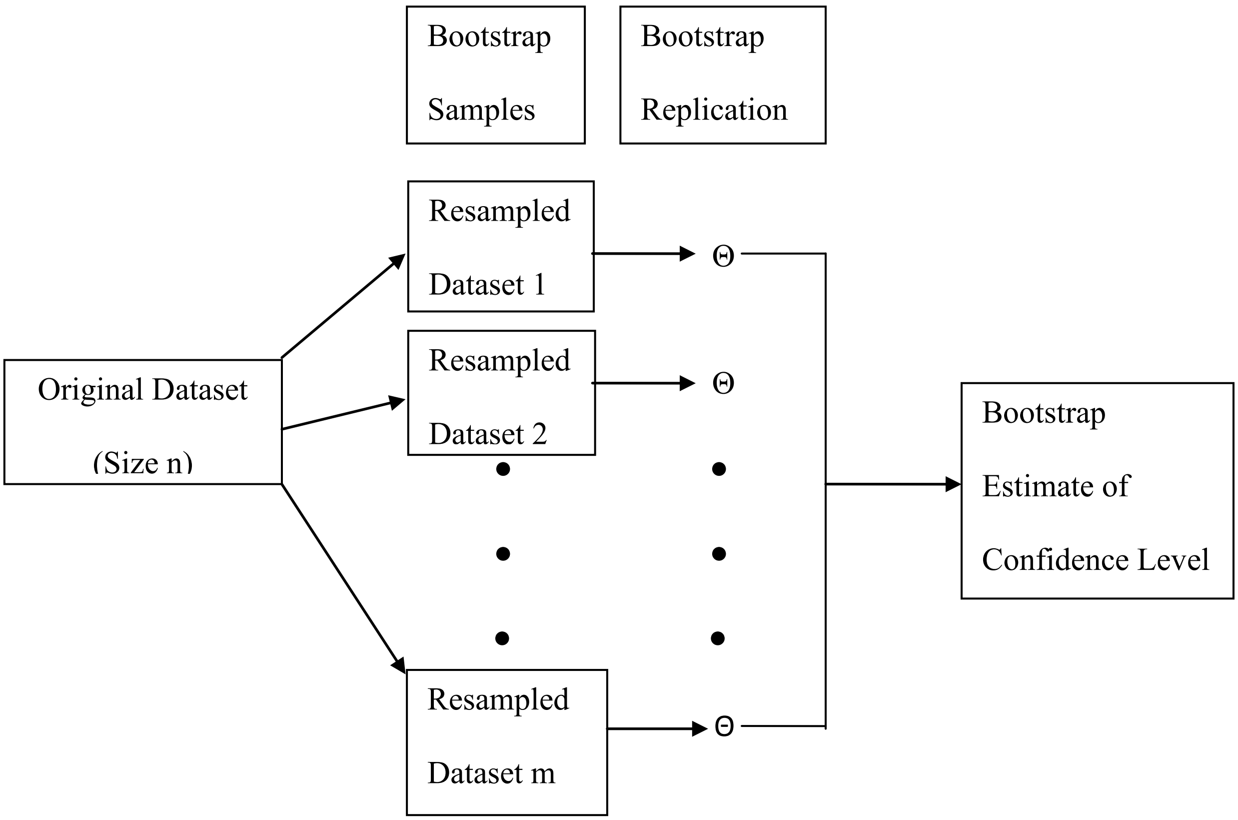

Figure 4.2 Schematic depiction of the steps in bootstrap

Bootstrapping Results

I decided to conduct 1000 iterations to make sure my bootstrapping results were significant. There is no consensus on how many iterations are enough. Tong and Brennan (2004) choose 100 iterations. Mick and Ratain (1994) used 200 iterations. Chambers and Dorfman (2004) chose 500 iterations in their study. One consideration in choosing the number of iterations is computer CPU time, which totally depends on the complexity of the underlying model. For some research, testing models are relative simple; while for others, the testing models may need intensive computation. For models involving heavy computation, a big iteration number may exceed the computer's burden. In this research, the data set had 80 observations and the model framework was relative simple. Therefore, 1000 iterations took only about two minutes CPU time on a commonlaptop computer.

In my analysis, bootstrapping was used to validate research findings by calculating 95% confidence interval. The lower 95% and upper 95% confidence levels from my data were .37 and .41, respectively. From the definition of confidence interval, I concluded that there were 950 out of total 1000 iterations that the *p*-value of the research statistic is between .37 and .41. Both these numbers are far higher over the preset significant level .05. I can conclude with 95% confidence that the difference between traditional and computer teaching methods are not significant.

Summary

This quasi-experimental study was to examine the effects of a selected computer simulation on the academic performance of 80 high school students in technology education classes in a career academy.After an introduction to ANOVA and ANCOVA was given, basic sample statistics were also presented. ANOVA assumption tests and outlier checks were also conducted to ensure the samples were suitable for ANOVA tests. Data analysis indicated no statistically significant difference between the treatment and control groups. In other words,no differences were found in academic performance between classes taught with traditional method and those using a computer simulation, WPBD. Bootstrapping tests further confirmed the result.

CHAPTER 5

DISCUSSION

This chapter summarizes the study. Findings, conclusions, discussion, implications, and recommendations for practice and future research are also discussed.

Summary of Study

With the rapid development of science and technology, the world has been progressing quickly (Friedman, 2005). To develop a capable workforce who can rapidly adapt to the fast changing world, one of the biggest challenges educators face is to find more efficient ways to teach. As a result, instructional technology has been an important element in recently initiated educational reforms (Lunce, 2004). Computer simulation has been increasingly used in education to try to make up for deficiencies in classroom learning environment (e.g., Marshall & Yang, 2006; Gorrell, 1992; Thomas & Hooper, 1991; Zirkel&Zirkel, 1997). Situated cognition theory proposes that learning environment should be as close to the real world as possible to achieve optimal learning results (Schell, 2001; Winn et al., 2005). Computer simulation has been increasingly used in many fields including education. Many studies have been conducted on the effect of computer simulation on preK–12 learning over the past decades. These studies have focused on the effectiveness of computer simulations when compared to other instructional methods (e.g., Akpan& Andrew, 2000; Gaddis, 2001). There have been inconsistent results among these studies. For instance, some research indicated computer simulations sometimes can replace real labs (e.g., Institute for Computer Based Learning, 1999). Others like Kruper and Nelson's (1991) showed no significant difference between traditional and simulated labs. In secondary technology education, little research has been conducted on computer simulation's effectiveness. This research study sought to examine the effectiveness of computer simulation by comparing the academic performance of computer simulation students to their counterparts in traditional technology laboratories.

Purpose of the Study

This quasi-experimental study examined the effects of a selected computer simulation on the academic performance of high school students in a selected technology education class. The research question asked, "Does involvement in a selected computer simulation improve high school students' basic knowledge of truss bridge building in secondary technology education classes?" The basic knowledge of truss bridge building was measured by a pre- and post-test.

Population and Sample

The abstract population for this study consisted of all students enrolled in high school technology education programs in the United States. I specifically focused attention on manufacturing, engineering, and architecture components of secondary technology education. The sample of this study was selected by convenience and drawn from a selected CTE academy. Eighty students participated in the study. Participants came from 6 different courses taught by 2 different teachers.

Research Procedures

The quasi-experimental research was conducted with a treatment and control group.All the participants took a pre-test and were then assigned to experimental groups. Teacher A's intact class were assigned to Group A; Teacher B's intact classes were assigned to Group B. Then, Group A and Group B were then randomly assigned to the experimental or comparison (control) conditions. After administration of the experimental treatment, all participants took a post-test, which was same as the pre-test. The tests included six kinds of assessment items: definition items, rank-order items (by strength and by cost), greater-than-less-than items, multiple-choice items, and short answer question items.

A pilot study was conducted, which focused on the wording used in pre- and post-tests to ensure that research participants would correctly understand and respond. Four high school students were recruited to participate in the pilot study. The focus of the pilot study was to determine the validity of the test instrument. It turned out to be very successful. All the wording is appropriate for high school students.

Data Analysis

I collected and graded both groups' pretest and posttest. Microsoft Excel was used to compile the test scores before using the SAS statistical software program to conduct data analysis. By calculating Cronbach alpha, which is 0.7, I made sure the research instruments (pretest and posttest) were reliable. Before conducting ANOVA, I did the ANOVA assumption testsusing SAS. Then, I first conducted ANOVA on the pretest mean scores to see if treatment and the control groups differed before the quasi-experiment. Since there was no statistically significant difference between the two groups, I only examined post-test scores to see if the two groups differed after the experiment. In addition to conducting the ANOVA test, I also checked Cook's distance for each observation to see if there were any outliers in the sample data. Finally, to further validate research findings, bootstrapping was used by calculating 95% confidence interval.

Findings and Conclusions

By calculating Cronbach alpha (which was above .70), I concluded that the research instruments (both pretest and posttest) were reliable. I also did the ANOVA assumption test to make sure variances between treatment and control groupswere homogeneous; the sample data had normal distribution; and the observation between the two groups was independent. It turned out that the data met the criteria and were suitable for ANOVA testing. I found no statistically significant difference between the treatment group (learning through computer simulation) and control group (learning through traditional method) post-test mean scores.Therefore, I only conducted an ANOVA on posttest mean scores using SAS. The result indicated no statistically significant difference between treatment and control groups.

I calculated Cook's distance for each observation and found no outliers in the sample data. Therefore, every observation was included in the research sample. In addition, I used bootstrapping by calculating their 95% confidence interval. The bootstrapping results were consistent with results from the ANOVA.

Discussion

Findings from the research found no statistically significant difference between the post-test mean scores for the group using the computer simulation and the group taught in traditional labs. This result is not fully supported by the proposed theoretical framework for this research, i.e., that the computer simulation group should outperform the hands-on group in academic performance. Referring back to the continuum discussed previously, we see that the learning environments created by computer simulation occupy only the middle section of the continuum and, therefore, are only partially situated and authentic. Under this partially situated environment, teachers' scaffolding is very important to ensure students' best learning outcome. In this study, the teacher in the computer simulation group had very little facilitating role. This factor may have adversely affected the group's learning results.

Due to limitations, this study only focused on comparing test scores of the two groups after treatment. Future research should also look at the effectiveness of computer simulation from other perspectives. While the academic achievement of the two groups showed no difference, the computer simulation group appeared to provide me with some positive results compared to the hands-on group at least in three aspects, including time efficiency, students' attitude, and teachers' involvement. Most students in the computer simulation group finished the task well ahead of time. Meanwhile, the hands-on group could hardly finish the task on time. They spent at least 2-3 periods longer to finish. The computer simulation group was more efficient because they were able to control their own process. As a result, most of them appeared to be more involved into their work. The hands-on group had to follow the teacher's prescribed process and, at times,appeared bored. The teacher in the hands-on group also had to exert far more effort and had greater responsibilities than the teacher in the computer simulation group. He had to prepare for and give the instruction on the truss bridge before the students started to work on the hands-on part. He also had to prepare all the materials needed for the hands-on project. However, the teacher in the computer simulation group only needed to do some logistical things, such as remind students to read tutorials included in the simulation software when they had difficulties and encourage students to challenge themselves.

In technology education, though computer simulation has been increasingly used in classrooms, research on its effectiveness has been rare. This research adds more knowledge to existing literature on integrating computer simulation into (technology) education. Generally speaking, researchfindings on effectiveness of computer simulation has been controversial. Some researchers have found computer simulation superior to other teaching methods; others have found no difference between computer simulation and other instructional strategies. My research findings support the second view. They are similar to those findings including Michael's (2001), Kelly's (1997-98), and Parher's (1995). Michael examined the effect of computer simulation on product creativity by comparing it with hands-on activities in technology education. Participants were randomly assigned to either a hands-on or simulation group. Both groups were asked to create a creature to be found on a Lego planet. The hands-on group used kits of *Classic Lego Bricks* to build a physical object. The simulation group used the demonstration version of simulation software *Gryphon Bricks*, which was installed on Macintosh computersfor the research. Each student in the computer simulation group worked on a computer to play with computer-generated Lego bricks. Each student in the hands-on group had a box of Lego bricks similar to those in the Gryphon software. Product creativity was measured by a section of *Creative Product Semantic Scale*. Michael found that there were no significant differences between the computer simulation and hands-on group in terms of achievements.

Kelly also had similarresults. Kelly (1997-98) conducted a quasi-experiment involving 39 9th-grade earth science students, which were divided into two groups. One group identified mineral in a laboratory. They needed to correctly list five propertiesof given mineral samples and use a computerized key to identify those minerals. Another group learned through a computer simulation developed by Kelly. The software simulated a mineral identification activity often completed in high school earth science labs. The simulation group could only see scanned pictures of mineral samples on the computer screen. They needed to finish the same tasks as the first group. A week after the treatment was completed, students took the "New York State Regents High School Examination Earth Science Performance Test." The mineral identification section of the exam was used to compare the two groups. Data analysis showed no statistically significant difference in total scores between the two groups on the mineral performance test.

Parher's(1995) research shared similar results, too. Parher conducted research comparing an earthworm dissection computer simulation with traditional high school biology dissection methods over a four-day period. Participants were 30 high school students enrolled in an advanced placement biology class.All participants received lectures on the anatomy and functions of the earthworm, then completed a pre-test on the earthworm. On the third day students were randomly assigned to two equal groups. One group dissected an earthworm using an Apple computer dissection simulation. The other group dissected a real worm. On the fourth day students were tested again. It turned out that there was no statistically significant difference between the two groups.

Implications

There were no statistically significant differences between the group using computer simulation and the one in a traditional lab. This finding implies that computer simulation may be an alternative to traditional teaching that produces comparable results. However, we should further consider when and how computer simulation may replace traditional teaching. Should computer simulation totally replace traditional teaching or only partially replace it? If a partial replacement, when is it ideal for computer simulation to step in? We also need to consider factors as time and cost- effectiveness. For example, if simulation software is available at no cost, as the case in this research, it can be simply implemented in classrooms without any investment. If instructors need to write simulation programs, spend extra time to get familiar with new software, or purchase simulation software costs more than traditional labs, they need think it over before making decisions.

This research design was quasi-experimental, which used convenience sampling instead of random selection. Regardless, the research results are valid and consistent with those of the bootstrapping method. This implies that the bootstrap resampling method can be used in educational research to validate final results. (Thompson, 1993).

Recommendations

Based on findings and conclusions, some recommendations are given below.

Recommendations for Practice

Nowadays, many technology education programs have included computer simulation in their curriculums. School administrators/technology education teachers should find the best strategies for using simulation software, and consider whether using simulation software alone to replace a traditional lab or just adding it as a supplement, or simply not using it because of some difficulties such as lack of funding.

Recommendations for Future Research

1. More research should be conducted in the field of technology education to study if computer simulation increases students' academic performance.

2. Much research on effects of computer simulation has been conducted in such areas as science education by comparing using both computer simulation and traditional teaching methods with either one of the two approaches, or studying which of the two methods should be used first. Similar research could also be conducted in technology education classrooms.

3. In this research, only 9 females participated. Therefore, I was not able to examine whether females differed from males in their academic performance using the two instructional approaches. Additional research should focus on female students to examine if any gender differences in academic achievement exist between the two instructional methods.

4. Due to many limitations, this research could only study computer simulation's effects on students' academic performance. Future studies could look at other areas in addition to academic achievements, such as appreciation, students' motivation and perception towards computer simulation.

5. Future research could also consider the social aspects of learning through computer simulation. For instance, since high-tech electronic devices are very popular among most students, it may be possible to make use of those devices to facilitate students' learning.

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APPENDICES

APPENDIX A

PRE_TEST ON WPBD

PRE_TEST ON*WPBD*

Please finish following form before beginning the test.

Name:

Grade: □ 9th□ 10th□ 11th□12th

GPA: □ 4.0-3.0 □ 3.0-2.0 □ 2.0-1.0 □ Not Applicable

Gender: □ Male □ Female

Ethnicity: □ Hispanic □ Asian □ Africa □ African-American □ Caucasian

□Other Please specify ____________________

Previous computer experience: Have you ever used West Point Bridge Designer before?

□ Yes □No If yes, please specify how you used it____________________________

Have you taken any other courses in the career academy?

□ Yes □No If yes, please specify the names of the courses ______________________

____

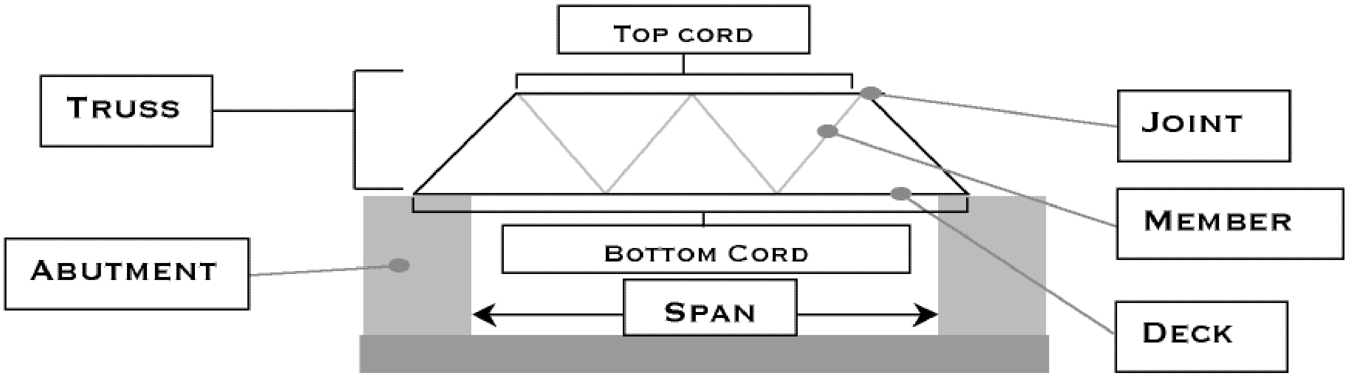
Are you currently taking any other courses in the career academy?

□ Yes □No If yes, please specify the names of the courses ______________________

____

Test Content

For your reference, here is a labeled model of a bridge:



Provide a definition for the following terms:

- Load:

- Tension:

- Compression:

- Failure

Rank order each type of steel, from weakest (1) to strongest (3):

Strength Rank Order	Steel Type
□ 1 □ 2 □ 3	Carbon Steel

□ 1 □ 2 □ 3 H igh-strength Low-alloy Steel

□ 1 □ 2 □ 3 Quenched and Tempered Steel

Rank order each type of steel, from cheapest (1) to most expensive (3):

Strength Rank Order	Steel Type
□ 1 □ 2 □ 3	Carbon Steel
□ 1 □ 2 □ 3	H igh-strength Low-alloy Steel
□ 1 □ 2 □ 3	Quenched and Tempered Steel

Indicate which material is more expensive (>) or less expensive (<).

a. Hollow Tube □>□< Solid Bar

b. Longer Member □>□< Shorter Member

c. Smaller Cross-section □>□< Larger Cross-section

Multiple Choices (Choose the best answer for each question)

1. As cross-sectional dimension increases, member strength ____________.

(a) increases

(b) stays the same

(c) decreases

2. Hollow tubes have ____________ tensile strength than solid bars.

(a) higher

(b) same

(c) lower

3. Tensile strength is always ____________ the maximum compressive strength.

(a) greater than

(b) the same as

(c) weaker than

4. Under compression, longer members are ____________ shorter members.

(a) stronger than

(b) the same as

(c) weaker than

5. Suppose we took a bridge and made it taller (in the vertical plane), without changing the overall configuration. The internal member forces of the top and bottom cords will ____________

(a) increases

(b) stays the same

(c) decreases

6. The top of a bridge is always under ____________, while the bottom is always under ____________.

(a) compression; compression

(b) compression; tension

(c) tension; compression

(d) tension; tension

7. Strength-to-force ratio: a value ____________ one means the member has failed, while a value ____________ one means the member can safely carry the load.

(a) greater than; greater than

(b) greater than; less than

(c) less than; greater than

(d) less than; less than

8. Under tension, longer members are ____________ shorter members.

(a) stronger than

(b) the same strength as

(c) weaker than

9. Where does the bridge experience the most stress?

(a) The top cord

(b) The middle

(c) The bottom cord

(d) The two ends

10. Using members of several different sizes ____________ the overall cost of the bridge.

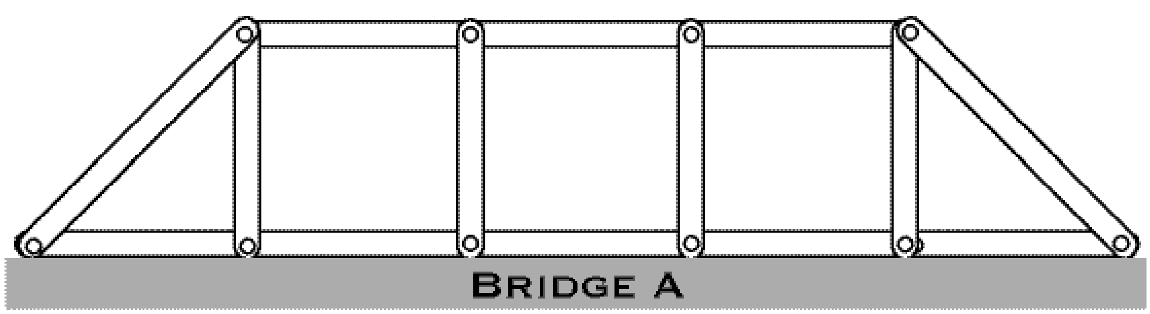
(a) increases

(b) does not change

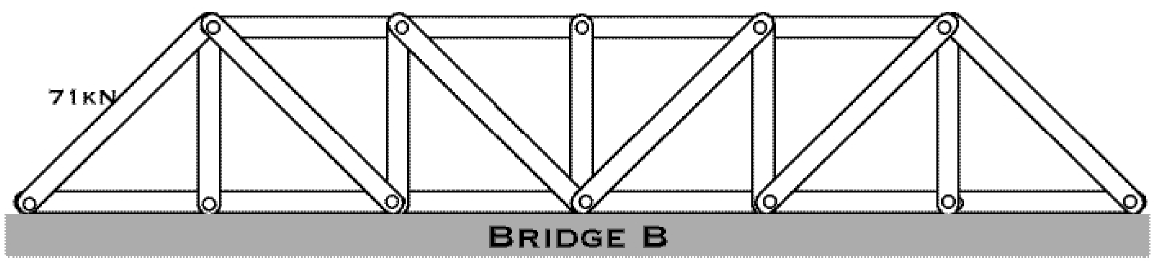
(c) decrease

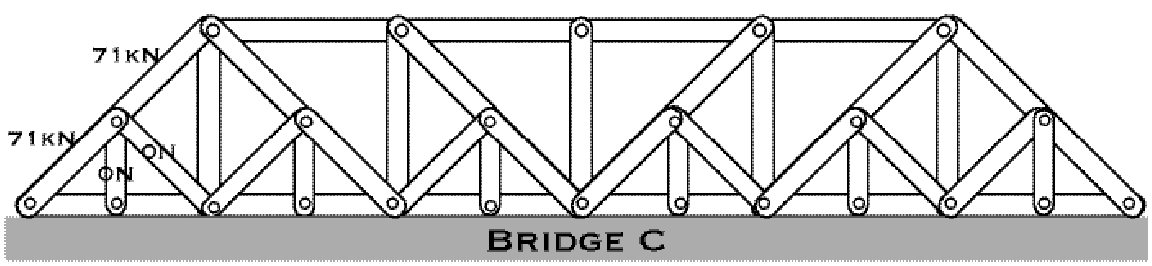
Short Answer

1. The bridge below (Bridge A) is flawed in a significant way. What might be done to the bridge to allow it to carry a load? (Describe your modifications to the bridge)



2. Consider two bridges shown below (Bridge B and Bridge C). Their configurations are similar, with one exception. Bridge C has 12 additional members. Although none of the internal member forces in the diagonals (71kN) change, the bridge is stronger. Why does adding supports, which themselves experience no internal member forces, increase the overall strength of the bridge?





3. Since we have considered the members under compression, describe what you might do to the members under tension (Bridge C), assuming they are made of solid carbon steel bars (160mm), to make the structure cheaper?

APPENDIX B

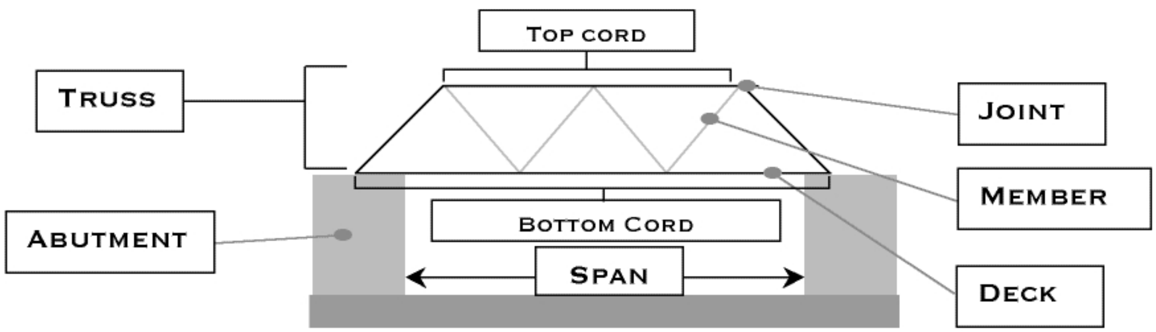
POST-TEST ON WPBD

POST-TEST ON*WPBD*

Name:

Test Content

For your reference, here is a labeled model of a bridge:



Provide a definition for the following terms:

• Load:

• Tension:

• Compression:

• Failure

Rank order each type of steel, from weakest (1) to strongest (3):

Strength Rank Order	Steel Type
□ 1 □ 2 □ 3	Carbon Steel
□ 1 □ 2 □ 3	H igh-strength Low-alloy Steel
□ 1 □ 2 □ 3	Quenched and Tempered Steel

Rank order each type of steel, from cheapest (1) to most expensive (3):

Strength Rank Order	Steel Type
□ 1 □ 2 □ 3	Carbon Steel
□ 1 □ 2 □ 3	High-strength Low-alloy Steel
□ 1 □ 2 □ 3	Quenched and Tempered Steel

Indicate which material is more expensive (>) or less expensive (<).

d.	Hollow Tube	□>□<	Solid Bar
e.	Longer Member	□>□<	Shorter Member
f.	Smaller Cross-section	□>□<	Larger Cross-section

Multiple Choice (Choose the best answer for each question)

1. As cross-sectional dimension increases, member strength ____________.

(a) increases

(b) stays the same

(c) decreases

2. Hollow tubes have ____________ tensile strength than solid bars.

(a) higher

(b) same

(c) lower

3. Tensile strength is always ____________ the maximum compressive strength.

(a) greater than

(b) the same as

(c) weaker than

4. Under compression, longer members are ____________ shorter members.

(a) stronger than

(b) the same as

(c) weaker than

5. Suppose we took a bridge and made it taller (in the vertical plane), without changing the overall configuration. The internal member forces of the top and bottom cords will _________________.

(a) increases

(b) stays the same

(c) decreases

6. The top of a bridge is always under ____________, while the bottom is always under ____________.

(a) compression; compression

(b) compression; tension

(c) tension; compression

(d) tension; tension

7. Strength-to-force ratio: a value ____________ one means the member has failed, while a value ____________ one means the member can safely carry the load.

(a) greater than; greater than

(b) greater than; less than

(c) less than; greater than

(d) less than; less than

8. Under tension, longer members are ____________ shorter members.

(a) stronger than

(b) the same strength as

(c) weaker than

9. Where does the bridge experience the most stress?

(a) The top cord

(b) The middle

(c) The bottom cord

(d) The two ends

10. Using members of several different sizes ____________ the overall cost of the bridge.

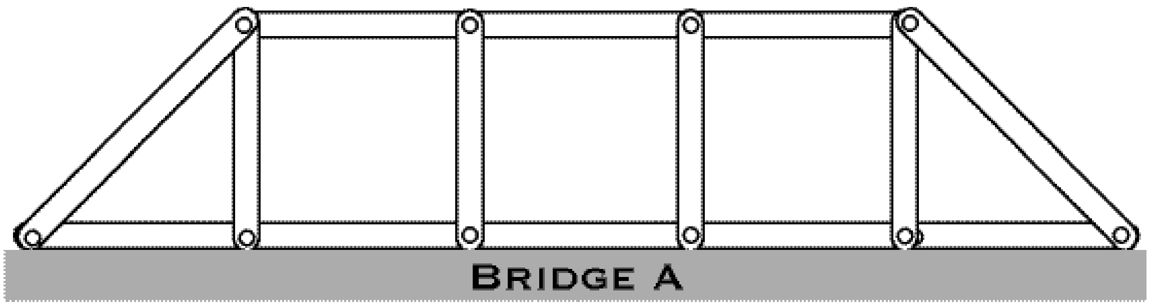
(a) increases

(b) dos not change

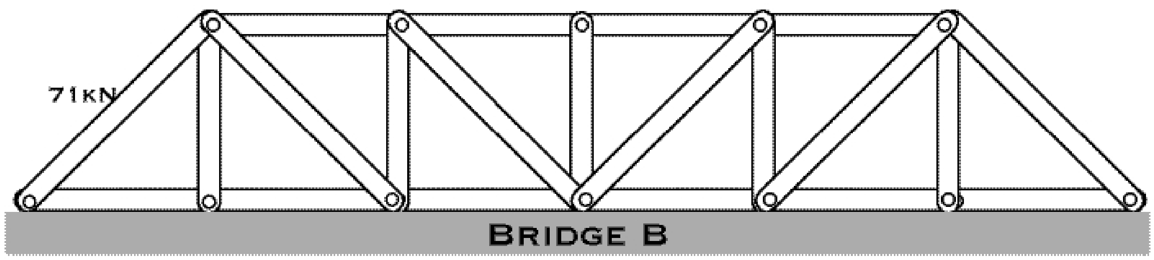
(c) decrease

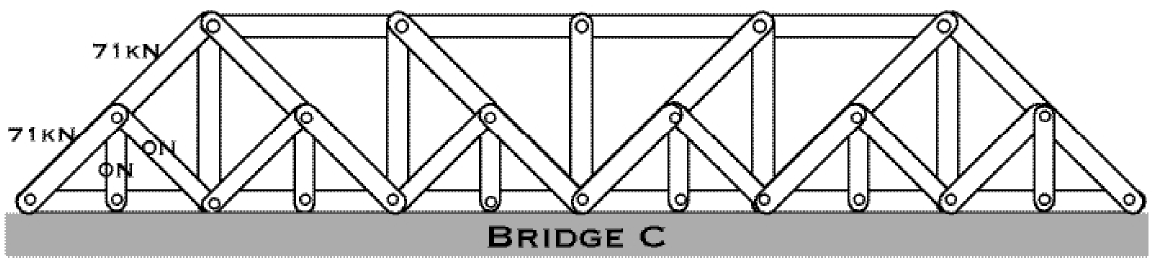
Short Answer

1. The bridge below (Bridge A) is flawed in a significant way. What might be done to the bridge to allow it to carry a load? (Describe your modifications to the bridge)



2. Consider two bridges shown below (Bridge B and Bridge C). Their configurations are similar, with one exception. Bridge C has 12 additional members. Although none of the internal member forces in the diagonals (71kN) change, the bridge is stronger. Why does adding supports, which themselves experience no internal member forces, increase the overall strength of the bridge?





3. Since we have considered the members under compression, describe what you might do to the members under tension (Bridge C), assuming they are made of solid carbon steel bars (160mm), to make the structure cheaper?

APPENDIX C

PROCEDURAL CHECKLIST (TREATMENT GROUP)

PROCEDURAL CHECKLIST (TREATMENT GROUP)

Procedural Steps	Completed		Date
1. Parent consent was obtained	Yes	No	
2. The pre-test was administered to the treatment group	Yes	No	
3. The instructor demonstrated how to launch West Point Bridge	Yes	No	
4. The instructor explained project requirements	Yes	No	
5. Participants in the treatment group used West Point Bridge to build virtual truss bridges and conduct load tests	Yes	No	
6. The post-test was administered to the control group	Yes	No	

APPENDIX D

PROCEDURAL CHECKLIST (CONTROL GROUP)

PROCEDURAL CHECKLIST (CONTROL GROUP)

Procedural Steps	Completed		Date
1. Parent consent was obtained	Yes	No	
2. The pre-test was administered to the control group	Yes	No	
3. The instructor gave a PowerPoint presentation on how to build a simple truss bridge	Yes	No	
4. The instructor explained project requirements	Yes	No	
5. Participants in the control group used given materials to build truss bridges and conduct load tests	Yes	No	
6. The post-test was administered to the control group	Yes	No	

APPENDIX E

PARENTAL PERMISSION FORM

PARENTAL PERMISSION FORM

I agree to allow my child, ____________________, to take part in a research study titled "Effect of a Selected Computer Simulation On High School Students' Academic Performance In Technology Education". The research will be done by Dr. Jay Rojewski and Ms. Feng, from the Department of Workforce Education, Educational Leadership, & Social Foundations at the University of Georgia (551-697-8517). My child does not have to be in this study. If my child does not want to, he/she can refuse to take part in this study. My child can stop taking part at any time without giving any reason, and without penalty.

- The main reason for the study is that in secondary technology education, though computer simulation has been increasingly used in instruction, little research has been done on its effects. Therefore, this research will examine the effects of computer simulation by comparing the scores of students using computer simulation to their counterparts in normal technology education classes.

- If students take part in the research, their understanding of engineering design basic process and related skills may be improved. The researchers also hope to learn something that may help other students learn basic engineering design better in the future.

- If I allow my child to take part in this research study, the following will happen

  1. My child may be chosen to use a computer simulation to create a bridge on computer screen. Or my child may be chosen to use some materials to create a physical truss bridge model. The research will last for three class periods. Each class period will last for one hour. These activities will take place in my child's normal technology education class in Rockdale Career Academy.
  2. My child will complete a test at the beginning of the class. My child will also complete a test at the end of the class. Each test will take about 30 minutes to complete. The tests will be completed in class.
  3. The teacher will collect my child's test scores, which will be used for research. My child's name will be removed from any score as soon as they are collected.

- The research is not going to cause any harm or discomfort. Participation or non-participation in the research will not affect my child's grade or status in the class. My child can stop at any time.

- The researchers will keep my child's identity confidential. No individually-identifiable information about my child, or given by my child during the research, will be shared with others, unless it is required by law. Any records relating to my child will be kept in a locked file. Only the researchers can see the file. After the dissertation is written, the researchers will remove any links between my child's name and my child's results

- The researchers will answer any questions about the research, now or during the course of the research. I can call them at: 551-697-8517.

- I understand the study procedures described above. My questions have been answered to my satisfaction. I agree to allow my child to participate in this study. I have been given a copy of this form to keep.

_________________ _________________ _________________

Name of Researcher Signature Date

Telephone: 551-697-8517
Email: hongfeng@uga.edu

_______________________ _________________ _________________

Name of Parent or Guardian Signature Date

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding my child's rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu

APPENDIX F

STUDENT ASSENT FORM

STUDENT ASSENT FORM

I, ____________________, agree to take part in a research study titled, "Effect of a Selected Computer Simulation On High School Students' Academic Performance In Technology Education". The research will be done by Dr. Jay Rojewski and Ms. Feng, from the Department of Workforce Education, Educational Leadership, & Social Foundations at the University of Georgia (551-697-8517) I do not have to be in this study. If I do not want to, I can refuse to take part in this study. I can stop taking part at any time without giving any reason, and without penalty.

- The main reason for the study is that in secondary technology education, though computer simulation has been used in instruction more and more, little research has been done on its effects. Therefore, this research will examine the effects of computer simulation by comparing the scores of students using computer simulation to their counterparts in normal technology education classes.

- If students take part in the research, their understanding of engineering design basic process and related skills may be improved. The researchers also hope to learn something that may help other students learn basic engineering design better in the future.

- If I agree to take part in this research study, the following will happen

  1. I may be chosen to use a computer simulation to create a bridge on computer screen. Or I may be chosen to use some materials to create a physical truss bridge model. The research will last for three class periods. Each class period will last for one hour. These activities will take place in my normal technology education class.
  2. I will complete a test at the beginning of the class. I will also complete a test at the end of the class. Each test will take about 30 minutes to complete. The tests will be completed in class.
  3. The teacher will collect test scores, which will be used for research. My name will be removed from any score as soon as they are collected.

- The research is not going to cause any harm or discomfort. Participation or non-participation in the research will not affect my grade or status in the class. I can stop at any time.

- The researchers will keep my identity secret. No individually-identifiable information about me, or given by me during the research, will be shared with others, unless it is required by law. Any records relating to me will be kept in a locked file. Only the researchers can see the file. After the dissertation is written, the researchers will remove any links between my name and my results.

- The researchers will answer any questions about the research, now or during the course of the research. I can call them at: 551-697-8517.

- I understand the study procedures described above. My questions have been answered to my satisfaction. I agree to take part in this study. I have been given a copy of this form to keep.

____________________	____________________	____________________
Name of Researcher	Signature	Date

Telephone: 551-697-8517
Email: hongfeng@uga.edu

____________________	____________________	____________________
Name of Student	Signature	Date

Please sign both copies, keep one and return one to the researcher.

Additional questions or problems regarding my rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu