ACHIEVEMENT OF STUDENTS RECEIVING COMPUTER SIMULATION OR HANDS-ON INSTRUCTION IN POSTSECONDARY ELECTRONICS TECHNOLOGY LABORATORY INSTRUCTION

by

KEN ROBERTS

(Under the Direction of ROBERT WICKLEIN)

ABSTRACT

The purpose of this experimental study was to compare the differences in achievement scores in categories based on resistance, voltage, current and power for series/parallel electronics circuits of students receiving laboratory computer simulation or hands-on laboratory skills instruction. The experiment involved beginning technical students in a 2-year community college in an electronics technology associates degree program that required both classroom and laboratory instruction. The dependent variable of this experiment was student achievement scores using a t-test for categories based on resistance, voltage, current and power. The t-test score of the resistance category ($M = 78.57$, $SD = 19.26$) for the hands-on laboratory and ($M = 81.25$, $SD = 16.08$) for the simulation laboratory showed no significant statistical difference. The t-test score of the voltage category ($M = 67.41$, $SD = 15.62$) for the hands-on laboratory and ($M = 69.49$, $SD = 15.30$) for the simulation laboratory showed no significant statistical difference. The t-test score of the current category ($M = 63.99$, $SD = 17.74$) for the hands-on laboratory and ($M = 71.28$, $SD = 15.79$) for the simulation laboratory showed a significant statistical difference and also a greater mean score for the simulation (treatment group) over the the hand-on (control group) post-test scores. The t-test score of the power category (M = 60.12, SD = 17.37) for the hands-on laboratory and (M = 66.52, SD = 12.54) for the simulation laboratory showed no significant statistical difference. The independent variables were the method of providing laboratory skills instruction, either computer simulation of laboratory work or the physical construction of laboratory work.

The study found a significant statistical difference in the current category but not a significant difference in the resistance, voltage and power category between achievement scores using computer simulation laboratory or hands-on laboratory.

Computer simulation laboratory could be used in the development of distance learning or online classes. The computer simulation software could develop the skill set of the electronics student further by introducing various simulations of electronics circuits as the core competencies are achieved by the student.

INDEX WORDS: Technology Education, Computer Simulation, Electronics Technology Instruction, Laboratory Simulation

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CHAPTER 1

INTRODUCTION

The computer has drastically changed the way that technical education is taught in the classroom and the laboratory environment. Computer aided learning and laboratory based education can now be performed with computer simulation that can emulate the tools, laboratory environment and experimentation for developing technical education laboratory assignments. Computer simulations are “designed for acquiring skills, problem solving, or obtaining concepts” for technical education (Shaw & Okey, 1985, p. 1). “The computer simulation becomes important not for what students do while using it, but rather what other things they can now do because of some generalizable skills they have acquired” by using computer simulation (Shaw & Okey., 1985, p. 4). The computer simulation “promises some significant advantages in learning” that “allow students to make choices and observe and act on consequences, provide a way to study cause and effect relationships, make predictions, test hypotheses, gather data and draw conclusions” (Shaw & Okey., 1985, p. 1). Online classes and traditional lecture classes can use the ability of the computer simulation to build laboratory experiments using the computer (Javidi & Sheybani, 2008). McHaney (2009) described computer simulation software together with statistical analysis techniques evolving to give decision makers tools equal to the task for systems development in business, industry and government.

The use of computer simulation increased due to the “availability of computing power and improvements in programming languages to help describe complex real world systems using analytical or purely mathematical models” (McHaney, 2009, p. 9).

This construction of laboratory simulation builds upon instructional methodology and pedagogy based on the cognitive psychology of learning. Cognitive psychologists observe aspects of learning and how students “create and/or learn strategies of reasoning and problem-solving” (Ornstein & Hunkins, 2004, p. 106).

Bruner (1960) researched cognitive learning theory that based learning upon the experiences of the individuals by understanding the changes made on knowledge acquired by enhancing that knowledge further. This learning theory is based on critical thinking skills that are required for most science and mathematical based curriculum that require intuition or “implying the act of grasping the meaning, significance, or structure of a problem or situation without explicit reliance on the analytic apparatus of one’s craft” (Bruner, 1960, p. 60).

The Electronics Technology curriculum at the two-year community college is based on an increasing knowledge set of the fundamentals of electronic circuits and functionality that direct the student to a full understanding of the body of work for the electronics field.

Computer simulation of electronic circuits has become a vital part of learning, discovering and researching the broad understanding of electronics. Throughout the last two decades of the twentieth century, the computer and computer software provides the capabilities for emulation of electronic circuits. Simulated Program with Integrated Circuit Emphasis (SPICE) is an electronic circuit simulation program that was designed by the Electronics Research Laboratory at the University of California at Berkeley in 1973 (Tuinenga, 1988, p. 2).

The Simulated Program with Integrated Circuit Emphasis, version 2, SPICE2™ program was developed from the original SPICE™ program and was finally made a public domain software for use by the general public. The company, MicroSim Corporation, established the first commercial software for use for the personal computer in the early 1980’s that was called

PSPICE™. This software used the same standard programming procedures as SPICE™ called "netlist" files. The netlist file referred to the nodal analysis of the circuit based upon the discrete components connected by nodes.

Software companies such as OrCad and National Instruments now use the fundamental programming from SPICE™ to simulate various electronic circuits. The company, OrCad, now manages the advanced PSPICE™ software for existing computers and is the standard for electronics simulation. The company, National Instruments, also designs and develops software for simulation of electronic circuits called MultiSim™ and Electronics Workbench™.

Aspects of electronic circuit simulations have differed distinctly over the many years since SPICE™ was developed. The simulations have gotten more visual and realistic in comparison to real world circuitry and now have simulated instrumentation such as digital volt meters, signal generators and oscilloscopes that can be used to measure the electronic circuits in software.

Simulation software and its ability to emulate real world electronic circuits have changed distinctly since Microsoft introduced their Windows™ software in 1985. The software environment is graphical in nature using a paper space that simulates paper and a pointing instrument called the mouse that simulates a pen or pencil on the paper space. This added simulation is useful for the new electronics simulation software that could visually display the electronic circuit, discrete devices and wiring.

Problem Statement

This study will research the effectiveness of computer simulation laboratory instruction in comparison to hands-on based laboratory instruction to provide information for use in technical education and the effectiveness of instruction based upon the environment required for both types of laboratory instruction. The simulation based method of laboratory instruction could reduce laboratory expenditures and decrease the amount of laboratory space and equipment for the student and the institution by delivering the simulation of laboratory equipment and procedures within a computer program and implementing the laboratory equipment that would normally have costs associated with the hands-on laboratory instruction.

The visualization and viewpoint of the learner might change with increased use and enhancement of the electronics simulation. In this study the effects of changes to the learning environment for students that are using electronics simulation software will be observed.

Purpose of the Study

The purpose of this experimental study will be to compare the differences in achievement scores of students receiving laboratory simulation or hands-on laboratory skills instruction. The experiment will involve beginning technical students in a 2-year community college in the Electronics Technology Associates Degree Program that requires both classroom and laboratory instruction. The dependent variable of this experiment will be student scores on content knowledge tests covering resistance, voltage, current and power. The independent variable will be the method of providing laboratory skills instruction, either computer simulation of laboratory work or the physical construction of laboratory work.

Research Questions

1. What are the achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation versus those completing hands-on laboratory assignments?

2. Are there statistically significant differences in achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits for students who complete laboratory assignments through computer simulation versus those completing hands-on laboratory assignments?

Theoretical Framework

The overall framework of constructivism is the driving influence for the learner in the simulation environment in order "to engage himself or herself in internalizing and reshaping or transforming information via active consideration" (Ornstein & Hunkins, 2004, p. 117).

The learner in the simulation environment can "conceive their own knowledge base and using their conceptions of events and/or objects in the world." The simulation reveals aspects of discovery that "requires learners to infer knowledge from the information given" (Swaak, Van Joolingen & De Jong, 1998, p. 236). Swaak, Van Joolingen and De Jong (1998) understood that the simulation reveals aspects of discovery that requires learners to infer knowledge from the information given. The knowledge gained from the simulated environment is the basis for this epistemological theory of constructivism.

Constructivism, according to Ornstein and Hunkins (2004) shows that the "learner is the key player; the learner must participate in generating meaning or understanding." Ornstein and Hunkins (2004) continues to describe constructivism:

> The learner cannot passively accept information by mimicking the wording or conclusions of others, rather the learner must engage himself or herself in internalizing and reshaping or transforming information via active consideration. The learner constructs understanding from the inside, not from an external source. In formulating such understanding, the student connects the new learning with

> already existing knowledge, that is, prior experiences. This learning is optimized when the student is aware of the processes that he or she is structuring, inventing and employing. Such awareness of one's cognitive processes and structures and the products or anything related to them is defined metacognition. Metacognition of the constructivist processes means that an individual student is cognizant of the procedural knowledge being employed in order to create knowledge, regulate it, and use it. He or she is also cognizant of the fact that, as a human being, he or she is constantly growing, developing, and evolving. He or she apprehends himself or herself as participating in constructing both physical and cognitive selves interacting with various worlds (Ornstein & Hunkins, 2004, p. 117).

Even Dewey (1910) understood a limited view of constructivism in regard to empirical and scientific thinking in his book, "How We Think":

> Experience is not a rigid and closed thing; it is vital, and hence growing. When dominated by the past, by custom and routine, it is often opposed to the reasonable, the thoughtful. But experience also includes the reflection that sets us free from the limiting influence of sense appetite and tradition. Experience may welcome and assimilate all that the most exact and penetrating thought discovers. Indeed, the business of education might be defined as just such an emancipation and enlargement of experience. Education takes the individual while he is relatively plastic, before he has become so indurate by isolated experiences as to be rendered hopelessly empirical in his habit of mind (Dewey, 1910, p. 156).

The psychologist Jerome Bruner understood the constructivist theory as an "active process" where learners construct new ideas based upon current or past knowledge. The learner selects and changes the information to make decisions based on “cognitive structure.” The cognitive structure is the meaning or organization of the structured experiences to allow the learner to build upon existing knowledge and discovery.

Bruner (1960) made the distinction that analytical learning and intuitive learning were delineated by a linear process of thinking for analytical reasoning and a varied learning process for intuitive learning. The constructivist theory of knowledge would therefore show that the combination of both analytical reasoning and intuitive reasoning are “complementary” (Bruner, 1960, pp. 57-58). Bruner (1960) was concerned with the nature of learning at an observable level and to be able to recognize if the learner is using analytical reasoning or intuitive reasoning.

The computer simulation environment provides a high level of interaction where learners are able “to vary the parameters of a system and thus actively control both the course and final state of the simulated process.” Computer simulations can help support learners “cognitively and emotionally and thus lead to increased learning gains” (Yaman, Nerdel & Bayrhuber, 2008, p. 1784).

The simulated experiment will furnish the situation and context in which students can create and learn the physical environment of the simulated real-life interaction. The computer simulation doesn’t totally create the realities of the laboratory experience, but will enhance the properties that stimulate the learning experience for the student through the use of computer software and hardware. The student can orient their own meaning through the use of the computer simulation and manipulate outcomes based upon this altered state of reality (Ornstein & Hunkins, 2004, p. 118).

Significance of the Study

Okey and Oliver (1987) showed that simulation modeling has yielded findings related to the design, preparation, and study in both the science and engineering professions. The computer simulation "provides a means of experimenting with the world and allows interaction with difficult, dangerous, expensive or time-consuming events" (Okey & Oliver, 1987, p. 1)

Academic institutions are presently using computer simulation to model actual equipment that can sometimes be costly to build. The computer simulation helps to alleviate the problem of budget and space in order to enhance the learning environment with limited costs and equipment. The computer simulation can also be used to enhance existing laboratory equipment and give comparisons to the student when using computer simulation software and the actual laboratory work (Yaman et al., 2008).

Computer simulation can "incorporate worked-out examples that have the potential to positively influence the learner's situational-subject-interest in highly complex subject-matters" (Yaman et al., 2008, p. 1784). The computer simulation "adds pedagogic value involving time compression and reduction of danger" within the learning environment to allow "students to make choices, observe consequences, study cause and effect relationships, make predictions, test hypotheses, gather data and draw conclusions" (Okey & Oliver, 1987, p. 3)

Constructivism "places the individual as the active person in the process of thinking, learning and coming to know" (Ornstein & Hunkins, 2004, p. 117). The learner must "engage himself or herself in internalizing and reshaping or transforming the information via active consideration" (Ornstein & Hunkins, 2004, p. 117). Ornstein and Hunkins (2004) continues to explain this interaction as:

> a process that he or she is structuring, inventing and employing. Such awareness of one's cognitive processes and structures and the products or anything related to them is defined as metacognition. Metacognition of the constructivist processes means that an individual student is cognizant of the procedural knowledge being employed in order to create knowledge, regulate it, and use it. He or she is also cognizant of the fact that, as a human being, he or she is constantly growing, developing, and evolving. He or she apprehends himself or herself as participating in constructing both physical and cognitive selves interacting with various worlds.

Constructivism combines the learner with his or her environment as a symbiotic relationship within both the "nature of learning and the nature of knowledge" (Ornstein & Hunkins, 2004, p. 116). Ornstein and Hunkins (2004) reveal that constructivism emphasizes the learner and that the learner must participate in generated meaning or understanding within the learning process. The learner must "engage himself or herself in internalizing and reshaping or transforming information via active consideration (Ornstein & Hunkins, 2004, p. 117)

The learner "constructs understanding from the inside, not from external sources and connects the new learning with already existing knowledge that is prior experience" (Ornstein & Hunkins, 2004, p. 117). Javidi (2004) concluded the significance of computer simulation as:

> having a role to play in distance education, the question still remains as to whether they can replace the need for real and practical laboratory knowledge. The goal of this study is to contribute to traditional and online engineering education by infusing simulation for performing laboratory experiments and investigating its effects (Javidi, 2004, p. 12).

Summary

This study will provide an understanding of simulation as used in laboratory experiments for learning electronics fundamentals and its advantages for teaching traditional technical coursework in electronics. The use of computer simulation for laboratory experimentation might improve both traditional classroom instruction and enhance traditional laboratory hands-on experimentation in electronics technology education. Simulation software during the past several years have considerably improved the organization, structure and reality of the emulation of electronics circuits and helped to improve the simulated environment of the traditional electronics laboratory. Improvements in software design and computer hardware requirements including computational speed have helped the simulation software to be used in a traditional electronics laboratory. Therefore, traditional methods of hands-on experimentation in electronics technology education could be enhanced through the use of computer based laboratory instruction.

CHAPTER 2

REVIEW OF THE LITERATURE

The History of Technical Education

In U.S. education practices during the years after World War II, an expansion of growth continued in the post-secondary level of higher education that would transform the technological prowess and technical education of the United States of America. The Serviceman's Readadjustment Act of 1944 or otherwise known as the G.I. Bill enacted by congress would provide new opportunities for returning veterans to enjoy the pursuit of higher education and additional training and technical education (Gutek, 1991, p. 150).

From the years after the war until about the 1970's, this generation of returning veterans would coincide with some of the most drastic changes in American technological history. The history of technology spans the centuries of mankind's practical use of the physical elements in order to harness and control the environment in which we work, play and enjoy intellectual stimulation. The infant country of the United States began with this ability of shaping one's environment and utilizing technology in order to fulfill personal "manifest destiny" and as a whole for a nation. Buildings, bridges, roads, canals and cities were designed and built using the latest technologies based upon empirical discoveries of the sciences throughout history. A new world required the ability to adapt to a new environment that was controlled through technology. By the turn of the twentieth century, modern technology had achieved the advent of flight, railroads, automobiles, electrical energy and power production and modern lighting (Kirby., Withington, Darling & Kilgour, 1990, p. 385).

The applied sciences had followed the Industrial Revolution and the civilian engineering professions (buildings, bridges and canals) that brought the importance of scientific and technical education as a "prerequisite for engineering practice" (Kirby et.al., 1990, p. 327).

The earliest schools of engineering were established in the eighteenth century by the French including the well known school, *Ecole des Ponts et Chaussees,* founded in 1747, *Ecole des Mines*, *Ecoles d'Arts et Metiers* and the *Ecole Polytechnique* in 1794. According to Kirby, Withington, Darling and Kilgour (1990), who summed up best the history of this period in technical education by making the following statement:

> By 1840 in the United States there were only two schools offering instruction in engineering, the Military Academy at West Point and the Renssalaer School at Troy. In the ten years following the passage of the Morrill Land Grant Act of 1862, the objective of which was to stimulate the establishment of new technological schools by the granting of lands from the public domain, the number of such American schools jumped from 6 to 70. In general, American schools up to 1900 adapted European educational techniques and had little direct share in the advancement of the art. American schools did not begin to give formal instruction in electrical engineering until toward the end of the nineteenth century. The rapid rise of engineering science in the nineteenth century extensively altered the practice of engineering and lent considerable impetus to the evolution of technical education (Kirby et al., p. 328).

In some ways the technological education of this period was based on a utilitarian view of education rather than an academic rationale. The technological advances required an education that was not only utilitarian, but also hands-on and practiced as a craft responding to the guilds of previous technological history (Lewis, 2004, p. 21).

In the United States, technical education evolved from four major phases of settlement and growth as described by Thompson (1973):

> The first permitted the (a) harnessing of power and the bringing of work to machines. The second permitted (b) mass production through assembly-line techniques. The third phase saw (c) automation applied to assembly-line techniques. And the fourth is defined by (d) new materials and new processes. The first phase was of English origin and American adoption. The other phases were of American origin. (Thompson, 1973, p. 47)

American technology history begins with the urbanization of the American people and the combination of the Industrial Revolution that required the craftsmen to hone their skills in factories. Mass production increased the efficiency at which capital could manufacture and created a new type of craft which required understanding machinery that was automating the processes. These combinations of changes in the technological environment increased the demand for specialized and increase technical education for the various parts of the changing American workplace (Thompson, 1973).

In the United States, higher education was directly affected by the Second World War and returning veterans and the enrollment at colleges and universities increased dramatically during the 1950’s and early 1960’s. President Kennedy enacted the Higher Education Facilities Act of 1963 that helped to alleviate the growing pains of expansion and enrollment during this time. As an extension to the Smith-Hughes Act of 1917, the added national fiscal needs for technical education could be extended through the placement of the G.I. Bill, and the Higher Education Facilities Act of 1963 (Thompson, 1973).

The two-year college or junior college increased in enrollment during the early part of the twentieth century. From the years of 1922 to 1939, the number of two-year institutions had increased from 207 to 575. The two-year colleges were first conceived by presidents as a “means to divert the responsibility for educating first and second-year undergraduates to other institutions” (Gutek, 1991, p. 156). Eventually the two-year college in the United States would develop curriculum that would meet the needs to serve the community, “socially, civically, religiously and vocationally” (Gutek, 1991, p. 156).

During the Depression of the 1930’s, many two-year institutions began to “place greater emphasis on vocational and technical training programs” (Gutek, 1991, p. 156). The Smith-Hughes Act of 1917 provided federal aid for technical education for the two-year colleges and helped these institutions to establish an environment that “justified contributions to economic and social utility” (Gutek, 1991, p. 157). Occupational skills were encouraged during the Depression that was to become a demanding period of American history that encouraged further educational pursuits and technical education (Gutek, 1991, pp. 156-157).

These changes corresponded with demands by technology, especially through the use of electricity. The invention of the vacuum tube at the turn of the century and modern electronic equipment that were invented from this device helped to increase the rapid growth of the electronics industry. The study of electronics was considered a small subset of the study of the physical sciences, but grew rapidly as new electronic devices were developed. The invention of the radio in the 1920’s and television broadcasting were a direct result of understanding the fundamental devices of electronics. During World War II, the electronics field began to expand due to the need for radar and high-frequency communication. The electronic computer was developed during this period for complex computations for both civil and military applications. With the invention of the transistor in 1947 at Bell Labs by Walter Brattain, John Bardeen and William Shockley, the advent of solid-state electronics and miniaturization would unfold. In 1950, the integrated electronic circuit was invented at Texas Instruments by Jack Kilby, which could place many electronic devices on a single semiconductor material. This led to an increase in productivity, manufacturing and further miniaturization. The electronics industry was further enhanced by the United States involvement in the "space race" with the Soviet Union by designing new spacecraft, rockets and aircraft using many electronics devices in order to achieve their goals (Floyd, 2002).

These rapid changes in the electronics industry and the increasing knowledge base of electronic devices information required an informed worker that could learn this new field of physics. The two-year institutions and technical schools expanded the curriculum to match the demands of this new industry.

The History of Electronics Education

The concepts of teaching electricity and electronics have been a challenge for education. The attempts to overcome these challenges have been applied by writing texts that facilitate the conceptual understanding of electric circuits. The difficulties that students have are an incomplete understanding of the theoretical models of electric circuits to real circuits (Jaakkola & Nurmi, 2004, p. 2).

The national trade associations provided guidelines for the technical education curriculum, and the Electronics Industry Association cooperated with industry and educational institutions. The Electronics Industry Association wanted a constant exchange of "information to keep the program realistic and to fit the changing needs of the electronic industry" (Burt, 1967, p. 32). In 1953, the Voorhees Technical Institute in New York City was assisted by the Electronics Industry Association to develop curriculum, courses of study and instructional material for use in secondary and post-secondary schools (Burt, 1967, p. 193).

The success of this partnership between the Electronics Industry Association and the Voorhees Technical Institute prepared a basic "pre-employment course designed to train beginners in the growing field of electronics" and publishing training manuals for electronics technicians (Burt 1967, p. 193).

The use of programmed instruction in electronics education was developed to enhance the learning of the basic material that required repetition of difficult subject areas. The programmed instruction method began a print-based text but eventually the process incorporated both mechanical and computerized means in order to benefit the learner. Programmed instruction is meant to give the learner immediate feedback and information for assisting in additional challenges for the electronics curriculum (Lockee, Moore & Burton, 2001, p. 61).

The teaching of electronics requires a basic understanding of applied physics and math, basic electricity, electronic components and circuits and how they contribute to the overall understanding of electronic devices for the foundations of modern electronic equipment (radio, television, robotics, computers, amplifiers, digital systems, communication devices, cell-phones, radar and many others). The electronic technician should be able to troubleshoot, repair, service and install electronic products.

Terman (1998) related the emphasis of teaching electronics fundamentals and electrical engineering courses as being transformed during the decade after the war. World War II brought "such new electrical and electronic techniques such as radar, microwaves, control systems, guided missiles and proximity fuses that led electrical engineers unprepared in the fundamental knowledge required to think creatively about these new concepts” (Terman, 1998, p. 1792). Terman (1998) further explained that:

> The history of electrical engineering education parallels the development of the electrical industry, particularly of the electrical manufacturing industry. The electrical experimenters, inventors, and innovative entrepreneurs such as Edison, Morse, Weston, Brush, Bell, Sprague, Westinghouse, Thomas, etc. who developed the early practical applications of electrical phenomenon, were either trained in related disciplines such as physics, chemistry, mechanics, etc. or were self-trained resourceful tinkerers possessing elements of genius. However, once industrial applications had been developed to the point where there were electrical installations to be designed and electrical equipment to be manufactured and sold in substantial volume, a need existed for trained electrical engineers to design, test, and improve this equipment as well as to supervise production, installation, and maintenance. Thus the history of electrical engineering education over the years has paralleled the developments taking place in electrical manufacturing (Terman, 1998, p. 1792).

The first educational program in the United States to develop an electrical curriculum was the Massachusetts Institute of Technology (MIT) in 1882. The courses were developed under the sponsorship of Professor Charles Cross, the head of the Physics Department designed for students interested in the branches of study in electrical engineering. The curriculum was finally changed to Electrical Engineering in 1884 under the Physics Department, but later changed to the Department of Electrical Engineering in 1904. “Similar programs quickly followed at other institutions like Cornell University and the University of Wisconsin" (Terman, 1998, p. 1794).

Terman (1998) continued to explain the situation of electrical engineering curriculum before and after World War II:

> World War II made profound changes in the education of electrical engineers. The war developments such as radar, microwaves, pulse technology, sophisticated control systems, electronic navigation systems, new types of electronic instrumentation, etc. added dimensions to the electrical (electronics) industry that did not die out at the end of the war, but rather continued as permanent additions to the field of electricity. Furthermore, the technological impetus generated by the war continued into the postwar period, and led to such postwar developments as the transistor, integrated circuits, magnetic recording, computers and calculators, guided missiles, communications satellites, the laser, etc. Television displaced radio as the most popular medium of mass entertainment, to be followed by color television. The result was a virtual explosion of the electrical (electronic) industry. Innumerable new products and devices found a ready reception in the marketplace, and new companies sprang up, first by the hundreds and then by the thousands. Moreover, the tight patent monopoly that had been maintained in the electronics industry through the 1920's and 1930's by RCA, General Electric, Westinghouse, etc., was loosened by the war developments, and the field became essentially open to all comers on reasonable terms. Those electrical engineering educators who participated in the war developments recognized this situation, and

> upon returning to their institutions at the end of the war, were forces for upgrading the education of electrical engineers (Terman, 1998, p. 1798).

During the 1960's the federal government and the military became more involved in the curriculum development of electronics education. Through the use of research and development labs the large curriculum development projects educators accepted the idea that instruction could be developed by professional organizations beyond the educational institution (Shrock, 1995, p. 6)

The Definition of Computer Simulation

Years of research in simulation modeling has been achieved over the past several decades for finding research results for design, preparation and study in both the science and engineering professions. The aerospace industry has been using flight simulators to evaluate the progress of aerodynamic design and development for experimental aircraft and commercial flying purposes. The computer has allowed designers, architects and engineers to simulate everything from buildings, bridges and roads to assessing the structural limitations and uses by the general public through computer simulation.

Even in the aeronautical and aerospace industries the flight simulator has been used to train beginning pilots and experienced pilots on unknown parameters and situations to best determine actual flight circumstances. Through this use of computer simulation, the education of flight engineers, pilots and navigators has been advanced to ensure the safety of the general public and expensive aircraft. The computer simulation software is now used as an educational instructional tool to enhance the learning environment of fundamentals of the sciences and engineering.

The Impact of Computer Simulation

Academic institutions sometimes use computer simulation to model actual equipment that can sometimes be costly to build. The computer simulator helps to alleviate the problem of budget and space in order to enhance the learning environment. The computer simulation can also be used to enhance existing laboratory equipment and give comparisons to the student when using computer simulation software and the actual laboratory work (Yamen et al., 2008).

Accordingly, computer simulation can “incorporate worked-out examples that have the potential to positively influence the learner’s situational-subject-interest in highly complex subject-matters” (Yaman, et al., 2008, p. 1785).

Bayrak, Kanli and Ingec (2007) explained the methodology of the learning environment in primary and secondary schools that teach electronics with the use of a computer simulation environment:

> The students can learn the knowledge most easily in real surroundings where they can observe the concepts and processes, but in these surroundings it can not always be possible to make observations. To teach this kind of knowledge simulated environments such as laboratories are widely used. In laboratories, studies can be done by means of concrete, real or artificial materials. The studies done in laboratories increase the interests and successes of the students for the subjects of science (Bayrak, Kanli, & Ingec, 2007, p. 2).
>
> The subjects of science are usually complex and abstract. A number of students attending primary and secondary schools need experiences which they will be able to get through concrete materials in laboratories to comprehend abstract subjects. The active participation of the student in the analyses of the real events

> and in the process of collecting data is the main element of the program which is depended on the philosophy of inquisitive approach. This provides ease for the student to understand the method and the essence of the science, to improve the ability of solving problems, to have ability of making inquisitions and generalizations, to get the scientific knowledge and to improve positive attitudes (Bayrak et al., 2007, p. 2).
>
> Computer based learning is a method, which uses computers in a learning media and strengthens students' motivation and educational processes (Bayrak et. al., 2007, p. 2).

Bayrak et al. (2007) continued to explain that simulations are "transfers of the events with specific limitations in daily life to the computer medium." He also saw that "simulations help the students to form their own cognitive models about events and processes and offer the opportunities for observing easily the events that occur too slowly or too fast in the laboratory and might cost too much to evaluation or be too hazardous to build" (Bayrak et al., 2007, p. 2).

Dobson, Hill and Turner (1995) also gave the underlying pedagogy for laboratory experimentation with electronics:

> All core course are backed-up by practical and laboratory work. In electronics the aim is to impart an understanding of systems and devices without spending excess time learning circuit fabrication skills. A prime motivation for the work described was to reduce the amount of time spent by undergraduates building and debugging circuits, so that the important lessons of circuit behavior are not obscured" (Dobson, Hill & Turner, 1995, p. 13).

Dobson et al. (1995) further noted that the computer simulation of the laboratory exercises might "increase speed and efficiency of learning." Through his study, the software simulation package had the advantage of reducing the amount of time that students would spend in "building or debugging electrical circuits" (Dobson et al., 1995, p. 13).

Ronen and Eliahu (2000) introduced a simulation of electric circuits to high school students and noted the following:

> Electricity is a basic science topic with relevance to everyday life; it is studied a number of times, at various levels, from elementary school to college. Teaching and learning is based on extensive use of formal representations and on real experiments. Most of the common difficulties students have in the study of simple electric circuits are due to an incomplete understanding of the concepts by which idealized models predict the behavior of the system. Other difficulties seem to stem from an inability to relate formal representations to real circuits (Ronen & Eliahu, 2000. p. 14).

Ronen and Eliahu (2000) explained that constant assistance needed to be provided to the students in order to convey this connection between formal representation and real experimentation. He thought that computer simulation might enhance the speed at which this feedback to the students could be helpful.

In a similar vain of thought, Sahin (2006) suggested that computer simulation "supplement classroom instruction and laboratory dependent upon the instructor's use and implementation." He further noted that:

> Multimedia supported, highly interactive, collaborative computer simulations appealing growing interest because of their potentials to supplement constructivist

> learning. They offer inquiry environments and cognitive tools to scaffold learning and apply problem-solving skills. Computer simulations are good tools to improve students' hypothesis construction, graphic interpretation and prediction skills. They have the potential for distance education laboratories (Sahin, 2006, p. 1).

In studying simulation for physics students, Jimoyiannis and Komis (2001) suggested that "conventional instruction is ineffective in dealing with misconceptions and that students' alternative conceptions of velocity and acceleration are considered not to be as easily affected by traditional instructional methods" (Jimoyiannis & Komis, 2001, p. 183).

Jimoyiannis and Komis (2001) further stated that:

> A common research assumption is that students possess a system of beliefs and intuitions about physical phenomena mainly derived from their everyday experience. Such systems and beliefs and intuitions are usually incompatible with scientific theories and knowledge; they have been referred to as misconceptions or alternative conceptions (Jimoyiannis & Komis, 2001, pp. 183-204).

> Jimoyiannis and Komis (2001) continued with understanding "the main aim of an alternative constructivist teaching approach should then be the development of such conditions that would facilitate students' active engagement in learning and functional understanding of physics." He believed that the important issues for this constructivist theory of education was to "approach learning as the study of the effects of computer tools aimed to facilitate students' active engagement in physics teaching and learning (Jimoyiannis & Komis, 2001, pp. 183-204).

Computer Simulation for Teaching Electronics

The traditional method for teaching electronics in the laboratory environment has been an applied laboratory procedure for measuring, troubleshooting and evaluating electronics circuits. This method involves basic understanding by the student of foundational knowledge in the field of electronics. A student who works in the electronics laboratory must understand an analytical view of the electronics circuit by understanding basic algebraic laws that are derived to understand resistance, circuit behavior, electrical circuit flow and troubleshooting.

The basics of understanding the laboratory procedures for a given electronics circuit begin with electron flow, power storage, circuit current flow and Ohms' Law.
An electronics circuit can be built with resources such as wiring, batteries, resistors, capacitors and inductors. The traditional method of construction of an electronic circuit in the laboratory would consist of acquiring the required components for creating a working electronics circuit. The circuit can be built by a wiring method that requires breadboards that can be soldered, or can be built using solderless breadboards that can easily be built and taken apart. The use of the solderless breadboard decreases the amount of time to build a working electronics circuit.

The computer simulator helps to alleviate the problem of using actual parts to construct the electronics circuit. The parts are easily used within the computer simulator to create the electronics circuit to be analyzed and simulated. Companies have built simulators for many years to emulate the materials and breadboard needed for building electronics circuits in the laboratory. National Instruments in Austin, Texas have been selling the computer simulator, *Multisim* or *Electronics Workbench* since 2001. This simulator is a leader in the simulation market for electronics circuit simulation that uses standardized programming and analysis of circuits with the SPICE programming language for electronics circuits.

In the traditional laboratory setting for teaching electronics to students, the physical components are required to build, test and troubleshoot a particular electronics circuit. The electronics circuit is developed by the initial understanding of basic electronics concepts that rely on scientific observation, scientific laws and practice. The electronics circuit that is used in laboratory work should represent the mathematical and theoretical framework that is required for the study of electronics. The laboratory prepares the student to use skills that translate the theoretical framework into practice by building a step process for understanding basic electronics circuits to more complex electronics circuits.

The computer can be used to complement the teaching of electronics by assisting the student in the laboratory. Gandole, Khandewale and Mishra (2006) believed that there were many ways to implement the computer in laboratory instruction. Of these different implementations are (a) to communicate the basic knowledge or theory related to practical work in electronics, (b) to assist the students in selecting the measuring instruments and electronics components required for performing an experiment in the laboratory, (c) to develop the competency of assembling the practical circuit, (e) to communicate procedure or demonstration of an experiment and (f) to reduce the labor of calculation and to obtain accuracy in design or results.

Computer or software uses within the computer have changed the way that education is delivered in the classroom to the student. Gandole et al. (2006), explains that “software tools in various forms have started playing an increasing important role in educating students of traditionally hard engineering subjects like electrical, mechanical or civil engineering.” It can be shown that as “computer-based tools have become more affordable, the expectation that time and distance factors will have less impact on the way instruction is delivered to students of such subjects." (Gandole, Khandewale & Mishra, 2006, pp. 1-2)

Okey and Oliver (1987) conducted a study on the impact of computer simulations as having a positive interaction when laboratory experiments can be "difficult, dangerous, expensive and time-consuming." They continued to praise aspects of computer simulation as "promising some significant advantages to learning which would allow students to make choices and observe and act on consequences." The computer simulation would "provide a way to study cause and effect relationships, to make predictions, to test hypotheses, to gather data, and to draw conclusions" that allow the student to implement. (Okey & Oliver, 1987, p. 1)

The analytical thinking skills and higher level problem solving supplied by the computer simulation would constitute an "important objective that would accompany classroom work" and laboratory skills. Okey and Oliver (1987) came to an important aspect of computer simulation that showed that the "computer simulation becomes important not for what students do while using it but rather what other things they can now do because of some generalizable skills they have acquired." (Okey & Oliver, 1987, p. 2)

Shaw and Okey (1985) also understood that computer simulations "are designed for acquiring skills, problem solving, or obtaining concepts." The computer simulation "enables students to focus their attention on common parts of concepts and results in some attitude change about the learning skills using the computer simulation." In the Shaw and Okey (1985) study of middle school students using computer simulation for science concepts, they noticed that it was "logical for high cognitive level students to score high on performance tasks which involve simulations as an instructional strategy" (Shaw & Okey, 1985, p. 2).

Yaman, Nerdel and Bayrhuber (2008) discussed the influence of computer simulation as:

> the instructional tasks can help the learner identify the simulation's learning objectives as well as central aspects of the topic in question. Thus they serve to structure the learning process and make learning objectives more transparent. The interest resulting from the computer simulation is considered both the objective of a learning session (situational subject-interest) and an explanatory factor for learning results (individual subject-interest and computer-interest) (Yaman et al., 2008, p. 1786).

Yaman et al. (2008) showed that "computer simulations have special value as they offer a high potential for interactive learning, where learners are able to vary the parameters of a system and thus actively control both the course and the final state of the simulated process" (Yaman et al., 2008, p. 1784).

Javidi and Sheybani (2008) discussed computer simulations in their study as "offering students opportunities to explore situations that may be impossible, too expensive, difficult and time-consuming to accomplish with actual laboratory or real-life experiences." They implied that "even if real-life experiences seem feasible, simulations offer students the opportunity to explore a wide range of variables quickly to supplement such experimentations." Javidi and Sheybani (2008) believed that computer simulations as "being safe, convenient and controllable and the simulation-based laboratories can be made available to anyone, anywhere and anytime" (Javidi & Sheybani, 2008, p. 65).

In a study of computer simulations in teaching physics, Jimoyiannis and Komis (2001) explained the complexities of learning a scientific subject as:

> Research on physics and science education has often focused on the study of alternative conceptions and mental representations that students employ before

> and after instruction. Related to the above is research focused on the study of the consequences of special teaching interventions aiming to transform students' alternative conceptions. A common research assumption is that students possess a system of beliefs and intuitions about physical phenomena mainly derived from the everyday experience. Such systems of beliefs and intuitions are usually incompatible with scientific theories and knowledge; they have been referred to as misconceptions, or alternative conceptions. Research findings also suggest that conventional instruction is ineffective in dealing with misconceptions. Students' alternative conceptions of velocity and acceleration, for example, are considered to be as not easily affected by traditional instructional methods. The main aim of an alternative constructivist teaching approach should then be the development of such conditions that would facilitate students' active engagement in learning and functional understanding of physics. Furthermore, such an approach should enable students to effectively apply physical concepts and principles in novel situations (Jimoyiannis & Komis, 2001, p. 184).

In the research on problem-solving approaches by Geban, Askar and Ozkan (1992) believed that "instructional methods used in school science courses are important for developing higher mental ability, science achievement, and attitudes toward science." In this study, they stated that "problem-solving, discovery, or inquiry approaches are generally referred to as the investigative approach" (Geban, Askar & Ozkan, 1995, p. 5).

In this study of computer simulation, Geban et al. (1995) explained the "capabilities of computers, such as providing individualized instruction, teaching and problem-solving, and immediate feedback are desirable properties in using computers as instructional devices for developing learning outcomes" (Geban et al., 1995, p. 6).

Experience Based Learning and Discovery Theory

Experienced based learning and discovery were the determining theories of inquiry for this study. These theories were used to assess a student's ability to perform a computer based laboratory assignment that simulates a real world based laboratory assignment. The overall framework of constructivism is the driving influence for the learner in the simulation environment in order "to engage himself or herself in internalizing and reshaping or transforming information via active consideration" (Ornstein & Hunkins, 2004, p. 117).

Learners in the simulation environment are "conceived as constructing their own knowledge base and using their conceptions of events and/or objects in the world." The simulation reveals aspects of discovery that "requires learners to infer knowledge from the information given" (Swaak et al., 1998, p. 236).

The computer simulation environment provides a high level of interaction where learners are able "to vary the parameters of a system and thus actively control both the course and final state of the simulated process." Computer simulations can help support learners "cognitively and emotionally and thus lead to increased learning gains" (Yaman et al., 2008, p. 1784).

The simulated experiment will "furnish the situation and context" in which students can create and learn the physical environment of the simulated real-life interaction. The computer simulation doesn't totally create the realities of the laboratory experience, but will enhance the properties that stimulate the learning experience for the student through the use of computer software and hardware. The student can orient their own meaning through the use of the computer simulation and manipulate outcomes based upon this altered state of reality (Ornstein & Hunkins, 2004, p. 118).

The constructivist view of education has an extended history that can be shown derived from educational thinkers like Piaget, Vygotsky and Dewey. The constructivist view is similar to a new understanding of reconstructionist theories as describe by Lerwick (1979).

According to Lerwick (1979), the reconstructionist viewpoint for the vocational teacher or instructor:

> Should have the competencies and knowledge required to prepare students for entry level employment (momentary expediency). He or she also ought to be able to influence, motivate and direct beliefs or attitudes toward a desired future order. The teacher is responsible for evaluating the past history of work, and to either expose its undesirable traditions or eliminate them from the curriculum. The teacher should be a dedicated social activist who is routinely involved in promoting a more humane and democratic working environment. The best method of teaching is real-life involvement in work projects and in their related social aspects. Students need to experience real vocations and occupations and then be taught to analyze them for ways of making the work more humanly rewarding. Direct student involvement in all aspects of the job ought to be encouraged (Lerwick, 1979, p. 31).

Constructivist Learning Theory

Constructivism, according to Ornstein and Hunkins (2004) shows that the “learner is the key player; the learner must participate in generating meaning or understanding.” Ornstein and Hunkins (2004) continues to describe constructivism as:

> The learner cannot passively accept information by mimicking the wording or conclusions of others, rather the learner must engage himself or herself in internalizing and reshaping or transforming information via active consideration. The learner constructs understanding from the inside, not from an external source. In formulating such understanding, the student connects the new learning with already existing knowledge, that is, prior experiences. This learning is optimized when the student is aware of the processes that he or she is structuring, inventing and employing. Such awareness of one's cognitive processes and structures and the products or anything related to them is defined metacognition. Metacognition of the constructivist processes means that an individual student is cognizant of the procedural knowledge being employed in order to create knowledge, regulate it, and use it. He or she is also cognizant of the fact that, as a human being, he or she is constantly growing, developing, and evolving. He or she apprehends himself or herself as participating in constructing both physical and cognitive selves interacting with various worlds (Ornstein & Hunkins, 2004, p. 117).

Even Dewey (1910) understood a limited view of constructivism in regard to empirical and scientific thinking in his book, "How We Think":

> Experience is not a rigid and closed thing; it is vital, and hence growing. When dominated by the past, by custom and routine, it is often opposed to the reasonable, the thoughtful. But experience also includes the reflection that sets us free from the limiting influence of sense appetite and tradition. Experience may welcome and assimilate all that the most exact and penetrating thought discovers. Indeed, the business of education might be defined as just such an emancipation

> and enlargement of experience. Education takes the individual while he is relatively plastic, before he has become so indurate by isolated experiences as to be rendered hopelessly empirical in his habit of mind (Dewey, 1910, p. 156).

The psychologist Jerome Bruner understood the constructivist theory as an "active process" where learners construct new ideas based upon current or past knowledge. The learner selects and changes the information to make decisions based on "cognitive structure". The cognitive structure is the meaning or organization of the structured experiences to allow the learner to build upon existing knowledge and discovery.

Constructivism supports the hands-on approach to learning and discoveries and conclusions that the learner can provide. The electronics curriculum lends itself to a constructivist learning environment due to programmed instruction and the hands-on environment of learning electronics circuits.

Review of Previous Computer Simulation Research

In their paper, *Supporting Simulation-Based Learning: The Effects of Model Progression and Assignments on Definitional and Intuitive Knowledge*, Swaak et al. (1998) understood "with respect to learning from simulation, a stable finding across most studies is that simulation-based learning is hard, posing problems for the learner" (Swaak et al., 1998, p. 237). Even though they understood this tendency in simulation environments, a "way to help learners extract knowledge from simulation environments entails providing learners with support that properly deals with the low transparency and the richness of simulation" (Swaak et al., 1998, p. 237). Swaak et al. (1998) further believed that the "transparency aspect is not an issue with expository instruction or traditional textbooks, where expository instruction usually directly exposes the structure and contents of the subject matter to learners" (Swaak et al., 1998, p. 237).

Some areas of electronics instruction have used programmed instruction to guide the student in understanding the material and help the student to learn by behavioral circumstances. During the 1950's the developed program instructional development became popular as a behavioral method advocated by B. F. Skinner. Programmed instruction involved behavioral objectives, self-pacing techniques and learner response to give the learner immediate feedback for response to questions. These parameters of learning in programmed instruction emphasize various aspects of electronics definitions and usage such as Ohm's law, Kirchoff's voltage and current equations, power law, series resistance calculation and parallel resistance calculations. The computer simulation software achieves further expansion of learning by immersing the student in participation and creativity.

Criteria for distinguishing the use of the computer simulation for an electronics laboratory versus a hands-on environment can be determined as the following in table 1:

Table 1

Hands-On versus Computer Simulation Criteria

Hands-On	Computer Simulation
Collecting data	Simulating behavior of circuits
Processing measurements	Simulating measurement of circuits
Testing wiring	N/A
Equipment configuration	Simulation of circuit components
Troubleshooting	Analytical troubleshooting
Assembly	N/A
Space required	Unlimited Space requirements
Cost of components	Cost of Simulator
Safety precautions	N/A
Senses required	N/A

Note: Criteria for comparison of hands-on laboratory and computer simulation laboratory exercises. Adapted from "A Comparison of Students' Attitudes Between Computer Software Support and Traditional Laboratory Practical Learning Environments in Undergraduate Electronics Science", *e-Journal of Instructional Science and Technology*, Gandole, Khandewale and Mishra, 2006, p.11.

Swaak et al. (1998) further observed that “assignments in simulation environments suggest ways for learners to extract knowledge or assignments support learners in discerning relevant variables, stating hypotheses, and interpreting progression in computer simulations” (Swaak et al., 1998, p. 237).

The experimental learning and discovery takes place in the simulation environment and could assist in transfer of knowledge in different ways that develop critical-thinking and reasoning skills. As Reimann (1994) explains in his article, *Supporting Instance-Based Learning in Discover Learning Environments*:

> Most exploratory learning environments and instructional simulations in particular are based on the principle of learning by induction: The student can generate for herself specific instances and is supposed to generalize over such observations or experiments. From this point of view the pedagogical idea behind simulation environments is completely in line with the idea in concept acquisition and problem solving research, namely, that learning consists of discarding specific, superficial information in favor of general, abstract information. Students can acquire knowledge about principles governing elastic impact phenomena by designing experiments and predicting the outcomes (Reimann, 1994, p. 2).

Bayrak et al. (2007) explained discovery in simulation experimentation as “the students can learn the knowledge the most easily in real surroundings where they can observe the concepts and processes of the simulated environment.” They further understood that the “simulation studies increase the interests and successes of the students that are studying subjects in science” (Bayrak et al., 2007, p. 1).

Summary

The use of computer simulation for laboratory experimentation in electronics technology enhances discovery and learning. Simulation software could improve the organization, structure and reality of the emulation of electronics circuits and help to improve the simulated environment of the traditional electronics laboratory. Improvements in software design and computer hardware requirements including computational speed have helped the simulation software to be used in a traditional electronics laboratory. Traditional methods of hands-on experimentation in electronics technology education could be supplemented with the use of computer based laboratory instruction.

CHAPTER 3

METHODS AND PROCEDURES

Purpose of the Study

The purpose of this experimental study was to compare the differences in academic achievement of students receiving laboratory simulation and hands-on laboratory skills instruction. The experiment will involve beginning technical students in a 2-year community college in the Electronics Technology Associates Degree Program that requires both classroom and laboratory instruction. The dependent variable of this experiment will be student scores on content knowledge tests covering resistance, voltage, current and power. The independent variables were the method of providing laboratory skills instruction, either computer simulation of laboratory work or the physical construction of laboratory work.

Research Questions

1. What are the achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?
2. Are there statistically significant differences in achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?

Design

This study used an experimental design to compare the skill improvements of students completing computer-based simulation laboratory work and students completing hands-on laboratory work required for freshman-level electronics technology students at a 2-year postsecondary technical school. The design included a posttest as a measure that determined the skill changes that were developed during the experiment for both computer-based and hands-on laboratory work.

The design of an experiment can come in many varieties, but is typically implemented with prior testing (pre-test) or final testing (post-test) to convey differences that might incur with treatments. The experimental designs can be configured at three separate groups, (a) pre-experimental designs, (b) quasi-experimental designs and (c) true experimental designs. For the purposes of this study, the true experimental design was used which is the “classical design or the procedure involving random assignment of participants to two groups, where both groups are administered a post-test” (Creswell, 2009, p. 161).

The two group experimental design is configured with a post-test only using both the control and treatment for two groups including both randomization of the participants for the study and post-test results for both groups. The experiment implemented the (a) randomization of the participants, (b) the division into treatment and control groups and (c) the administration of the posttest.

The experiment’s length, intensity and duration can be evaluated by reducing the first three traits of internal validity, (a) history, (b) maturation and (c) testing. The effects of history or extended time on the experiment “provide opportunities for other events to occur besides the experimental treatment”. This could be an undue effect that would not reflect the actual treatment within the experiment if the experimental treatment was extended or a duration of time elapsed between treatments that limited the effects strictly to the treatment.

Maturation also might occur during the experiment that would show "progress or psychological changes in the research participants or other words they would become more cognitively capable, self-confident or independent." An extended time-frame for an experiment would allow for natural maturation within students who are developing either physically or psychologically (Gall, Gall & Borg, 2007, pp. 384-385).

The two-group experimental design does not always require the pre-test but is sometimes used to determine comparison of groups before performing the treatment within the experimental design. The randomization helps to determine the probabilistically equivalent samples for the population to be tested. This type of experimental design is best for limiting threats to internal validity that require (a) participant characteristics and (b) researcher manipulation through experimentation, but tend to not meet the requirement for (c) effects of procedures used in the experiment. (Creswell, 2009, p. 162)

To increase the treatment fidelity, the order and structure of the laboratory experiment was adhered to as shown in the observation checklist in appendix F. Each participant was given an introduction to (a) circuit functionality and setup, (b) measuring values in the circuit, (c) calculation of additional characteristics of the circuit and (d) calculating differences between measurement and calculation. The proper equipment was calibrated and setup at the laboratory stations before the participants entered the laboratory. The computer simulation software was loaded on the computers and the laboratory procedure was opened prior to the participants entering the laboratory. The proctor of the laboratory experiments for treatment and control groups adhered to guidelines for administration of the experiment and observation of the participants through the observation checklist in appendix F.

Treatment

Students were randomly selected based on alphabetical selection and the use of a randomization table assignment in order to determine the treatment and control groups. The randomization table from Moore (2004) that gives random digits was sorted with the alphabetical names of the participants. The sorting of the random digits in numerical order were then divided into two groups of fourteen participants for each group. The treatment group was assigned the first fourteen participants and the control group was assigned the second fourteen participants. Each group was divided equally to administer the subjects to computer simulation laboratory work or hands-on laboratory work. With a total of twenty-eight subjects, fourteen subjects were required for the control group and treatment group. The chosen laboratory administration occurred during the second week of the winter quarter of the class and last for two hours during the laboratory period. The control group consisted of the hands-on laboratory assignment and the treatment group consisted of the computer simulation of the laboratory assignment. The subjects were required to complete the laboratory assignment given the same instruction and syllabus for the laboratory experiment. After the laboratory, the subjects were given a follow-up post-test that tested for skill building capabilities after treatment. The total experiment and the post-test assessment required three hours during a one week period of time during the second week of winter quarter.

According to Keppel and Wickens book on *Design and Analysis* the sample size up to forty-five subjects for a 1-way Analysis of Variance (ANOVA) can have an effect size between 0.15 and 0.60 with a power of 0.60, or an effect size between 0.15 and 0.10 for a power of 0.80, and an effect size between 0.15 to 0.12 for a power of 0.90 from Table 8.1 (Keppel & Wickens, 2004, p. 173).

In order to achieve the correct effect size, it was noted that Olejnik (1984) showed the average effect size for achieving computer-based college teaching achievement would be approximately 0.25 and attitude as 0.24, given from Table 1 of a report for recent meta-analytic studies on a variety of variables of interest to social scientists. This effect size would be related to the amount for a small to medium effect size for a reasonable effect (Olejnik, 1984, p.43).

The ideas for developing the treatment were guided by the characteristics of the study. The computer simulation versus hands-on skill instruction lends itself to a true experimental study due to the participant availability and the ability to be randomly assigned.

The laboratory was separated into two parts that include computer stations for simulation of the series/parallel circuit laboratory and laboratory stations for the hands-on series/parallel circuit laboratory exercises. The computer stations included a personal computer that has the simulation software already present on the computer with the computer program for the series/parallel laboratory exercise opened for the student. The hands-on laboratory stations will include the circuit board prepared with the series/parallel circuit built for the student to use with the digital volt meter (DVM) and power supply. The fourteen participants in the treatment were divided into two groups. The first group of ten participants completed the treatment the first day and the next four participants completed the treatment the second day. Only ten computer stations were available at any given time, and two sections of participants were required as in Table 2. Each section of participants was given the treatment or control laboratory. The first group of six participants completed the control laboratory the first day, the second group of six participants completed the control laboratory the second day and the last two participants completed the control laboratory the third day. The first group of ten participants completed the treatment laboratory the first day, the second group of two participants completed the treatment laboratory the second day and the last two participants completed the treatment laboratory the third day. The laboratory class continued to be used for the electronics technology laboratory in microprocessors, linear circuits and solid-state devices classes that were separated from the control and treatment groups for the experiment.

Table 2

Section Requirements for Treatment or Computer Simulation with 14 participants

Time Requirement	Treatment	Control
3 hrs	Section 1 (10 participants)	Section 1 (6 participants)
3 hrs	Section 2 (2 participants)	Section 2 (6 participants)
3 hrs	Section 3 (2 participants)	Section 3 (2 participants)
	Total Participants of 14	Total Participants of 14

The proctor for the experiment was given a checklist for performing the functions of both the hands-on and computer simulation laboratory. This checklist was part of the laboratory handout and is also part of the observation sheet which shows four sections for completion by the participant which include (a) circuit functionality and setup, (b) measuring the circuit, (c) calculating additional characteristics of the circuit, and (d) calculating differences between measurement and calculation. The participants were spaced apart and monitored by the proctor during the entire laboratory and post-test procedures. The effect of the checklist for the proctor was to limit extraneous variables that can affect the experimental outcome to strengthen the internal validity of the treatment and the overall experiment (Gall et al., 2007, p. 383).

Participants

The participants for this study were entering freshman in a beginning electronics course that pertains to direct current circuits class in the department of electronics technology. The participants consisted of males with an age ranged from eighteen to fifty-five years of age. Some of the younger participants had not been exposed to electronics technology and some of the older participants had come from manufacturing backgrounds with some previous knowledge of basic electrical circuits. The direct current circuits class is an introductory class in electronics technology that students must take in order to learn core competencies in areas of (a) basic electrical atomic theory and chemistry, (b) basic electronic components like batteries and resistors, (c) basic electrical circuits that consist of series components, (d) basic electrical theory including Ohm's law, (e) troubleshooting basic electrical circuits, (f) understanding the power law, (g) understanding Kirchoff's laws of electrical circuits and (h) building these circuits with laboratory instruction. The course in direct current circuits is a foundation for all electronics technology students that will be graduating and is a basic course for an occupation in the field of electronics technology. The course in direct current circuits should be mastered in order to continue study in the department of electronics technology. This course is a good indicator of success for the future of students in both the department of electronics technology and the occupation as an electronics technician.

The 2-year post-secondary technical college for this study offers coursework in industrial and technical, health sciences, business and computer technology. There are approximately fifty students in the electronics technology program at any given time which would include about 1.3% of the total enrollment at the institution. All electronics technology students are required to take the introductory direct current circuit class which is a requirement for the overall curriculum. During each winter quarter there are approximately twenty-five students that are enrolled in the freshman direct current circuit class in the department of electronics technology which would be about 37% of the total enrollment for the electronics technology program.

Before the experiment, a laboratory preliminary lecture was given to each of these students that would strengthen skill sets for laboratory work that would include computer simulation and hands-on laboratory work. This preliminary lecture was given to all students during a pre-determined laboratory period at the beginning of the course in direct current circuits during the winter quarter.

The experiment involved first-year students in electronics technology and basic concepts of electronics consisting of twenty-eight students enrolled in the basics of direct current circuits during the winter quarter of 2011. The treatment of simulation laboratory exercises was accessed within a laboratory environment which provided computer hardware and software to use the electronics circuit simulator. The electronics circuit simulator that was used is called Electronic Workbench© which is a product of National Instruments, Inc. Observation effects were limited by providing an observation checklist, detailed syllabus and instructions for laboratory and tests. The use of a qualified proctor and laboratory assistant that has been an instructor at Athens Technical College for many years used a scheduled syllabus and observation checklist in Appendix F to limit bias and reduce compensatory rivalry between participants.

Instrumentation

In order to distinguish the measurement of technical skill improvement among post-secondary technical education students especially in the science of electronics, prepared laboratory assessments were developed from core competencies as outlined in the Technical College System of Georgia curriculum guide for the electronics technology degree. The assessments are an estimation of skill construction and improvement based on problem solving abilities and cognitive aptitudes for the fundamentals of direct current circuits in an electronics technology curriculum.

The laboratory exercises consisted of understanding series and parallel circuits as used in an electronics curriculum. The post-test assessed students' abilities to understand fundamental concepts of series and parallel circuits and their relationship to Ohm's law, Kirchoff's law and the power law. Participants had the capability to answer questions about particular series/parallel circuits using methods such as mesh analysis, nodal analysis and reduction/expansion. Each post-test was given to all students in the study requiring approximately 1 hour and given by the proctor after the participants completed the laboratory exercise on the same day.

Cronbach's alpha measures how a set of variables measures a single one-dimensional latent construct and written as a function of the number of test items and the average intercorrelation among the items.

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$$

N = number of test items,
c = inter-item covariance among the items,
v = average variance

An iter-item correlation was analyzed for laboratory exercise reliability by using data from labwork in direct current curriculum for series/parallel labs from a class during the spring quarter of 2010. The Cronbach's alpha across inter-item measurements of (a) setup, (b) measure and (c) calculation was 0.7056 using SPSS statistical software. The setup section consisted of six questions related to resistance, the measure section consisted of twelve questions related to voltage and current, and the calculation section consisted of six questions related to power. Each section was assessed separately to give the inter-item Cronbach's alpha. An inter-test correlation was analyzed for measuring test scores between homework, assessments and laboratory assessment using two quarters of data from direct current series/parallel exercises. The Cronbach's alpha across inter-test measurement of (a) homework, (b) assessments and (c) laboratory assessments was 0.7624. Each of the homework, assessments and laboratory assessments consisted of four categories: (a) resistance, (b) voltage, (c) current and (d) power. The Cronbach alpha for the experiment assessment had values of 0.6286 for the resistance category, 0.5116 for the voltage category, 0.6250 for the current category and 0.6950 for the power category.

The instruments used for post-test assessments were also verified by a group of departmental instructors and advisory committee members to ascertain the effectiveness and reliability of the evaluation of series/parallel circuits in the direct current circuits curriculum.

Procedure

Before the experiment was determined, an application was applied for and approved by the University of Georgia's Institutional Review Board (IRB) of the Human Subjects Office under the Office of the Vice President for Research. Once this information and permission was obtained, the experiment began during the winter quarter of 2011 beginning during the second week of the quarter. During the second week, the experiment required about 2 hours for each control and treatment group and additional follow-up time in order give appropriate time for completion of the laboratory task. The post-test was administered directly after the treatment and control experiment with the help of a proctor and allowed 1 hour for this assessment

The procedural dates will be as follows:

November 2010 – IRB approval

January 2011 – second week, control and treatment experiment

January 2011 – second week, post-test and follow-up after experiment

February 2011 – data analysis

To reduce the sensitivity effect the post-test was given directly after the administration of the experiment to reduce the extraneous variables that might affect internal validity of the experiment (Gall et al., 2007, p. 383).

Data Analysis

The independent variables and dependent variables that will be assessed for this experiment are tabulated in Table 3.

Table 3

Independent and Dependent Variables

Question	Independent Variable	Dependent Variable	Statistical Procedure
1. What are the achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?	(1) computer simulation laboratory (2) hands-on laboratory	(1) student achievement scores based on resistance, voltage, current and power for series/parallel electronics circuits	t-test
(2) Are there statistically significant differences in achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?	(1) computer simulation laboratory (2) hands-on laboratory	(2) differences in student achievement scores based on resistance, voltage, current and power for series/parallel electronics circuits	t-test

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Once the authorization was given, an administrator of the experiment was required to administer the laboratory exercise using both the control for hands-on laboratory and the treatment for computer simulation laboratory.

All data was received from both control and treatment groups and additional experiments for hands-on laboratory and computer simulation laboratory. This data was then entered into the SPSS© version 16, statistical analysis software for evaluation of test scores for academic achievement of hands-on laboratory and computer simulation laboratory post-tests. The information to answer the research questions and methodology are listed in Table 1.

A statistical t-test was administered to test for statistical significance of the data for comparison of scores based on computer simulation of the laboratory experiment and hands-on laboratory experiment. The probability that the t-test analysis will find a statistically significant difference in test score means is to increase the power of the analysis or to increase the significance criteria, α, and reducing the risk of a Type II error, but increasing the risk of a Type I error. The statistical power will be between 0.7 to 0.85 for this type t-test. With a population for the treatment the effect size can be rather large when the population is between fifteen to twenty subjects at a power of 0.7. Olejnik (1984) discusses an alpha or significance criteria for this power and effect size to be 0.05, in order to reduce the Type I and Type II errors (Olejnik, 1984, p. 44).

The statistical analysis of the post-test scores was measured at the alpha level of 0.05. The skill sets of the experiment were based on four categories: (a) resistance, (b) voltage, (c) current and (d) power. The assessment required multiple calculations of total resistance for a given experiment for series/parallel circuits. The post-test consisted of nineteen questions that will be grouped as one question for the resistance category, six questions for the voltage category, six questions for the current category and six questions for the power category. Each question has a weighted value of 5.26% and each category will have the following percentages of the total average as 5.26% for the resistance category, 31.57% for the resistance category, 31.57% for the voltage category and 31.57% for the power category giving a total of 100% for all nineteen questions.

Each question was graded according to a percentage error or range of the exact calculated answer given by the student. The ranges were determined in 10% intervals in seven different ranges from 10% to 70%. The scores were calculated by a deviation from the answer for a positive or negative percentage. As a given example, if the student gives a resistance of 4850 ohms for a response that has an answer of 4700 ohms, a calculated range in the first 10% gives a range of 4700 + 470 ohms or 5170 ohms and 4700 – 470 ohms or 4230 ohm. The first 10% range is between 4230 and 5170 ohms, where the student will be given full credit for their answer of 4850 ohms. For each additional range a 16% reduction in their grade is awarded and a student that has a given answer that is beyond a positive or negative 70% range will not be given any points for that particular question. These ranges are required for the student as they calculate answers based upon electronics formulas that are dependent on a previous calculation. The calculation of current requires the calculation of the total resistance of the circuit based on both series and parallel equations. The current equation also requires the student to calculate the proper value based upon Ohm's law, Kirchoff's current law and Kirchoff's voltage law. There can be a substantial percentage difference in a student's calculation based upon the addition of multiple percentage errors in each step for calculating current in a series/parallel circuit.

For each question a range percentage was found based on the exact answer for the question as: range percentage = (student's answer – correct answer) / correct answer x 100%. For the previous example of an answer of 4850 ohms, the calculated range percentage: range percentage = (4850 – 4700) / 4700 x 100% = 3.19% which is less than the 10% answer range to give full credit. Each additional range reduces the student's score by 16%. A table to verify the scoring matrix for the student's post-test scores can be show in table 4.

Table 4

Scoring Ranges for Post-test scores

Range	Percentage	Points Given for Each Question
Within 10%	100	5.26
Within 20%	84	4.42
Within 30%	68	3.57
Within 40%	52	2.73
Within 50%	36	1.89
Within 60%	20	1.05
Within 70%	4	0.21
Greater than 70%	0	0

The computer simulation and hands-on laboratory experiment showed the effects and differences between the two different pedagogical approaches for teaching an electronics laboratory for a 2-year post-secondary college curriculum in electronics technology. The student learning outcomes for these two different approaches will support the constructivist theory of interaction and learning using both simulation software and hands-on laboratory instruction.

CHAPTER 4

RESULTS

Purpose of the Study

This experimental study compared the differences in academic achievement of students receiving laboratory simulation and student receiving hands-on laboratory skills instruction. Beginning students in a 2-year community college in electronics technology associates degree program that requires both classroom and laboratory instruction were the participants. From a pool of twenty-eight students, they were randomly selected and divided to participate in either a simulation laboratory exercise or a hands-on laboratory exercise. The laboratory exercises were related to the study of series/parallel electronic circuits in relation to resistance, current, voltage and power. Results of the analysis are presented in this chapter along with descriptive statistics for each area of the experimental study. Analyzed data for the research questions involved separate areas of the experimental exercise (a) resistance, (b) voltage, (c) current and (d) power.

Problem Statement

This study researched the effectiveness of computer simulation laboratory instruction in comparison to hands-on based laboratory electronics instruction to determine the effectiveness of each method in academic achievement. A simulation-based method of laboratory instruction could reduce laboratory expenditures and decrease the amount of laboratory space and equipment required for students and the institution.

Research Questions

1. What are the achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?
2. Are there statistically significant differences in achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?

Results Related to Research Question 1

Achievement scores of students who completed laboratory assignments through computer simulation and those completing hands-on laboratory assignments are described through the post-test assessment scores for both the treatment group (computer simulation laboratory participants) and control group (hands-on laboratory participants). Post-test scores are divided into four categories: (a) resistance, (b) voltage, (c) current, and (b) power. These areas of the study were analyzed using a family of comparisons for multiple comparisons using the Bonferonni procedure (Keppel & Wickens, 2004, p. 117). The total error rate of the multiple comparisons will not exceed the alpha level of 0.05. The Sidak-Bonferonni procedure for multiple comparisons was applied to avoid reduced power of the familywise testing and Type I error instead of the normal Bonferroni procedure which is considered to be too conservative (Keppel & Wickens, 2004, p. 119).

The means and standard deviations for all four categories of the post-test scores are given in Table 5.

Table 5

Academic Post-Test Means and Standard Deviations for Treatment and Control Groups

Electronics concepts	Hands-On M(SD)	Simulation M(SD)
Resistance	78.57(19.26)	81.25(16.08)
Voltage	67.41(15.62)	69.49(15.30)
Current	63.99(17.74)	71.28(15.79)
Power	60.12(17.37)	66.52(12.54)

The alpha level of 0.01274 was calculated by using the overall familywise alpha level of 0.05 and using the Sidak-Bonferonni procedure for four categories: (a) resistance, (b) voltage, (c) current and (d) power. The resistance category consisted of only one question of the nineteen total questions, the voltage category consisted of six questions of nineteen total questions, the current category consisted of six questions of nineteen total questions, and the power category consisted of six questions of the nineteen total questions of the post-test assessment.

Results Related to Research Question 2

A t-test analysis for unpaired groups showed the following data and statistical descriptives for the resistance category post-test analysis in Table 6 testing at the alpha level equal to 0.01274 for the familywise comparison. The resistance category showed no significant difference between the hands-on laboratory and simulation laboratory groups at the familywise comparison using the Sidak-Bonferonni procedure.

Table 6

Post-Test Descriptive Statistics for Comparison of Treatment and Control Groups for the Resistance Category

Hands-On		Simulation					
M(SD)	98.7% CI	M(SD)	98.7% CI	df	*t	p	Cohen's d
78.57(19.26)	[63.71,93.42]	81.25(16.08)	[68.84,93.65]	25	0.945	0.353	0.156

Note: *t is two-tailed, where α=0.00637, *p < 0.01274, two-tailed p-value.

A t-test analysis for unpaired groups showed the following data and statistical descriptives for the voltage category post-test analysis in Table 7 testing at the alpha level equal to 0.01274 for the familywise comparison. The voltage category showed no significant difference between the hands-on laboratory and simulation laboratory groups at the familywise comparison using the Sidak-Bonferonni procedure.

Table 7

Post-Test Descriptive Statistics for Comparison of Treatment and Control Groups for the Voltage Category

Hands-On		Simulation					
M(SD)	98.7% CI	M(SD)	98.7% CI	df	*t	p	Cohen's d
67.41(15.62)	[55.34,79.44]	69.49(15.30)	[57.67,81.28]	25	2.463	0.021	0.139

Note: *t is two-tailed, where α=0.00637, *p < 0.01274, two-tailed p-value.

A t-test analysis for unpaired groups showed the following data and statistical descriptives for the current category post-test analysis in Table 8 testing at the alpha level equal to 0.01274 for the familywise comparison. The current category showed a significant difference between the hands-on laboratory and simulation laboratory groups at the familywise comparison using the Sidak-Bonferonni procedure.

Table 8

Post-Test Descriptive Statistics for Comparison of Treatment and Control Groups for the Current Category

Hands-On		Simulation					
M(SD)	98.7% CI	M(SD)	98.7% CI	df	*t	p	Cohen's d
63.99(17.74)	[50.29,77.66]	71.28(15.79)	[59.09,83.44]	25	3.368	0.002	0.450

Note: *t is two-tailed, where α=0.00637, *p < 0.01274, two-tailed p-value.

A t-test analysis for unpaired groups showed the following data and statistical descriptives for the power category post-test analysis in Table 9 testing at the alpha level equal to 0.01274 for the familywise comparison. The power category showed no significant difference between the hands-on laboratory and simulation laboratory groups at the familywise comparison using the Sidak-Bonferonni procedure.

Table 9

Post-Test Descriptive Statistics for Comparison of Treatment and Control Groups for the Power Category

Hands-On		Simulation					
M(SD)	98.7% CI	M(SD)	98.7% CI	df	*t	p	Cohen's d
60.12(17.37)	[46.70,73.50]	66.52(12.54)	[56.83,76.17]	23	1.991	0.058	0.438

Note: *t is two-tailed, where α=0.00637, *p < 0.01274, two-tailed p-value.

The effect size for each of the comparisons were found using Cohen's d, The effect size for the current category is greater than the effect size of the resistance category, the voltage category and the power category. The effect sizes and the statistical significance is summarized in Table 10.

Table 10

Post-Test Comparisons and Alpha levels using Sidak-Bonferroni Correction, $\alpha_{familywise}$

Electronics categories	*p	Cohen's d
Resistance	0.353	0.156
Voltage	0.021	0.139
Current	0.002	0.450
Power	0.058	0.438

Note: Sidak-Bonferroni correction using $\alpha_{familywise}$ = 0.05 and α_{level} = 0.01274

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purpose of the study was to ascertain the effectiveness of computer simulation laboratory instruction in comparison to hands-on based laboratory instruction to provide information for use in post-secondary technical. Assessment scores were then compared to determine if simulation laboratory instruction was as effective in the learning environment as hands-on laboratory instruction (Bayrak et al., 2007).

This experimental study broadened the understanding of comparisons between hands-on laboratory instruction and computer simulation instruction described by Gandole et al. (2006), Jimoyiannis and Komis (2001) and Ronen and Eliahu (2000), which advocated that the learning environment of the simulation laboratory would enhance experience based learning and discovery. The following research questions were identified to ascertain the primary purpose of this study.

1. What are the achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?
2. Are there statistically significant differences in achievement scores on knowledge tests based on resistance, voltage, current and power for series/parallel electronics circuits of students who complete laboratory assignments through computer simulation and those completing hands-on laboratory assignments?

In order to analyze the achievement scores of the students in the hands-on laboratory and computer simulation instruction groups, the laboratory and posttest scores were categorized into four different categories: (a) resistance, (b) voltage, (c) current, and (d) power. The categories compared the differences in hands-on laboratory instruction and computer simulation laboratory instruction.

Summary

The analyzed data for the resistance category of the post-test results show that there was not a significant statistical difference of scores for the hands-on laboratory and the computer simulation laboratory exercises for the resistance category of the post-test. The resistance category was determined to be the minimum statistical difference among the four categories. The impact of evaluating only one area of this category was difficult because the resistances on an assessment are usually given and each individual resistance is not tested. The final total resistance is the assessment for the resistance category which requires calculation of many resistances in series and in parallel. The resistance category does no yield enough information about statistical significance with this aspect of the assessment. A familywise correction or Sidak-Bonferroni correction was used for comparison of the post-test results and their significance (Keppel & Wickens, 2004). The comparisons were divided into four categories in order to compare the means of both the hands-on laboratory and simulation laboratory results using the formula, $\alpha_{level} = 1 – (1 - \alpha_{familywise})^{1/c}$. The familywise alpha level for all categories were determined at 0.05 and the alpha level for each category was 0.01274.

In most cases for a series/parallel electronic circuit, the known resistances are calculated to find the total overall resistance. There is only one answer to the total resistance of a series/parallel circuit in the post-test. The student utilizes multiple analyses of series circuit calculation and parallel circuit calculation in order to find the total resistance of the series/parallel electronic circuit. The analyzed comparisons between the hands-on laboratory and computer simulation laboratory post-test scores for the resistance instruction category do not give enough information about the statistical differences based on only one question. The statistical information could be expanded by increasing the amount of questions available to the participant, which might include calculating each resistance of the circuit separately if time was entitled to the laboratory exercise. The assessment required only the total resistance to be calculated and not individual series and parallel resistances within the circuit.

The analyzed data for the voltage category of the post-test results show that the there was not a significant statistical difference in scores for the hands-on laboratory and the computer simulation laboratory exercises for the voltage category of the post-test. The increased number of questions for the voltage instruction category revealed a statistical difference between the hands-on laboratory instruction and the computer simulation instruction. The voltage instruction category showed the participants capability of calculation using Kirchoff's voltage and current equations, nodal analysis and mesh currents. The efficiency of the student to calculate the desired results and the increased statistical differences of the voltage category in comparison to the resistance category might be attributable to experienced base learning and discovery as exhibited in using computer simulation laboratory instruction.

The analyzed data for the current category of the post-test results show that there was a significant statistical difference of scores for the hands-on laboratory and the computer simulation laboratory exercises for the current category of the post-test.

The current instruction category showed the only statistical differences for comparison of the hands-on laboratory instruction and the computer simulation laboratory instruction. There was a significant difference in mean scores as measured from both groups. The skill set in the current instruction category required careful calculation for a series/parallel circuit using the capabilities of Ohm's law, Kirchoff's voltage and current law, nodal analysis and mesh current analysis in order to complete this category of the laboratory instruction. The statistical difference could be attributable to the time to complete this category in reference to the overall time for the laboratory exercise and post-test. The skill sets of Ohm's law, Kirchoff's voltage and current law, nodal analysis and mesh current analysis that are required for this category are fully utilized to solve the questions for a series/parallel electronic circuit.

The analyzed data for the power category of the post-test results show that there was not a significant statistical difference of scores for the hands-on laboratory and the computer simulation laboratory exercises for the power category of the post-test. The power instruction category showed the participants capability of calculation using Ohm's law, Kirchoff's voltage and current equations, nodal analysis, mesh currents and the Power law. The analytical ability of the participant and their skill level is greatest in the power category. The student in both the hands-on laboratory exercise and the computer simulation laboratory exercise are utilizing all the skill sets of solving the series/parallel electronic circuit including Ohm's law, Kirchoff's voltage and current equations, nodal analysis, mesh currents and the Power law.

The combination of all instructional categories also combines the overall skill sets required to complete the hands-on laboratory exercise and computer simulation laboratory exercise. These skill sets include, series resistance calculations, parallel resistance calculations, overall total series/parallel resistance calculations, Ohm's law, Kirchoff's voltage law, Kirchoff's current law, nodal analysis, mesh analysis and Power law.

The strength of the comparisons of the means of each category group can be determined by understanding the effect size as calculated by Cohen's d.

Conclusions

According to Olejnik (1984), the stated effect size for computer-based college teaching for achievement variables within the social sciences was found to be 0.25 for a small effect size. With the smaller sample of participants, the effect size was still above this range in 2 of the 4 comparisons of data for simulation laboratory or hands-on laboratory exercises.

The range of effect size and the alpha level were in agreement with the results of the study and could only be improved with an increase in the randomized population sample. According to Geban et al. (1992), the control of the simulation experiment variables could be re-examined in part due to the ability of the student using the simulation environment. The students using the simulation laboratory were expected to "acquire a wider variety of skills such as data collection, data analysis, measuring, stating hypothesis, and drawing valid conclusions and making generalizations while solving the problem" (Geban et al., 1992, p. 9).

The design of the experiment could have affected the outcomes based on the order of the design. The experiment used a single case of treatment and control groups and required multiple calculations and time for completion. The laboratory experiment for both hands-on and simulation groups might have caused participant fatigue with the amount of calculations required for a series/parallel electronics circuit which would cause an order effect. An additional amount of time could have been allowed between the laboratory experiment and the post-test in order to reduce the participant fatigue. The amount of time could have been between several hours and a full day instead on only several minutes in the experiment.

The post-test only design was administered to reduce the pretest effect upon the experiment and to reduce the amount of participant fatigue. The post-test only design helps to administer the experiment within a given amount of time to strengthen internal validity. A pretest could have been given to both groups and might have benefited the maturation of the experiment, but more than likely would have extended the amount of participant fatigue.

The design of the instrumentation for the experiment probably increased the amount of time that was required for each category differently. The calculations for a series/parallel circuit are incremental and care should be taken when using calculated values in order to find other values used in an assessment.

According to Bayrak et al. (2007) the results of the computer simulation of electric circuits and the hands-on laboratory experiment of electric circuits using series/parallel circuits showed that there was not a statistical difference between the two groups and that computer simulation laboratory was just as effective in learning outcomes (Bayrak et al., 2007, p.6).

Jimoyiannis and Komis (2001) concluded that “the role of computer simulations helped to assist students to overcome their cognitive constraints and refine their alternative conceptions in the learning environment” (Jimoyiannis & Komis, 2001, p. 204). The experiment helped the students using the computer simulation laboratory to improve their post-test scores based on the current category and knowledge tests.

The research showed these variables within the gradation of the categories based on the *p-values, Cohen’s d and effect size. The participants of the computer simulation based laboratory might have an initial reaction to the computer simulation as they would to a computer game.

Computer-based learning in laboratory settings could enhance the abilities of the electronics student and develop their reasoning skills, critical thinking skills and creativity. The electronics student requires an array of skill sets across the curriculum of electronics that can be enhanced by introducing computer simulation in laboratory exercises, instruction and assessment. The hands-on laboratory is not to be discarded, but the computer simulation reveals and area of student learning that can enhance the overall experience and learning ability of the electronics student during their time of study in the electronics department.

Increased exposure of the student to computer simulation yielded further intuition, experimental learning and discovery, and new paths to an educational pedagogy as shown in Jmoyiannis and Komis (2001) study based on computer simulation assisting students for the study of series/parallel electronics circuits. The development of a computer simulation for an electronics course for both laboratory and lecture could be achieved efficiently knowing the impact that computer simulation might help in developing student outcomes in electronics courses.

Computer simulation laboratory could be used in the development of distance learning or online classes. The addition of computer simulation would be advantageous to an enrolled student that is already familiar with computer based learning. The computer simulation software could develop the skill set of the electronics student further by introducing various simulations of electronics circuits as the core competencies are achieved by the student. The computer simulation would give the student the support needed to understand the fundamentals or working knowledge of the electronics circuit.

Recommendations for Further Research

The following recommendations are based on the results and conclusions of this study.

1. Increasing the amount of participants in the study and possibly identify an area of the study that could be measured by controlling the amount of given feedback for each participant. The study was conducted with a limited amount of problem-solving assistance before the laboratory was administered. An extensive study could further divide the participants into groups based upon categorical skill set preparation and possibly environment of the experiment.

2. A further study of categorical sets based upon age of the participants could be achieved that might show more information about the abilities and proclivity towards technology and computers. The continued use of a hands-on environment is still important to the learning environment, but the computer-based learning environment using computer simulation reveals an individual discovery that continues to expand our knowledge of epistemology and learning pedagogy that could be dependent upon generational differences. These differences of age groups would show the researcher a statistical difference in hands-on laboratory exercises and computer based laboratory exercises that might contribute to the avenues of use for computer simulation and how to deliver teaching methods to different age groups.

3. Different types of simulation software are available to electronics students from software companies that use the simulation software to design and develop electronics circuits. These simulation software programs would be a good starting point for comparison of the effectiveness of the software for teaching electronics students. The abilities and user friendliness of the software could possibly determine variations on student outcomes. By using various computer simulations the study could compare statistical differences between the computer simulation software.

With the advent of new hardware like the Apple Ipad © and Netbook technology, the actual computer environment could be compared. The user friendliness of the computer hardware might enhance the ability of the computer simulation software and allow the user to feel more at ease with using the software.

4. The limits and the abilities of computer simulation software could be applied to other competencies within the field of electronics that might include digital systems, communications systems, microprocessors, power electronics and emerging technologies. The assessment of simulation software to other competencies could show these limits for use within classroom and laboratory exercises. Many areas of electronics are continuing to expand yearly as both new electronic hardware and software are becoming available to the general public.

The use of computer simulation is already being used to design and build new technologies like carbon fiber technology and superconductive materials. The computer simulation software used for development could possibly be applied to teaching the same discipline and use in the laboratory and classroom.

(5) The computer simulation software could also be applied to non-technical aspects of the electronics curriculum that might include schematic recognition, pattern recognition, signal generation and instrumentation. The areas of assessment in the electronics curriculum could be applied to definitions, emerging technologies based on information, knowledge based learning, self-test and internet wireless technologies.

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APPENDIX A

Consent Form

I am a doctoral student at the University of Georgia completing my dissertation, *Academic Achievement of Students Receiving Laboratory Simulation or Hands-on Laboratory Skills in Post-Secondary Electronics Technology Instruction.* You were identified as a potential participant in a study on the effects of simulation laboratory instruction at the post-secondary level of an Electronics Technology curriculum at Athens Technical College. Your help in this study will establish a selection of participants needed for further understanding of using computers and simulation in teaching the field of Electronics Technology and its effects upon learners. THE PURPOSE OF THIS EXPERIMENTAL STUDY WILL BE TO COMPARE THE DIFFERENCES IN ACADEMIC ACHIEVEMENT OF STUDENTS RECEIVING LABORATORY SIMULATION OR HANDS-ON LABORATORY SKILLS INSTRUCTION. THE EXPERIMENT WILL INVOLVE BEGINNING TECHNICALSTUDENTS IN A 2-YEAR COMMUNITY COLLEGE IN THE ELECTRONICS TECHNOLOGY ASSOCIATES DEGREE PROGRAM THAT REQUIRES BOTH SIMULATION OF LABORATORY WORK BY COMPUTER SOFTWARE AND ACTUAL PHYSICAL LABORATORY WORK WITH LABORATORY EQUIPMENT. THE INDEPENDENT VARIABLES WILL BE THE METHOD OF PROVIDING LABORATORY SKILLS INSTRUCTION, EITHER COMPUTER SIMULATION OF LABORATORY WORK OR THE PHYSICAL CONSTRUCTION OF LABORATORY WORK.

If you plan to participate, you will be randomly assigned to either a pool of participants using the computer simulation software or a pool of participants using hands-on laboratory exercises and equipment. The laboratory experiment should last no longer than 2 hours and a post-test that lasts 30 minutes will be given after the laboratory experiment, ONLY STUDENTS WHO HAVE DECIDED TO PARTICIPATE IN THE LABORATORY EXPERIMENT.

IF YOU DO NOT PLAN TO PARTICIPATE YOUR GRADES WILL NOT BE PENALIZED OR CHANGED IN ANY WAY FOR THE CLASS THAT YOU ARE ENROLLED IN ELECTRONICS TECHNOLOGY.

Your participation, of course, is voluntary but would be greatly appreciated. You may choose not to participate or to withdraw your consent at anytime without penalty or loss of benefits to which you are otherwise entitled. If you agree to the use of your information/data for this research project, please simply sign on the line below; if you don’t agree, none of your data will be included in the research and you can still participate in the program.

The results of the research study may be published, but your name or any identifying information will not be used. In fact, the published results will be presented in summary form only. There are no known risks associated with this laboratory exercise. The findings from this project may help researchers to understand the differences between using simulated laboratory exercises and hands-on laboratory exercises.

The researchers conducting this study are: Ken Roberts and Dr. Robert Wicklein. You may ask any questions you have now. If you have questions later, you are encouraged to contact them at Athens Technical College, (706) 355-5068, kroberts@athenstech.edu, University of Georgia, (706) 542-4503 , wickone@uga.edu,

Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, **629** Boyd GSRC, Athens, Georgia 30602-7411; telephone (706) 542-3199; email address irb@uga.edu.

Statement of Consent:

I understand that I am agreeing by my signature on this form to take part in this research project and understand that I will receive a signed copy of this consent form for my records.
Ken H Roberts

_________________________	_______________________	_________
Name of Researcher	Signature	Date
_________________________	_______________________	__________
Name of Participant	Signature	Date

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

APPENDIX B

Hands-on Laboratory Assessment

Laboratory Exercise – Introduction to Series/Parallel Circuits **B**

(HANDS-ON LABORATORY, 2 hours)

Name ______________________________ Date ___________________

Time Begin: ___________

Time End: ____________

Note: This is the Series/Parallel laboratory exercise for this class.

Please read the instructions carefully. Consider all laboratory hardware needed to complete this laboratory exercise. Answer the following questions completely.

Ken Roberts – Director of Electronics Technology
Athens Technical College
800 US Hwy 29 North
Athens, Georgia 30601
kroberts@athenstech.edu

Hardware needed to complete this laboratory exercise:

Breadboard
FUNCTION GENERATOR
Power Supply
Wire Jumpers
Resistors:

4.7K ohm
2.2K ohm
1.5K ohm
1K ohm
3.3K ohm

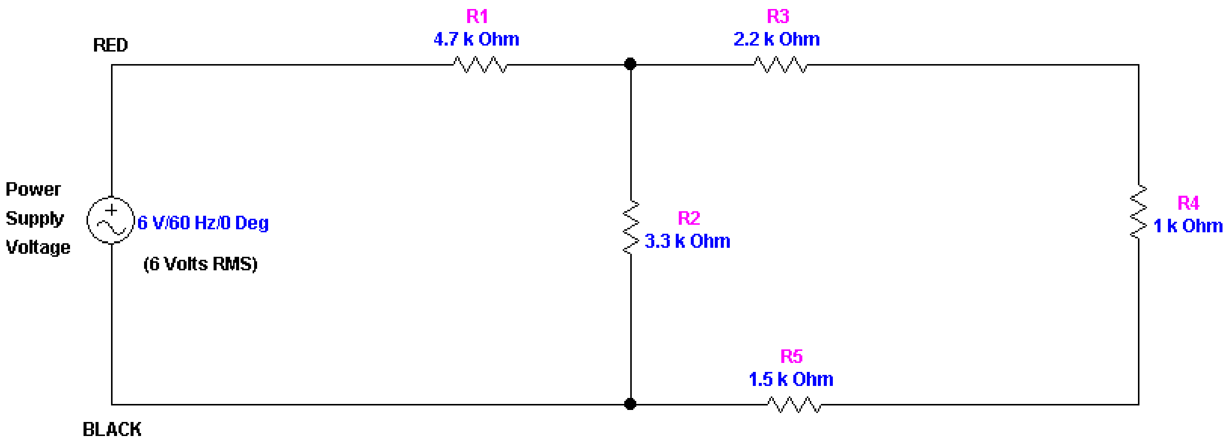
Objective: Understanding Complex Series/Parallel Circuits

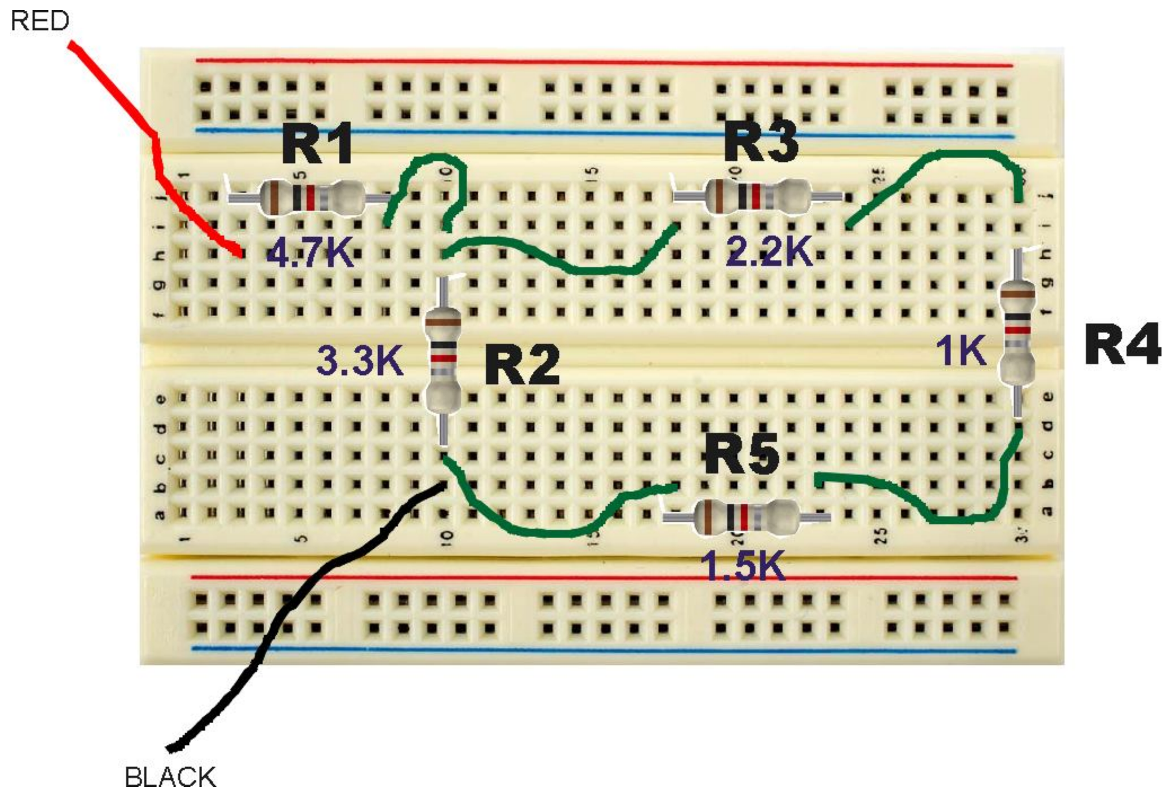
Summary: This laboratory will help the student learn the basics of complex DC series and parallel circuits and both measure and calculate the voltage drops, currents and power dissipation of each resistor in the series/parallel circuit.

Introduction: Obtain the breadboard, wiring, power supply, multimeter, and resistors from the instructor.

Part 1: Building the Circuit

The schematic for the circuit looks like this:





The breadboard should contain the resistors and wiring as shown above. The red wires indicate the POSITIVE voltage (+), and the black wires indicate the GROUND (-).

:

The power supply should be similar to the above, with the voltage adjusted to **6 volts RMS (root mean square)**, the frequency set at **60 Hz** and connected to the breadboard with the red wire (+) and black wire (-) AC voltage

[ ] Have the Instructor check this breadboard for circuit completion and proper voltage, PART 1

You should be able to use the Digital Volt Meter as shown, making sure the meter is in **AC** mode, and starting with the indicator knob turned to **V**, (**20 Volts)**. To measure current the indicator knob should be turned to **A, (200m or 20m/10A).**

Part 2: Measuring Voltages and Currents

(1) The first part of this lab will be to measure all voltages drops across the resistors: (remember voltage drop is across the resistor)

R1 Voltage Drop ____________________ AC volts RMS
R2 Voltage Drop ____________________ AC volts RMS
R3 Voltage Drop ____________________ AC volts RMS
R4 Voltage Drop ____________________ AC volts RMS
R5 Voltage Drop ____________________ AC volts RMS

*Power Supply Voltage ____________________ AC volts RMS

* measured from the RED wire to the BLACK wire in the circuit.

(2) The second part of this lab will be to measure all currents. Turn the knob to **A** (amperes), indicated by **20m/10A**. The measurements will be read in milli-amperes. (remember, current flows thru the resistor, so the meter should be placed in the circuit)

R1 Current ____________________ milli-amps
R2 Current ____________________ milli-amps
R3 Current ____________________ milli-amps
R4 Current ____________________ milli-amps
R5 Current ____________________ milli-amps

*Total Current ____________________ milli-amps

* measured between the RED wire and the R1 resistor.

(3) The last part of this lab is to calculate power dissipation: Calculate each power dissipation for the resistors. (Power = Voltage X Current)

R1 Power ____________________ mill-watts
R2 Power ____________________ mill-watts
R3 Power ____________________ mill-watts
R4 Power ____________________ mill-watts
R5 Power ____________________ mill-watts

(4) Now add the power dissipations to arrive at the Total Power:

Total Power Measured ____________________ mill-watts *

* use this for PART 4

Part 3: Calculating the Power of the Circuit

Calculate the Total Resistance using the following formulas:

$$\mathbf{R_{series} = R_1 + R_2 + R_3 + \ldots + R_n}$$
$$\mathbf{R_{parallel} = 1 / (1/R_1 + 1/R_2 + 1/R_3 + \ldots + 1/R_n)}$$

Total Resistance ____________________ K-ohms

Calculate the Total Power with the following equation:

$$\mathbf{P_{total} = V_{total}^2/R_{total}}$$

Total Power ____________________ milli-watts

Your measured total power should be similar to your calculated power.
Now calculate the anticipated power of the circuit by the following equation:

$$\mathbf{P = V^2/R}$$

Use the previous voltages (part 1), and given resistances (not measured as shown below)
(Example: **3.3K** is the same as **3300** ohms)

R1 (4.7K) Power	____________________	milli-watts
R2 (3.3K) Power	____________________	milli-watts
R3 (2.2K) Power	____________________	milli-watts
R4 (1K) Power	____________________	milli-watts
R5 (1.5K) Power	____________________	milli-watts

Now add these together to find the total calculated power:

Total Power Calculated ____________________ milli-watts *

* use this for PART 4

Part 4: Calculating the Difference between the Measured and Calculated Power

Now calculate the difference between the calculated power and measured power:

% difference = (measured – calculated)/calculated X 100

____________________ %

End of Laboratory Exercise

APPENDIX C

Computer Simulation Laboratory Assessment

Laboratory Exercise – Introduction to Series/Parallel Circuits **A**

(COMPUTER SIMULATION LABORATORY, 2 hours)

Name ________________________________ Date ____________________

Time Begin: ___________

Time End: ____________

Note: This is the Series/Parallel laboratory exercise for this class.

Please read the instructions carefully. Consider all laboratory hardware needed to complete this laboratory exercise. Answer the following questions completely.

Ken Roberts – Director of Electronics Technology
Athens Technical College
800 US Hwy 29 North
Athens, Georgia 30601
kroberts@athenstech.edu

Hardware and Software needed to complete this laboratory exercise:

Personal Computer (Microsoft Windows© based software XP or higher)
National Instruments© Electronics Workbench Software

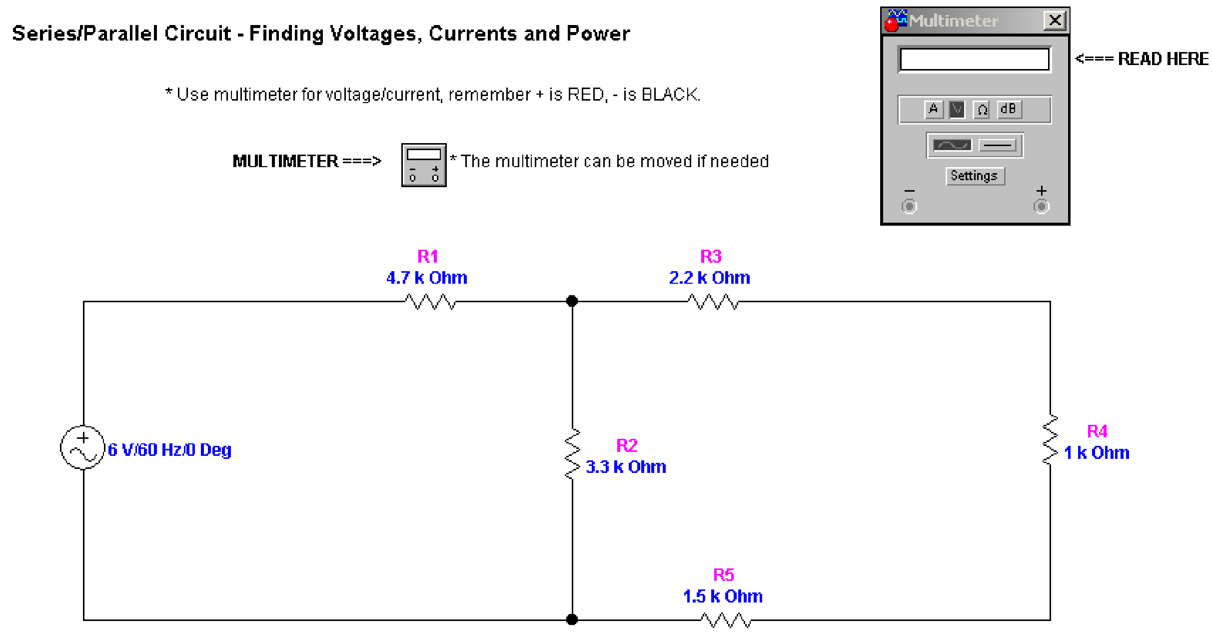
Objective: Understanding Complex Series/Parallel Circuits using Electronics Circuit Simulation Software on the Personal Computer

Summary: This laboratory will help the student learn the basics of complex AC series and parallel circuits and both measure and calculate the voltage drops, currents and power dissipation of each resistor in the series/parallel circuit.

Introduction: Personal Computer loaded with National Instruments© Electronics Workbench software opened with the laboratory obtained from the instructor.

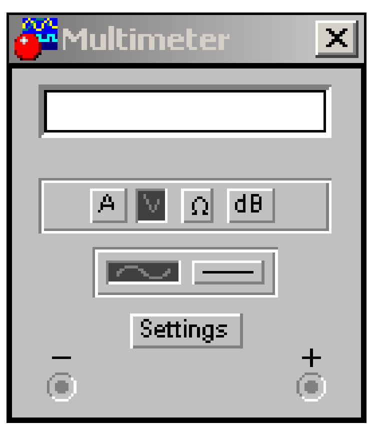
Part 1: The circuit in software

The software program should be loaded to look like this:

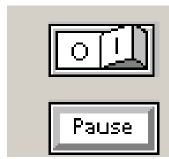


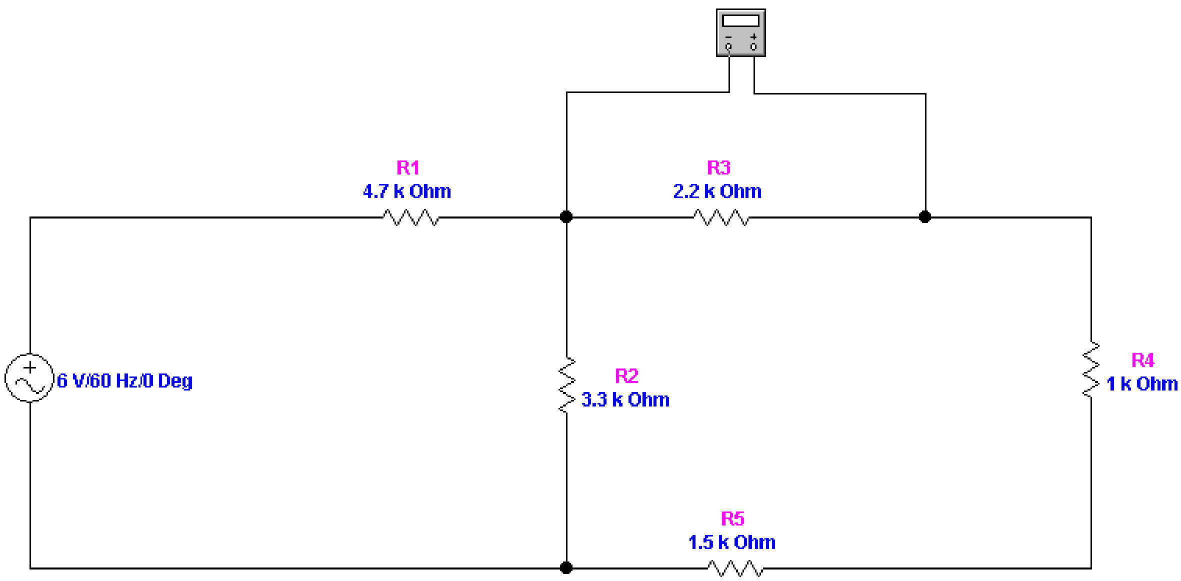
[ ] Have the Instructor check the software to make sure the program is running and looks like the above circuit, PART 1

You should be able to use the Digital Volt Meter in software as shown:

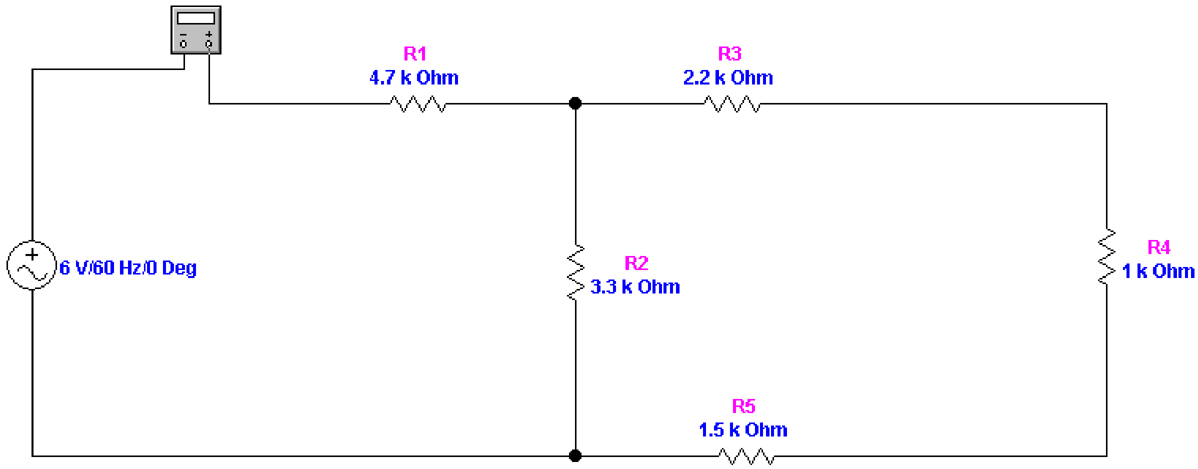


You can measure the voltage drop of the 2.2K ohm resistor by dragging the meter and attaching the wires (dragging the mouse) to the **2.2 K-ohm** resistor then reading the voltage on the software DVM (digital volt meter). The wires can be dragged from the nodes on the multimeter and placed at the wire until a new node is created. Make sure the simulation is turned on by the switch on the software that looks like:





You can measure the current of the circuit by dragging the meter and attaching the wires (dragging the mouse) to the **6 volt RMS source** then reading the current on the software DVM (digital volt meter) remembering to change from V to A on the Multimeter



Part 2: **Measuring Voltages and Currents** (All readings should be 2 decimal places to the right of the decimal point, Example: A reading of **3.375** can be written as **3.37** volts, a reading of **1.2** can be written as **1.20** volts)

(1) The first part of this lab will be to measure all voltages drops across the resistors: (remember voltage drop is across the resistor)

R1 Voltage Drop ____________________ AC volts RMS
R2 Voltage Drop ____________________ AC volts RMS
R3 Voltage Drop ____________________ AC volts RMS
R4 Voltage Drop ____________________ AC volts RMS
R5 Voltage Drop ____________________ AC volts RMS

Power Supply Voltage ____________________ AC volts RMS

(2) The second part of this lab will be to measure all currents. (Check to make sure the multimeter is set to "A" for amperes) . (remember, current flows thru the resistor, so the meter should be placed in the circuit) The measurement will be in milliamperes. (Example: **0.79** reading would be **0.79 milli-amps**)

R1 Current ____________________ milli-amps

R2 Current ____________________ milli-amps
R3 Current ____________________ milli-amps
R4 Current ____________________ milli-amps
R5 Current ____________________ milli-amps

Total Current ____________________ milli-amps

(3) The last part of this lab is to calculate power dissipation: Calculate each power dissipation for the resistors. (Power = Voltage X Current)

R1 Power ____________________ milli-watts
R2 Power ____________________ milli-watts
R3 Power ____________________ milli-watts
R4 Power ____________________ milli-watts
R5 Power ____________________ milli-watts

(4) Now add the power dissipations to arrive at the Total Power:

Total Power Measured ____________________ milli-watts *

* use this for PART 4

Part 3: Calculating the Power of the Circuit

Calculate the Total Resistance using the following formulas:

$$\mathbf{R_{series} = R_1 + R_2 + R_3 + \ldots. + R_n}$$
$$\mathbf{R_{parallel} = 1 / (1/R_1 + 1/R_2 + 1/R_3 + \ldots. + 1/R_n)}$$

Total Resistance ____________________ K-ohms

Calculate the Total Power with the following equation:

$$\mathbf{P_{total} = V_{total}^2/R_{total}}$$

Total Power ____________________ milli-watts

Your measured total power should be similar to your calculated power

Now calculate the anticipated power of the circuit by the following equation:

$$\mathbf{P = V^2/R}$$

Use the previous voltages (part 1), and given resistances (not measured as shown below)
(Example: **3.3K** is the same as **3300** ohms)

R1 (4.7K) Power	____________________	milli-watts
R2 (3.3K) Power	____________________	milli-watts
R3 (2.2K) Power	____________________	milli-watts
R4 (1K) Power	____________________	milli-watts
R5 (1.5K) Power	____________________	milli-watts

Now add these together to find the total calculated power:

Total Power Calculated _____________________ milli-watts *

* use this for PART 4

Part 4: **Calculating the Difference between the Measured and Calculated Power**

Now calculate the difference between the calculated power and measured power:

% difference = (measured – calculated)/calculated X 100

_____________________ %

End of Laboratory Exercise

APPENDIX D

Post-test Skills Assessment

Introduction to Series/Parallel Circuits Assessment **A or B (circle one that matches laboratory)**

(POSTTEST, 1 hour)

Name ________________________________ Date ____________________

Time Begin: ___________

Time End: ____________

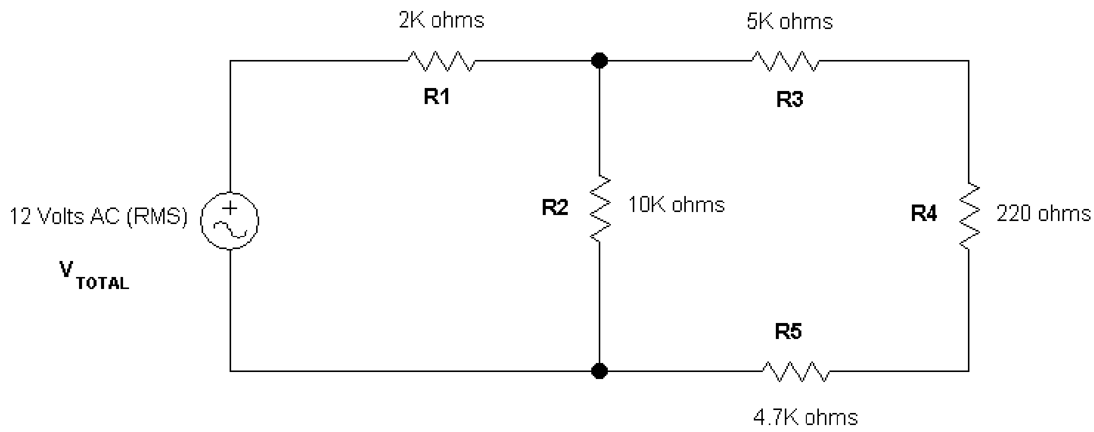
Note: This is the Series/Parallel Circuits Assessment

Please read the instructions carefully. Answer the following questions completely. Required: Scientific Calculator, Extra Paper if Needed.

Ken Roberts – Director of Electronics Technology
Athens Technical College
800 US Hwy 29 North
Athens, Georgia 30601
kroberts@athenstech.edu

For the following circuit, find the voltage drops across each resistor (RMS values), the current through each resistor (RMS values) and the power dissipation of each resistor (RMS values). Also determine the total resistance, the total current, and the total power: (Kirchoff's Equations, Ohm's Law and Power Law can be used to determine your answers. You can use a separate piece of paper and calculator for your calculations)

(All calculations should be 2 decimal places to the right of the decimal point, Example: A calculation of **3.375** can be written as **3.37** volts, a calculation of **1.2** can be written as **1.20** volts….K is kilo, meaning 1000 times the number, a **6.8K** ohm resistor is **6800** ohms)



USEFUL EQUATIONS:

$$V = I * R$$
$$P = V * I$$

Kirchoff's Voltage Equation: $\Sigma V = 0$

Kirchoff's Current Equation: $\Sigma I = 0$

$$R_{series} = R_1 + R_2 + R_3 + \ldots. + R_n$$
$$R_{parallel} = 1 / (1/R_1 + 1/R_2 + 1/R_3 + \ldots. + 1/R_n)$$
$$P = V^2/R$$

Total Resistance ________________ **ohms**

R1 Voltage ______________________ **AC volts**
R2 Voltage ______________________ **AC volts**
R3 Voltage ______________________ **AC volts**
R4 Voltage ______________________ **AC volts**
R5 Voltage ______________________ **AC volts**

Total Voltage ______________________ **AC volts**

Total Current ______________________ **milli-amps**

R1 Current ______________________ **milli-amps**
R2 Current ______________________ **milli-amps**
R3 Current ______________________ **milli-amps**
R4 Current ______________________ **milli-amps**
R5 Current ______________________ **milli-amps**

R1 Power Dissipation ___________ **milli-watts**
R2 Power Dissipation ___________ **milli-watts**
R3 Power Dissipation ___________ **milli-watts**
R4 Power Dissipation ___________ **milli-watts**
R5 Power Dissipation ___________ **milli-watts**

***Total Power** ___________ **milli-watts**

* Sum the Power Dissipations of R1 through R5.

End of Assessment

APPENDIX E

IRB Application

The University of Georgia

Human Subjects Office (HSO)
612 Boyd GSRC ■ Athens, GA 30602-7411
Phone: 706-542-3199 ■ Fax: 706-542-3360 ■ irb@uga.edu
DHHS Assurance No.: FWA00003901

Institutional Review Board (IRB)
HUMAN RESEARCH APPLICATION

To submit: http://www.ovpr.uga.edu/hso/how/application

IMPORTANT: ***Please respond to all the questions. Do not leave items blank; if not applicable, mark N/A. Please note that incomplete applications may result in delayed review. Click on the hyperlinks (text underlined in blue)***	***For Human Subjects Office Use Only*** **Project #:** **Date Received:** **Type of Review:** ☐**Exempt** ☐**Expedited**

Section A: PROJECT INFORMATION

1. **Study Title:** Academic Achievement of Students Receiving Laboratory Simulation and Hands-on Laboratory Skills in Post-Secondary Electronics Technology Instruction
2. **Application Type:** ☒ New Project ☐ Response to Initial Review (*All revisions must be in italics or different font color.*)
   ☐ 5-Year Renewal; Previous IRB number:
3. **Principal Investigator:** (*Must be UGA faculty or senior staff. See **Eligibility to Serve as PI**.*)
   Name: Robert Wicklein **Title:** Dr.
   Department Name: Workforce Education, Leadership and Social Foundations, College of Education
   Mailing Address: 221 River's Crossing, University of Georgia, Athens, Georgia 30602
   Phone: 7065424503 **UGA E-mail** (Required): wickone@uga.edu
4. **Co-Principal Investigator:** (*Required only if for thesis/dissertation or other student project.*)
   Name: Jay Rojewski **Title:** Dr.
   Department: Workforce Education, Leadership and Social Foundations, College of Education
   Mailing address: 221 River's Crossing, University of Georgia, Athens, Georgia 30602
   Phone: 7065424461 **UGA E-mail** (Required): rojewski@uga.edu
5. **Anticipated Start Date:** (*Must be at least 4 weeks after application is received.*) 011011

Section B: PROJECT FUNDING

1. **Funding Status:** ☐ Funded ☐ Pending ☒ No Funding
2. **Funding Source:** ☐ Internal Account #:
   ☐ External Funding Source: OSP Proposal or Award #:
3. **Name of Proposal or Award PI** (if different from PI of IRB protocol):
4. **Proposal or Award Title** (if different from title of IRB protocol):

Section C: STUDY PERSONNEL / RESEARCH TEAM

Including the PI, identify all personnel who will be engaged in the conduct of human research. ***Important Note:*** *All researchers listed below are required to complete the **CITI IRB Training** prior to submission of this application. This application will be returned to PI for resubmission if training requirement has not been satisfied. To add more names, bring cursor to outside of last row, and press "enter" key.*

Name	E-mail	*Institution
Dr. Robert Wicklein	wickone@uga.edu	University of Georgia
Ken Roberts	kroberts@athenstech.edu	Athens Technical College

*Submit an ***Individual Investigator Agreement*** for all study personnel affiliated with an institution that does not have an assurance with the Office for Human Research Protections or OHRP (typically, local schools, private doctors' clinics).*

Section D: PRINCIPAL INVESTIGATOR'S ASSURANCE

As the Principal Investigator, I have the ultimate responsibility for the conduct of the study and the protection of the rights and welfare of human participants. *By affixing my signature below,*

- I assure that all the information contained in this Human Research Application is true and all the activities described for this study accurately summarize the nature and extent of the proposed participation of human participants.
- If funded, I assure that this proposal accurately reflects all procedures involving human participants described in the grant application to the funding agency.
- I agree to comply with all UGA policies and procedures, as well as with all applicable federal, state, and local laws on the protection of human participants in research.
- I assure that all personnel listed on this project are qualified, appropriately trained, and will adhere to the provisions of the approved protocol.
- I will notify the IRB regarding any adverse events, unexpected problems or incidents that involve risks to participants or others, and any complaints.
- I am aware that no change(s) to the final approved protocol will be initiated without prior review and written approval from the IRB (except in an emergency, if necessary to safeguard the well-being of human participants and then notify the IRB as soon as possible afterwards).
- I understand that I am responsible for monitoring the expiration of this study, and complying with the requirements for an annual continuing review for expedited and full board studies.
- If human research activities will continue five years after the original IRB approval, I will submit a new IRB Application Form. (*Exceptions:* If the research is permanently closed to the enrollment of new participants, all participants have completed all research-related interventions, <u>and</u> the research will remain active only for long-term follow-up of participants; <u>or</u> if the remaining research activities are limited to analysis of individually-identifiable private information.)
- I understand that the IRB reserves the right to audit an ongoing study at any time.
- I understand that I am responsible for maintaining copies of all records related to this study in accordance with the IRB and sponsor guidelines.
- I assure that research will only begin after I have received notification of final IRB approval.

Signature of Principal Investigator Robt C. Wickler   **Date** (mm/dd/yyyy): 12/15/2010

Section E: CONFLICT OF INTEREST (COI)

1. Is there any real, potential, or perceived conflict of interest on the part of any study personnel *(e.g., financial or business interest, stock or stock options, proprietary interest, inventorship, consultant to sponsor)***?** ☐ **Yes** ☒ **No**

2. If yes, please identify personnel and explain. ***Important Note:*** *Please review the* ***UGA Conflict of Interest Policy****. Final IRB approval cannot be granted until all potential conflict matters are addressed.*

Section F: LAY PROJECT SUMMARY

Briefly describe in simple, non-technical language a summary of the study, its specific aim(s)/objective(s), and its significance or importance. ***Response should be limited to 250***

words and easily understood by a layperson. The purpose of this experimental study will be to compare the differences in academic achievement of students receiving laboratory simulation or hands-on laboratory skills instruction. The experiment will involve beginning technical students in a 2-year community college in the Electronics Technology Associates Degree Program that requires both classroom and laboratory instruction. The dependent variable of this experiment will be student performance when using both simulation of laboratory work by computer software and actual physical laboratory work with laboratory equipment. The independent variables will be the method of providing laboratory skills instruction, either computer simulation of laboratory work or the physical construction of laboratory work.

Section G: HUMAN RESEARCH PARTICIPANTS

1. **Provide a general description of the targeted participants** *(e.g., healthy adults from the general population, children enrolled in an after-school program, adolescent females with scoliosis)*, **and indicate the estimated total number, targeted gender, and age.** *To add a row, bring cursor to outside of last row, and press "enter" key.*

Targeted Population	Total Number	Targeted Gender	Specify age or age
Enrolled students in Electronics Technology	52	None	18 to 55

2. **Identify the inclusion and exclusion criteria.** If two or more targeted populations, identify criteria for each.
   a. **List inclusion criteria.**
   b. **List exclusion criteria.**
3. **If the research will exclude a particular gender or minority group, please provide justification.**
4. **Will participants receive any incentives for their participation** (e.g., payments, gifts, compensation, reimbursement, services without charge, extra class credit)**?** ☐ **Yes** ☒ **No**
   a. **If yes, please describe.** For multiple sessions, include scheme to pro-rate incentives.
   b. **If offering extra class credit, describe a comparable non-research alternative for receiving incentive.**

Section H: RECRUITMENT AND ELIGIBILITY OF PARTICIPANTS

1. **Describe how potential participants will be initially identified** (e.g., public records, private records, etc.). Matriculated students at Athens Technical College that are enrolled in the Electronics Technology Program
2. **Describe when, where, and how participants will be initially contacted.** Enrolled students in classes during the Winter Quarter of the Electronics Technology Program
3. **Advertisements, flyers, and any other materials that will be used to recruit participants must be reviewed and approved before their use.** Check all that apply below and submit the applicable recruitment material/s.
   ☒ **No Advertising** ☐ **Bulletin boards** ☐ **Electronic media (e.g., listserv, emails)**
   ☐ **Letters**
   ☐ **Print ads/flyers (e.g., newspaper)** ☐ **Radio/TV** ☐ **Phone call** ☐ **Other** *(please describe)*
4. **Describe any follow-up recruitment procedures.**
5. **Describe how eligibility based on the above inclusion/exclusion criteria will be determined** (e.g., self-report via a screening questionnaire, hospital records, school records, additional tests/exams, etc.).

Section I: RESEARCH, DESIGN, METHODS AND PROCEDURES

1. **Describe the research design and methods of data collection.** True experiment using both a control and treatment group of students using laboratory exercises and post-test assignments.
2. **If applicable, identify specific factors or variables and treatment conditions or groups (include control groups).** The treatment group will have a laboratory exercise using a computer simulation software at a work station, and the control group will have a laboratory exercise using normal equipment in an electronics laboratory.
3. **Indicate the number of research participants that will be assigned to each condition or group, if applicable.** 26 per group
4. **Describe in detail, and in sequence, all study procedures, tests, and any treatments/research interventions. Include any follow-up(s).** ***Important Note:*** *If procedures are long and complicated, use a table, flowchart or diagram to outline the study procedures from beginning to end.*
5. **Describe the proposed data analysis plan and, if applicable, any statistical methods for the study.** 1 way-ANOVA analysis between variables for treatment and control participants
6. **Anticipated duration of participation.** a. Number of visits or contacts: 2
   b. Length of each visit: **2 hours**
   c. Total duration of participation: 4 hours

Section J: DATA COLLECTION INSTRUMENTS

List and describe all the instruments (interview guides, questionnaires, surveys, etc.) to be used for this study. Attach a copy of all instruments that are properly identified and with corresponding numbers written on them.
To add a row, bring cursor to outside of last row, and press "enter" key.

Number	Instrument	Brief Description	Identify group(s) that will complete
26	Hands-On Laboratory Exercise	Laboratory exercise and Post-test	Students enrolled Winter Quarter in Electronics Technology
26	Simulation Laboratory Exercise	Laboratory exercise and Post-test	Students enrolled Winter Quarter in Electronics Technology

Section K: RISKS AND BENEFITS

1. **Risks and/or discomforts**
   Describe any reasonably foreseeable psychological, social, legal, economic or physical risks and/or discomforts from all research procedures, and the corresponding measures to minimize these. ***Important Note:*** *If there is more than one study procedure, please identify the procedure followed by the responses for both (a) and (b).*
   a. Risks and/or discomforts. none
   b. Measures to minimize the risks and discomforts to participants.
2. **Benefits**
   a. Describe any potential direct benefits to study participants. If none, indicate so. ***Important Note:*** *Please do not include compensation/payment/extra credit in this section, as these are "incentives" and not "benefits" of participation in research; any incentives must be described in Section G.4.* none
   b. Describe the potential benefits to society or humankind.
3. **Risk/Benefit Analysis**
   a. Indicate how the risks to the participants are reasonable in relation to anticipated benefits, if any, to participants and the importance of the knowledge that may reasonably be expected to result from the study *(i.e., How do the benefits of the study outweigh the risks, if not directly to the participants then to society or humankind?).*
4. **Sensitive or Illegal Activities**

a. Will study collect any information that if disclosed could potentially have adverse consequences for participants or damage their financial standing, employability, insurability, or reputation *(includes but not limited to sexual attitudes, preferences, or practices; HIV/AIDS or other sexually transmitted diseases; use of alcohol, drugs, or other addictive products; illegal conduct; an individual's psychological well-being or mental health; and genetic information)***?**
No

b. If yes, explain how the researchers will protect this information from any inadvertent disclosure.

5. Reportable Information

a. Is it reasonably foreseeable that the study will collect or be privy to information that State or Federal law requires to be reported to other officials (e.g., child or elder abuse) **or ethically might require action** (e.g., suicidal ideation, intent to hurt self or others)**?** No

b. If yes, please explain and include a discussion of the reporting requirements in the consent document(s).

Section L: DATA SECURITY AND FUTURE USE OF INFORMATION

1. Data Security

Check the box that applies.

☒ **Anonymous –** The data and/or specimens will not be labeled with any individually-identifiable information (e.g., name, SSN, medical record number, home address, telephone number, email address, etc.), or labeled with a code that the research team can link to individually-identifiable information.

☐ **Confidential –** The responses/information may potentially be linked/traced back to an individual participant, for example, by the researcher/s (like in face-to-face interviews, focus groups). **If necessary, provide additional pertinent information.**

☐ **Confidential – Indirect identifiers.** The data and/or specimens will be labeled with a code that the research team can link to individually-identifiable information. If the data and/or specimens will be coded, describe below how the key to the code will be securely maintained.

☐ **Paper records will be used.** The key to the code will be secured in a locked container (such as a file cabinet or drawer) in a locked room. The coded data and/or specimens will be maintained in a different location.

☐ **Computer/electronic files will be used.** The key to the code will be in an encrypted and/or password protected file. The coded data file will be maintained on a separate computer/server.

☐ **Other (please specify), or provide additional pertinent information.**

☐ **Confidential – Direct Identifiers.** The data and/or specimens will be directly labeled with the individually-identifiable information.

☐ **Paper records will be used.** The information will be secured in a locked container (such as a file cabinet or drawer) in a locked room.

☐ **Computer/electronic files will be used.** The information will be stored in an encrypted and/or password protected file.

☐ **Other (please specify), or provide additional pertinent information.**

If "Confidential" is marked, please answer all the following:

Explain why it is necessary to keep direct or indirect identifiers.

Identify who will have access to the individually-identifiable information and/or the key to the code.

☐ **Public. Information will be individually-identifiable when published, presented, or made available to the public.**

2. Future Use of Information

If individually-identifiable information and/or codes will be retained after completion of data collection, describe how the information will be handled and stored to ensure confidentiality. ***Check all that apply.***

☒ **All data files will be stripped of individually-identifiable information and/or the key to the code destroyed.**
☐ **All specimens will be stripped of individually-identifiable information and/or the key to the code destroyed.**
☐ **Individually-identifiable information and/or codes linking the data or specimens to individual identifiers will**
be retained. *If this box is checked, describe:*
 a. Retention period.
 b. Justification for retention.
 c. Procedure for removing or destroying the direct/indirect identifiers, if applicable.
☐ **Audio and/or video recordings (if applicable) will be transcribed/analyzed and then destroyed or modified to eliminate the possibility that study participants could be identified.**
☐ **Audio and/or video recordings (if applicable) will be retained. *If this box is checked, describe:***
 a. Retention period.
 b. Justification for retention.
☐ **Other (please specify), or provide additional pertinent information.**

Section M: CONSENT PROCESS

Important Note: *The IRB strongly recommends the use of consent templates that are available on the IRB website to ensure that all the elements of informed consent are included (per 45 CFR 116). If more than one consent document will be used, please name each accordingly.*

☐ **The PI is attaching a copy of <u>all</u> consent documents that participants will sign.**
☒ **The PI is requesting that the IRB waive requirement to document informed consent.** A signed consent form may be waived if one of the following criteria is met, ***check the box that applies.***
 ☐ 1. The only record linking the participant and the research would be the consent document <u>and</u> the principal risk would be potential harm resulting from a breach of confidentiality. Each participant will be asked whether the participant wants documentation linking the participant with the research, and the participant's wishes will govern; or
 ☒ 2. The research presents no more than minimal risk of harm to participants and involves no procedures for which written consent is normally required outside of the research context.

The consent script or cover letter that will be used in lieu of a consent form is attached. (Choose YES or NO)

☐ **The PI is requesting that the IRB approve a consent procedure which does not include, or which alters, some or all of the elements of informed consent set forth in 45 CFR 116, or waive the requirement to obtain informed consent.** An informed consent may be waived if the IRB finds that all of the following have been met:

1. The research involves no more than minimal risk to the participants;
2. The waiver or alteration will not adversely affect the rights and welfare of the participants;
3. The research could not practicably be carried out without the waiver or alteration; and,
4. Whenever appropriate, the participants will be provided with additional pertinent information after participation.

Provide justification for requesting a waiver.
Describe how, where, and when informed consent will be obtained from research participants (or permission from parent/s or guardian/s and assent from minor participants), if applicable.

Section N: VULNERABLE AND/OR SPECIAL POPULATIONS

1. **Check if some or all of the targeted participants fall into the following groups. *Important Note:*** *Some targeted populations require compliance with additional Subparts and the completion of an Appendix or of specific section (see last column).*

Population Type **Required to Complete**

☐ **Pregnant women, neonates, or fetuses**... Appendix for Subpart B
☐ **Prisoners**.. Appendix for Subpart C
☐ **Minors**
☐ **Mentally-disabled/cognitively-impaired/severe psychological disorders**
☐ **Physically-disabled**
☐ **Terminally ill**
☐ **Economically/educationally-disadvantaged**
☐ **A specific group based on religion, race, ethnicity, immigration status, language, or sexual orientation**
☐ **UGA Psychology Research Pool/Other UGA students/employees**
☐ **Other** (please describe)

2. **Explain justification for including the group(s) checked above in this particular study.**
3. **Is there a working relationship between any researchers and the participants** (e.g., PI's own students or employees)**?**
   No
   a. If yes, please describe.
4. **Describe any additional safeguards to protect the rights and welfare of these participants and to minimize any possible coercion or undue influence.** *For example, amount of payment will be non-coercive for the financially disadvantaged, extra-careful evaluations of participants' understanding of the study, advocates to be involved in the consent process, or use flyers to recruit participants instead of directly approaching own staff or students.*

Section O: COLLABORATIVE PROJECT OR OUTSIDE PERFORMANCE SITE

Check one of the two boxes below:

☐ **This project does not involve any collaboration with non-UGA researchers or performance in non-UGA facilities.**

☒ **This project involves collaboration with non-UGA researchers or performance in non-UGA facilities** (e.g., local public school, participants' workplace, hospital). ***If this box is checked, list all sites at which you will conduct this research.*** **Attach authorization/permission and/or current IRB approval.** *Checkboxes below are not clickable so place "X" before or over the box. To add a row, bring cursor to outside of last row, press "enter" key, and copy/paste the previous cells.*

Name of Institution	Location (County/State/Country)	Authorization/permission letter and/or current IRB approval.	
Athens Technical College	Athens, Georgia 30601	☐ Attached	x☐ Pending
		☐ Attached	☐ Pending

IMPORTANT NOTE: **If none of the following applies to your research, this is the END of the application form.**

Section P: METHODS AND PROCEDURES THAT REQUIRE ADDITIONAL INFORMATION

Check all that apply. ***Important Note:*** *The items listed below are* ***NOT*** *an inclusive list of methods and procedures that may be used in research studies. Some procedures require the completion of an Appendix or of specific sections (see last column).*

Method/Procedure **Required to Complete**

☒ **Student research (For student's thesis/dissertation/others)**............... Section Q (below)
☐ **Deception, concealment, or incomplete disclosure**.......................... Section R (below)
☐ **Internet research** .... Section S (below)

☐ **Blood sampling/collection**.. Section T (below)
☐ **Clinical trial (Drugs, biologics, or devices)**
☐ **Genetic analyses**
☐ **Data/Tissue repository**
☐ **HIPAA (Protected health information)**
☐ **DXA/X-RAY**
☐ **MRI/EEG/ECG/NIRS/Ultrasound**
☐ **Other** (please describe)

Section Q: STUDENT RESEARCH

Important Note: *The IRB recommends submission for IRB review only after the appropriate committee has conducted the necessary scientific review and approved the research proposal.*

1. This application is being submitted for: ☐ Undergraduate Honors Thesis ☒ Doctoral Dissertation Research ☐ Masters Thesis Research ☐ Other (please describe)

2. Has the student's thesis/dissertation committee approved this research? ☒ **Yes** ☐ **No**

Section R: DECEPTION, CONCEALMENT, OR INCOMPLETE DISCLOSURE

1. Describe the deception, concealment, or incomplete disclosure; explain why it is necessary, and how you will debrief the participants. ***Important Note:*** *The consent form should include the following statement: "In order to make this study a valid one, some information about (my participation or the study) will be withheld until completion of the study."*
2. Debriefing Form is attached. ☐ **Yes** ☐ **No;** If no, please explain.

Section S: INTERNET RESEARCH

If data will be collected, transmitted, and/or stored via the internet, the level of security should be appropriate to the level of risk. Indicate the measures that will be taken to ensure security of data transmitted over the internet. *Check all that apply.*
☐ A mechanism will be used to strip off the IP addresses for data submitted via e-mail.
☐ The data will be transmitted in encrypted format.
☐ Firewall technology will be used to protect the research computer from unauthorized access.
☐ Hardware storing the data will be accessible only to authorized users with log-in privileges.
☐ Other (please describe), or provide additional pertinent information.

Section T: BLOOD SAMPLING / COLLECTION

If blood will be collected for the purpose of this research, please respond to all the following:
1. **Route/method of collection** (e.g., by finger stick, heel stick, venipuncture):
2. **Frequency of collection** (e.g., 2 times per week, for 3 weeks):
3. **Volume of blood for each collection** (in milliliters):
4. **Total volume to be collected** (in milliliters):
5. **Are participants healthy, non-pregnant adults who weigh at least 110 pounds?** (Choose YES or NO)
   a. If no, indicate if amount collected will exceed the lesser of 50 ml or 3 ml per kg in an 8-week period and if collection will occur more frequently than 2 times per week.
6. **Will participants fast prior to blood collection(s)?** (Choose YES or NO)
   a. If yes, describe how informed consent will be obtained prior to fasting.

APPENDIX F

IRB Observation Checklist and Study Procedures

STUDENTS WHO DECIDE TO PARTICIPATE IN THE LABORATORY EXPERIMENT AND HAVE BEEN GIVEN THE INFORMATION SHEET AND CONSENT DOCUMENT will be randomly selected either based on alphabetical selection or randomization table assignment in order to determine the treatment and control groups. Each group will be divided equally to administer the subjects to computer simulation laboratory work or hands-on laboratory work. With a total of 28 subjects, 14 subjects would be required for both the control and treatment groups. The chosen laboratory administration will occur during the second week of the winter quarter of the class and last for 2 hours during the laboratory period. The control group would consist of the hands-on laboratory assignment and the treatment group would consist of the computer simulation of the laboratory assignment. The subjects are required to complete the laboratory assignment given the same instruction and syllabus for the laboratory experiment. The computer simulation assignment will require additional instruction for computer use, simulation setup and operating the simulation software. Within the next week, the subjects would take a follow-up posttest that would test for skill building capabilities after treatment. The total experiment would require approximately 2 hours during a 1 week period of time during the winter quarter. The laboratory will be separated into two parts that include computer stations for simulation of the series/parallel circuit laboratory and laboratory stations for the hands-on series/parallel circuit laboratory exercises. The computer stations will include a personal computer that has the simulation software already present on the computer with the computer program for the series/parallel laboratory exercise opened for the student. The hands-on laboratory stations will include the circuit board prepared with the series/parallel circuit built for the student to use with the digital volt meter (DVM) and power supply. The amount of students required for the experimental study might require additional preparation to allow groups within each treatment to be no more than 10 students. If 14 participants are to participate in the treatment and only 10 computer stations are available at any given time, then 2 sections of participants will be required as in Table 3. Each section of participants can be given the treatment consecutively and can occur simultananeously with a full section for the control group of the experiment or the other 14 participants.

Table 3

Section Requirements for Treatment or Computer Simulation with 14 participants

Time Requirement	Subject Participation	Number of Stations
2 hr	Section 1 (10 participants)	10
2 hr	Section 2 (4 participants)	10
4 hrs	Total Participants of 14	

Note: Subject participation for Treatment only, using 26 participants. A total of 52 participants that will be divided randomly for Treatment and Control experiments.

The proctor for the experiment will be given a checklist for performing the functions of both the hands-on and computer simulation laboratory. This checklist is part of the laboratory handout and is also part of the observation sheet which show 4 sections for completion by the participant which include (1) circuit functionality and setup, (2) measuring the circuit, (3) calculating additional characteristics of the circuit, and (4) calculating differences between measurement and calculation. The effect of the checklist for the proctor will be to limit extraneous variables that can affect the experimental outcome to strengthen the internal validity of the treatment and the overall experiment (Gall, Gall & Borg, 2007, p.383).

Observation Checklist for Laboratory/Testing

1. Circuit functionality and setup
    a. circuit construction or simulation software circuit construction
        i. Resistors (software)
        ii. Wiring (software)
        iii. Breadboard (software)
        iv. Personal computer loaded with National Instruments, Inc. Workbench software and loaded with circuits under experimentation
    b. proper equipment including measurement instruments
        i. DVM – digital volt meter to measure voltage, current and resistance
        ii. Power Supply
2. Measuring the circuit
        i. Proper removal or applying measurement instruments for measuring voltage, current or resistance.

ii. Replacing the circuit in proper working order for next measurements

iii. Applying power with power supply (software)

3. Calculations of additional characteristics of the circuit

i. Calculation of power dissipations of circuit components

ii. Application of Ohm's Law, Power Law and Kirchoff's Laws.

iii. Application of Calculation and Proper Readings. (milli, Kilo, micro)

4. Calculating differences between measurement and calculation of the circuit

i. Application and comparison from either software simulation or actual hands-on laboratory to calculation of results.

In order to distinguish the measurement of technical skill improvement among post-secondary technical education students especially in the science of Electronics, prepared laboratory assessments will be developed from core competencies as outlined in the Technical College System of Georgia curriculum guide for the Electronics Technology Degree. The assessments are an estimation of skill construction and improvement based on problem solving abilities and cognitive aptitudes for the fundamentals of Direct Current Circuits in an Electronics Technology curriculum.

The laboratory exercises will consist of understanding series and parallel circuits as used in an electronics curriculum. The posttest will assess students' abilities to understand fundamental concepts of series and parallel circuits and their relationship to Ohm's Law, Kirchoff's Law and the Power Law. The student will have the capability to answer the questions about a particular series/parallel circuits using methods such as Mesh Analysis, Nodal Analysis and Reduction/Expansion. Each posttest will be given to STUDENTS WHO ARE PARTICIPATING in the study requiring approximately 1 hour given by a proctor.

Observational Notes:

Timeline	*Note*
Monday, January 10	
16 students are given short discussion of	*9:25AM*
Breadboarding, DVM use and understanding	
Computer use of simulation instrumentation	
In the electronics technology classroom	
The students are separated by randomization	
To either the simulation or hands-on lab	*9:40AM*
In the electronics technology laboratory	
10 students are assigned the computer simulation	
And 6 students are assigned the hands-on lab	
Proctor makes sure they are comfortable and	
Limited to the 2 hour time for the laboratory	

And the 1 hour time for the post-test.	
The computer labs are separated from the hands-on	
Laboratory by opposite sides of the laboratory	*9:50AM*
Room and the proctor requires quiet and a show	*a student needed a calculator*
Of hands to indicate any questions.	*11:15AM*
	Some students finish the laboratory
	And post-test early and leave the
	Laboratory area.
	12:05PM
	All participants are completed

Tuesday, January 11

8 students are given short discussion of	*9:35AM*
Breadboarding, DVM use and understanding	
Computer use of simulation instrumentation	
In the electronics technology classroom	
The students are separated by randomization	
To either the simulation or hands-on lab	*9:45AM*
In the electronics technology laboratory	
2 students are assigned the computer simulation	
And 6 students are assigned the hands-on lab	
Proctor makes sure they are comfortable and	
Limited to the 2 hour time for the laboratory	
And the 1 hour time for the post-test.	
The computer labs are separated from the hands-on	
Laboratory by opposite sides of the laboratory	
Room and the proctor requires quiet and a show	
Of hands to indicate any questions.	*10:50AM*
	Some students finish the laboratory
	And post-test early and leave the
	Laboratory area.
	11:55AM
	All participants are completed

Wednesday, January 11

4 students are given short discussion of	*9:15AM*
Breadboarding, DVM use and understanding	
Computer use of simulation instrumentation	
In the electronics technology classroom	
The students are separated by randomization	
To either the simulation or hands-on lab	*9:25AM*
In the electronics technology laboratory	

2 students were assigned the hands-on lab And 2 students were assigned to the simulation lab	*9:45AM*
Proctor makes sure they are comfortable and Limited to the 2 hour time for the laboratory And the 1 hour time for the post-test. The computer labs are separated from the hands-on Laboratory by opposite sides of the laboratory Room and the proctor requires quiet and a show Of hands to indicate any questions.	*a student needs extra lighting*
	10:20AM *Some students finish the laboratory And post-test early and leave the Laboratory area.*
	10:40AM *All participants are completed*

APPENDIX G

Athens Technical College Letter of Approval

Athens Technical College

A Unit of the Technical College System of Georgia

800 U. S. Highway 29 North
Athens, GA 30601-1500
(706) 355-5000
www.athenstech.edu

Flora W. Tydings, Ed.D.
President

December 16, 2010

Mr. Ken Roberts
Program Chair
Electronics Technology
Athens Technical College
800 U.S. Highway 29 North
Athens, Georgia 30601

Dear Mr. Roberts:

This letter is to confirm the approval of your request to conduct an experiment with students in your Electronics Technology program as part of your dissertation research. Please submit a copy of your IRB proposal to Dr. Daniel J. Smith, vice president for institutional effectiveness here at the college, once you receive final approval from the Human Subjects Office at The University of Georgia.

Submitting the IRB proposal for final approval represents a major milestone in your path toward earning a doctorate. Congratulations and I wish you the best of luck with your research project! Please contact Dr. Smith or myself if we can be of further assistance.

Respectfully,

Flora W. Tydings

Flora W. Tydings, Ed.D.
President

cc: Dr. Dan Smith

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