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Comparison of student achievement among two science laboratory types: Traditional and

virtual.

By

Mary Celeste Reese

A Dissertation
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy
in Agriculture Science Education and Extension
in the College of Agriculture and Life Sciences

Mississippi State, Mississippi

August 2013

Comparison of student achievement among two science laboratory types: Traditional and

virtual.

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Pages in Study: 70

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Technology has changed almost every aspect of our daily lives. It is not surprising then that technology has made its way into the classroom. More and more educators are utilizing technological resources in creative ways with the intent to enhance learning, including using virtual laboratories in the sciences in place of the "traditional" science laboratories. This has generated much discussion as to the influence on student achievement when online learning replaces the face-to-face contact between instructor and student. The purpose of this study was to discern differences in achievement of two laboratory instruction types: virtual laboratory and a traditional laboratory. Results of this study indicate statistical significant differences in student achievement defined by averages on quiz scores in virtual labs compared with traditional face-to-face laboratories and traditional laboratories result in greater student learning gains than virtual labs. Lecture exam averages were also greater for students enrolled in the traditional laboratories compared to students enrolled in the virtual laboratories. To account for possible differences in ability among students, a potential extraneous variable, GPA and ACT scores were used as covariates

DEDICATION

    I would like to dedicate this dissertation to my son, Stone, for being my driving force, when many a night I wanted to give up; for your bear hugs and the countless times you asked me how my day was.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Laboratory instruction has long been thought of as an important component to learning and understanding science. Thus it has been used in science education since the late 19th century where its practice was for observation, application, furthering knowledge, and to excite the student's interest in science (Blosser, 1983). This philosophy holds true today, although a great deal of debate as to *how* those objectives should be met has arisen. Blosser (1983) noted as Shulman and Tamir wrote in the *Second Handbook of Research on Teaching* (Travers, 1973), the following groups of objectives can be accomplished through laboratory instruction: skills, concepts, cognitive abilities, understanding the nature of science, and attitudes toward science.

Traditionally, science courses include a laboratory component in which students are allowed a 'hands-on" approach to the concepts learned in the classroom. Practical skills are applied in these labs for any particular science discipline (Dalgarno et al., 2003), and being active participants in science through inquiry and manipulation is, in fact, the process of science (Hofstein & Lunetta, 2003). Thus, science laboratories have persisted in all levels of education.

Varying pedagogical approaches to laboratory instruction, such as inquiry-based, problem-based, and "cookbook" style, in introductory science courses have also been the topic of much discussion. The research has generated mixed conclusions regarding

student learning (Abdel-Salam, Kauffman, & Crossman, 2006, Balamuralithara & Woods, 2009; Bodzin, Waller, Santoro, & Kale, 2007; Cepni, Tas, & Köse, 2006; French & Russell, 2001). Moreover, there is an increasing shift by higher education institutions to replace traditional traditional laboratories with "virtual" laboratories that are conducted online in order to conserve institutional resources (Capper & Fletcher, 1996; Carnevale, 2003; Dalgarno, Bishop & Bedgood, 2003; Gilman, 2006; Harms, 2000). As the popularity of using online learning tools, like virtual laboratories, increase, questions about their effectiveness on student achievement should be addressed.

Why the Shift to Virtual Labs?

It is becoming increasingly difficult to offer traditional biology laboratories. Growing student enrollment, rising costs of laboratory supplies, and the growing popularity of distance learning, virtual laboratories offer solutions to these obstacles (Sommer &Sommer, 2003):

1. Increasing student enrollment is an issue many universities face. To address this concern, Walker et al. (2007) created an online virtual anatomy lab so students would not be turned away due to limited lab space. Campbell (2004) cited various reasons for replacing what he described as "place-based education" with alternatives like virtual labs.

2. The second reason is access. Labs are time-consuming and difficult to work into student and teaching assistant schedules (Campbell, 2004).

3. The third reason is consistency. Most often, several teaching assistants teach the same lab, often with varying degrees of expectations and commitment to student learning (Campbell, 2004).

4. Lastly, up-to-date lab equipment and lab supplies are costly. Lab simulations may be a great alternative to lower lab costs and increase conformity and access, thus creating good laboratory experiences (Campbell, 2004).

In concurrence, Muhamed et al. (2010) argued the benefits of virtual labs. Although this study addressed the same advantages previously mentioned, the authors noted the importance of meaningful learning as it relates to making connections among biological concepts. Active learning through hands-on approaches is still necessary, as pointed out by the researchers. However, the researchers believed virtual laboratories should also be used effectively as a tool to overcome constraints previously mentioned.

An Overview of the Advantages and Disadvantages of Utilizing Virtual Labs

Scheckler (2003) laid out the advantages and disadvantages of using only virtual labs. The advantages the author included were that demonstrations can be repeated and used as a review for exams; virtual laboratories allowed experimentation of concepts that may present danger, like using volatile chemicals or may take more time than is allowed in one laboratory setting to conduct; and web-based learning tools supplement content learning in both lecture and lab, especially for a developmental biology course.

Scheckler (2003) also pointed out the disadvantages of virtual labs. The researcher cited the greatest disadvantage of virtual labs as the simple removal of hands-on lab experiences such as slide preparation and dissection. Another disadvantage was the lack of direct supervision by an instructor or teaching assistant that is knowledgeable and can help guide students through the laboratory exercise. Other disadvantages included technological issues, transnational or transcultural learners having difficulty

with styles or language of virtual labs, and online or virtual simulations are only a representation of a natural system and therefore, learning may be lost on something unrealistic.

Finally, another disadvantage in virtual laboratories is the lack of a laboratory partner. Many educational studies have cited the importance of peer-learning. Carnevale (2003) described the development of a physics virtual lab called *Learn Anytime Anywhere Physics*, financed by a 1.8 million dollar grant from the Department of Education. This particular virtual lab included virtual lab partners that cooperated with the student, and created a realistic situation. The phantom lab partner gave either good or bad advice also, just like a real partner. This virtual partner is just one way some science professors have attempted to overcome the many disadvantages of virtual laboratories.

It is clear there are advantages and disadvantages in using virtual labs in laboratory-based science courses. The issues involved in running traditional laboratories, including institutional costs, are important components for educators to consider when deciding to switch to virtual labs. Wolf (2010) also recognized virtual laboratories are being utilized in increasing numbers, yet he pointed out assessments of their efficacy are limited. Since 1999 when the National Research Council called for educational reform in the sciences, educators have been evaluating the influence of virtual laboratory approaches on student achievement and student perceptions about the sciences. The advantages must be weighed against the disadvantages as educational reform continues.

Justification

Within the United States, STEM (Science, Technology, Education, and Mathematics) education has gained national attention. While the United States has seen

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some improvement in math and science scores, The National Assessment of Educational Progress (NAEP) found an overwhelming number of students still do not reach the proficiency level in these subjects. In fact, in 2003, the Program for International Student Assessment (PISA), performed by the NAEP (2003) found the U.S. ranked 28th in math literacy and 24th in science literacy out of the 40 countries sampled. To address this issue, the federal government, through review of many critical reports, has recommended educational policy should improve primary and secondary education, use tools to recruit more primary and secondary educators, perhaps in the specific math and science fields, and give current STEM educators more artillery for which to better facilitate this STEM initiative (U.S. Department of Education, 2009).

From these recommendations, The National Research Council's Board on Science Education sought input from post-secondary educators about critical issues concerning introductory undergraduate science courses (Labov, 2004). Much discussion has been generated about the current teaching strategies science educators employ in introductory biology classes. Science educators have noted many college students enter these courses with misconceptions about the process of science, having had past unsatisfactory experiences (McComas, 2002). According to the National Research Council (1999), providing students with a positive learning experience and helping students develop critical thinking skills in an introductory biology course is crucial to creating a scientifically literate public. Many times these introductory science courses make science seem uninteresting by reinforcing the misconception that science is simply memorizing long lists of facts (Svinicki, 1998). Finally, the National Research Council had concerns with the lack of underrepresented groups in the science field and therefore the U.S. may

be losing valuable scientific contributors due to this lack of diversity. Capturing and retaining underrepresented groups should be an important feature in STEM education.

Post-secondary educators continue to experiment on effective teaching-approaches and search for improved ways to reach students (Bodzin, Waller, Santoro & Kale, 2007; Dalgarno, Bishop & Bedgood, 2003; French & Russell, 2001; Gilman, 2006; Goldsmith, Stewart & Ferguson, 2006; Hicks & Bevsek, 2011). Development of new instructional styles to promote life-long learning of students, create a scientifically literate community, and impact future science educators to further facilitate educational goals is crucial (French & Russell, 2001). The influence these new techniques have on student attitude and competency must be carefully evaluated by researchers.

Purpose

The purpose of this research is to determine the influence of type of laboratory instruction on student achievement in a non-majors biology course, Plants and Humans (BIO 1023), taught on the campus of Mississippi State University. As virtual laboratories become increasingly popular as a means of saving money and decreasing instructional time for major universities, determining the effectiveness of virtual laboratories on student learning for this particular course will be important in understanding if this laboratory instruction type is viable and whether its use should continue. For this study, two distinct types of laboratory instruction will be used: traditional (traditional) and virtual laboratories. Student achievement as defined by final laboratory and final lecture averages will be used for this study. Demographic data will be examined to determine if differing groups are affected by the laboratory instruction type.

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Research Objectives

Research Objective 1:

To compare laboratory achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken at a four-year university with students enrolled in the virtual laboratory at the same university.

H_0:There is no difference in laboratory achievement rates of traditional versus virtual laboratory enrollment.

Research Objective 2:

To compare lecture achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken at a four-year university with students enrolled in the virtual laboratory at the same university.

H_0:There is no difference in lecture achievement rates of traditional versus virtual laboratory enrollment.

Research Objective 3:

To describe student achievement rates based on descriptive variables in the traditional and virtual laboratory achievement types.

Definitions of Terms

For the purpose of this research, the following terms have been operationally

defined:

1. Scientific process. Is a way to use the scientific method to discover the

   answer to a scientific question (Freeman, 2008). The concept of the

   scientific process is assessed using laboratory quizzes and questions on the

   first lecture exam.

2. Traditional (i.e., traditional) laboratory. A face-to-face laboratory

   whereby students are given a step-by-step plan for carrying out a specific

   experiment (Royuk & Brooks, 2003). For this study, students enrolled in

   the traditional laboratory were given instructions for completing the

   specific lab and then assessed using a 5 question mini-quiz at the end of

   the laboratory period. These quizzes were averaged at the end of the

   semester.

3. Virtual-based laboratory. A computer simulation that enables essential

   processes of laboratory experiments to be carried out on a computer

   (Harms, 2000). For this study, students enrolled in the virtual-based

   laboratory were given instructions for completing the specific lab,

   dismissed to conduct the lab on their own time, and then assessed using a

   8 question mini-quiz at the beginning of the next laboratory period. The

   students also turned in a lab report for 2 points. These quizzes and lab

   reports were averaged at the end of the semester.

Assumptions

1. Students participating in the virtual laboratory have competent computer skills.

Limitations

1. Randomization was not possible for this study.

2. Content covered in the traditional laboratory and the virtual laboratory is not equalized since virtual laboratories are created by McGraw Hill Publishing Company and selection of specific laboratories was limited by the labs provided by the publishing company. Table 1 shows the differences in topics covered.

3. Assessment of laboratory achievement was different in each laboratory type. Students in the traditional lab took quizzes on different content than students enrolled in the virtual labs. Number of items on the quizzes was also different in each lab type.

4. Number of students in each treatment group was significantly different. There was almost half the number of students sampled in the traditional versus the virtual laboratories.

5. Different graduate teaching assistants conducted both instructional types (i.e., traditional and virtual) of laboratories and therefore, instructional quality was not standardized.

Students have diverse educational backgrounds and therefore, prior scientific knowledge will be varied.

CHAPTER II

LITERATURE REVIEW

The Role of the Science Laboratory

Historically, the role of the science laboratory, regardless of intent, has been
considered fundamental to science education. Lunetta (1998), in a brief overview of the
historical perspective of the science lab, noted starting in the early nineteenth century,
observation was used to make inferences about occurrences in the natural world and this
was an important part of a student's education. In the early part of the twentieth century,
a progressive educational movement advocated the use of investigation and practical
application in the laboratories to impart the main goals of science education, which
included 1) understand scientific concepts at a deeper level; 2) learn practical skills, such
as, use of a microscope and dissection; problem-solving; 3) and creating motivation and
interest in the sciences.

Hofstein and Lunetta (2003) maintained the role of science laboratories has
always been to provide students with an opportunity to be active participants in the
process of science through inquiry and manipulation. However, they also maintained
although science laboratories offer unique means for learning the process of science,
there is still an insufficient amount of data confirming the various modes of lab
instruction have significant effects on student learning.

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In 1980, Miles Pickering, a lecturer and laboratory coordinator for the chemistry department at Princeton University wrote an opinion paper entitled, "Are Lab Courses a Waste of Time?" He brought up a fundamental issue with labs: If labs are costly and time consuming and typically despised by students and teachers who have to teach them, are they really important in science education? Also, most students that take labs are pre-medical students and engineers. If the role of the lab is to prepare future scientists, then how are these students benefitting?

Pickering outlined the misconceptions surrounding science laboratories:

1. Misconception: Labs should elucidate what is learned in lecture. However, that is nearly impossible in most cases because one afternoon in lab is not enough time to illustrate most concepts. Instead, a lecture demonstration or an audio/visual aid would work just as well.

2. Misconception: Labs exist to teach lab skills and techniques. However, most pre-medical and engineering students have no use for these skills, with possibly the exception of focusing a microscope. Plus, techniques used in teaching labs are typically outdated. Titration and dissection are not commonly used by biologists in this era.

In 2007, the National Science Teachers Association (NSTA) put out a position statement about the role of laboratory investigations in science instruction. The NSTA felt strongly that labs should maintain an essential part of science instruction and therefore effective teaching practices should be employed to do the following: Ensure students understand the purpose of the lab, emphasize the process of science as a way to connect the content, assimilate student thought and discussion throughout the laboratory

process, and finally, allow students to conscientiously develop proper lab procedures and safe habits. The NSTA felt strongly that there needs to be good support for the teachers that conduct these labs and there needs to be support for labs in general in order to facilitate the main objectives of the science laboratory.

The need to assess the science teaching laboratory has been ongoing. Many aspects to the lab have been researched including student attitudes, ability to critically think, retention of students in the sciences, whether students understand the process of science, as well as the instructional set-up of the laboratory in student achievement.

Currently, some post-secondary biology educators are contributing through publications to a metadata bank of information comparing instruction-type and student achievement. This information is available to all educators so the potential for quantification of instruction-type, assessment-type, and student achievement and student attitude will be viable. With the National Research Council calling for educational reform in the sciences since 1999, educators must continue to effectively evaluate the affect of science education on student achievement and student perceptions about the sciences.

In this review, current research findings will be examined and compared of the following laboratory instruction-types: (1) virtual (see definition #3 below); and (2) face-to-face or "traditional" on student achievement and student attitude. Research on laboratory-style instruction is limited in the sciences; and therefore the review will be broadened to include course instruction-types in multidisciplinary fields.

Technology and the Virtual Laboratory

The term "virtual laboratory" has become ubiquitous since it typically refers to different types of online learning modes in many various disciplines. As a result, Harms (2000) classified virtual labs according to five categories: (1) Simulations are literally simulations used to model concepts and/or processes of some natural phenomena (e.g., an object free falling to demonstrate the concept of acceleration in a physics class), have essential parts of laboratory experiments, and are shown locally (Jimoyiannis & Komis, 2001; Harms, 2000); (2) Cyber Labs are simulations used to model concepts and/or processes which have essential parts of laboratory experiments, are accessible through the internet, and use JAVA-Applets or some other type of plug-in (e.g., a student observing from his or her computer an object free falling in order to understand the concept of acceleration); (3) Virtual laboratory is a computer simulation that enables essential processes of laboratory experiments to be carried out on a computer. For example, a student may "virtually" pipette a solution from a beaker into a test tube to observe changes in pH concentrations from his or her computer; (4) Virtual Reality (VR) labs are simulations of lab experiments using virtual reality techniques that involve human senses and; (5) Remote Labs are real experiments that are physically controlled through the internet (e.g., controlling an apparatus used in an experiment via the internet). Since Harm's classification of virtual labs, other types of virtual labs have emerged, such as 3-D Simulations (Balamuralithara & Woods, 2009). As technology continues to evolve, virtual labs are also becoming more sophisticated, like 3-D graphics used in virtual labs. Videos of demonstrations or natural events may also be considered part or all of a virtual lab if students are viewing the video from a computer outside of the traditional lab. For

purposes of this review, the term virtual lab (as described in number three) will be used in a broad context and will encompass any of the aforementioned classifications.

Shih and Allen (2006), in a descriptive study, suggested today's generation of students differs significantly from previous generations and therefore technology, like the use of virtual labs, must be interweaved into the curriculum to capture and retain these types of learners. The D generation (D for Digital) or Net Generation are commonly engaged by cell phones, iPods, instant messaging, blogging, MMORGing (Massively Multiplayer Online Role-Play Gaming), downloading music and videos, etc. The researchers posited these learners have been raised on the fastest and latest technologies. The researchers maintained educators in all disciplines must realize in order to interface with these learners, technology-based learning must be embraced.

Are all individuals, as defined by their generation, information and communication technology (ICT) savvy? Nasah et al., (2010) addressed this question by asking, "Are certain socioeconomic groups more or less ICT literate than others?" The researchers conducted an email survey to determine ICT usage of the varying groups. Several constructs were examined, such as internet use preferences, gaming, online media activities, digital communications, and ICT-facilitated learning activities. The treatment group consisted of undergraduate and graduate students in the age range of 20–29 ($n = 523$). Of those sampled, 41% reported a family income range of over $60,000 ($n = 212$). In addition, 30% of the participants reported having at least two computers in the home. There was a statistically significant difference in socioeconomic groups with regard to ICT-facilitated learning activities. However, since the effect size ($r < .1$) was extremely

low and correlations were mostly negative, the researchers did not feel this result was conclusive. They reasoned the gap is closing between socioeconomic status and ICT use.

Although much of the literature suggested certain generations are more adept at using technology than others (e.g., Hannum & McCombs, 2008; Hart, 2008; Shih Allen, 2006), Bullen, Morgan and Qayyum (2011) discovered the opposite results. In an empirical study using group interviews and surveys of 69 undergraduate students, including net generation and non-net generation participants, the researchers concluded three main issues drive the use of ICT: familiarity, cost, and immediacy, rather than generational differences. Moreover, the researchers further concluded generational stereotypes impede our understanding of how students use technology to learn and therefore educators should address the context of technology use is the main premise.

For the case of virtual labs, the issues raised in the literature are important in understanding how we use technology in our courses. The debate on whether generational differences in technological use exist will only facilitate pedagogy and enhance online learning modes.

Benefits of Virtual Laboratory Instruction

Access and Consistency

Campbell et al. (2004) described various reasons for replacing "place-based education" with alternatives like virtual labs. Access is a large reason. Labs are time-consuming and difficult to work into student schedules and teaching assistant schedules. The second reason is consistency. Most often, several different teaching assistants teach the same lab, often with varying degrees of expectations and commitment to student learning. Online labs may control for the lack of consistency by standardizing all labs

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taught for a particular course. To test this, Campbell et al. (2004) compared two groups

of students, one group in a physical electronics lab and the other in a simulation

electronics lab. They found no statistical difference in lab grades at the end of the

semester. They also found students spent the same amount of time in each lab type,

confirming access and consistency were not an issue in the varying laboratory types.

Cost

Up-to-date lab equipment and lab supplies are costly for use in traditional

laboratories. Lab simulations may be a great alternative to lower lab costs, while still

creating good laboratory experiences (Campbell et al., 2004). Minasian-Batmanian and

Jayachandran (2003) noted in physiology courses conducted for health science students,

animal experimentation used in the laboratory, is costly in terms of supplies, technical

staff, and use of animals. To remedy this, the researchers used a pre-existing video that

allowed students to view the experiment and the results to the experiment. Students were

given quizzes at the end of each lab session to test knowledge of the concepts. The

authors only reported positive feedback and improved student achievement.

Repetition

Scheckler (2003) observed laboratory demonstrations could be infinitely repeated

by students in virtual labs, especially for students in a developmental biology course.

Supplementing lecture with virtual laboratories might further assist these students to

understand more difficult concepts.

Pre-laboratory Preparation

Pre-laboratory preparation for a chemistry lab, described by Dalgarno, Bishop and Bedgood (2003), has many benefits that could lead to greater student success. These benefits were described as: 1) students feel more relaxed and comfortable in a laboratory setting, 2) knowledge of the layout of the lab leads to less time being wasted on searching for an instrument, 3) instruments could be more easily assembled and used properly, 4) being familiar with lab protocols could lead to improved safety within the lab, and 5) with all of the aforementioned benefits, students could spend more time on learning concepts rather than familiarizing themselves with lab. The researchers used a 3-D program as a pre-lab for their students in order to familiarize students with laboratory lay-out, procedures and protocols. Then the researchers compared their results with students that viewed only still pictures. Data were collected using observation, questionnaires, and interviews. The researchers found a statistically significant difference among the two groups.

Other advantages

With continued increased enrollments across campuses nationwide, limited time and space availability is a realized issue for administrators. Virtual labs do not have these constraints (Nedic, Machotka & Nafalski, 2003). In addition, certain laboratories present danger (e.g., volatile chemicals). Virtual laboratories allow potentially dangerous experiments to be run, repeatedly if necessary, without danger (Scheckler, 2003). And finally, virtual labs allow experimentation that would not otherwise be feasible in a traditional lab. Laboratory experiments might take days or weeks to complete could be condensed in less than an hour. Students may have an opportunity to manipulate

variables of an experiment that might be impossible to manipulate in a traditional lab which in turn helps the student better understand concepts.

Disadvantages of Virtual Laboratory Instruction

Cost

Whereas Campbell et al. (2004) noted virtual labs were more cost-effective than traditional labs because lab supplies are expensive, Scheckler (2003) observed virtual labs were not as cost-effective and this notion is simply a myth. The researcher pointed out development of virtual labs and constant maintenance (i.e., debugging) are extremely costly and only when a virtual lab was non-interactive and served large numbers of students was it cost effective.

As an example of prohibitive cost of virtual labs, Coastline Community College was forced to terminate the development of a CD-ROM for twelve virtual based labs for a biology course. The project proved to be far more costly than first anticipated. Funded by the Department of Education for a total cost of $184,000, only one lab exercise was completed (Carnevale, 2003).

As pointed out previously, virtual labs take on many different forms. Based on the type of virtual lab, cost may be an issue for some institutions. Balamuralithara & Woods (2009) noted for remote labs, the price of devices, instruments, servers, and maintenance could potentially be a major cost factor and this cost should be considered when deciding whether to include these types of labs in engineering courses. Remote labs, compared to simulation labs, are typically more expensive. However, simulations also have costs, such as simulation software, license fees, and expertise needed to change or develop new software when objectives of courses change.

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Lack of 'Hands-On' Approach

Scheckler (2003) observed the biggest disadvantage of using virtual labs compared to traditional was the lack of a 'hands-on' approach for students. For instance, in a biology lab, much is gained from slide preparation (i.e., slicing, staining, and creating a microscope slide of a specimen). The researcher pointed out there is a tremendous positive impact on student achievement when specimens and organisms are handled.

Is there empirical evidence to show students are at a disadvantage when they do not experience a hands-on lab? Abdel-Salam, Kauffman and Crossman (2006) discovered no statistical significance among two groups of engineering students enrolled in a fluid dynamics course; one face-to-face and the other through distance education. The lab for the distance education group consisted of a video while the traditional lab students met face-to-face every week and worked in groups on projects. The researchers compared lab reports and scores on final exams and found no difference among the two groups. Klahr, Triona and Williams (2007) discovered a similar effect with two groups of middle school students: One group assembled a mouse trap race car physically, while the other group assembled the car using a virtual program. Students were told to assemble the cars in such a way to allow the car to travel the farthest. Using a post test, researchers discovered there was no statistical difference in the two groups. The lack of 'hands-on' experiences, therefore, may not be a disadvantage after all.

Lack of direct supervision

Scheckler (2003) again described another disadvantage of virtual labs as the lack of direct supervision and lab facilitation by an experienced and well-knowledgeable teacher. The researcher suggested only self-motivated and mature students were capable

of handling a virtual environment in a setting where there is little to no guidance. On the contrary, Abdel-Salam, Kauffman and Crossman (2006) discovered no statistical significance among two groups of engineering students enrolled in a fluid dynamics course, one in a face-to-face lab and one conducted online. The students in the traditional lab had an instructor present to answer questions and guide the lab. The students enrolled in the online version had only a video of a lab facilitator giving instructions. When averages on individual labs were compared, there was no difference between the groups. It appears lack of direct supervision may not be a disadvantage after all, at least for self-motivated engineering students.

Other disadvantages

Scheckler (2003) also described other disadvantages of virtual labs. Any time computers, computer programs, etc., are used, technological issues are always a negative aspect and usually cannot be avoided. Transnational and transcultural students may have a difficult time understanding language, online learning styles, or even course expectations without direct guidance.

Another disadvantage is the lack of a lab partner which in a typical lab setting may facilitate peer-learning. Peer-learning has been cited as an integral part of the learning experience in various disciplines, especially in laboratories (i.e., Bourne, McMaster, Rieger & Campbell, 1997; Goldsmith, Stewart & Ferguson, 2005; Keppell, Au, Ma & Chan, 2006). If peer-learning or collaboration is not incorporated as part of the lab design in virtual labs by the instructor, a valuable learning tool may be lost (Nedic, Machotka & Nafalski., 2003). To overcome this issue, a physics course designed within their lab software, a phantom partner that acts much like a real lab partner, even

giving bad advice (Carnevale, 2003). However, this was a very expensive project and not all institutions may be able to afford this technology.

Comparisons of Student Achievement in Virtual and Traditional Laboratories

Research comparing virtual and traditional laboratories on student achievement has shown varied results. Gillman (2006) discovered students enrolled in the virtual lab of a freshman level biology course performed only slightly higher on a cell division lab quiz when scores were compared to students in the traditional lab. Linton, Schoenfeld-Tacher and Whalen (2005) found no significant change in student achievement in a computer-based anatomy lab compared with students enrolled in the traditional lab. Cepni, Tas and Köse (2006) in contrast found students' comprehension and application of photosynthesis improved following a lab that included Computer-Assisted Instruction Material (CAIM). Although, it is unclear if CAIM would be as effective if students received the material virtually (self-paced) or if the results were due in part to instructor-facilitated learning. Raineri (2001) found anecdotal evidence to conclude for students enrolled in a molecular biology course, supplementing the traditional lab with virtual simulations enhanced learning and led to positive student attitudes about their own learning. Wolf (2010) concluded rather than educators assessing whether student learning had simply occurred, perhaps educators need to assess the amount of learning that has occurred.

A large body of research has been conducted comparing student achievement in technology-based and traditional-style lectures has indicated there was little difference in achievement (Benbunana-Fich, Hiltz & Turoff, 2001; Capper &Fletcher, 1996; Morrissey, 1998; Parker & Gemino, 2001; Paskey, 2001; Shutte, 1996; Suanpang, Petocz

& Kalceff, 2004; and Tacker, 2001). Some research has suggested technology-based learning has been effective in improving student test scores for solving complex problems (Daugherty & Funke, 1998; Jonassen, 1999).

Neuhauser (2002) compared two groups of students enrolled in the same course. One group met face-to-face and the other section was online. Each section was standardized to include the same material presented the same way by the same instructor. The researcher found no significant difference in scores among the two groups. On the contrary, Schutte (1996) found in a comparison of achievement among traditional and virtual classrooms in a social statistics course, students participating in the virtual classroom scored 20% higher than those in the traditional classroom. However, Schutte believed this difference was a consequence of the collaborative learning efforts of students enrolled in the virtual classroom following the frustration many felt after not being able to ask questions of the professor in the classroom.

With varied research reports, the question continues to be asked: How effective are virtual science laboratories? Very little research has been conducted on virtual versus traditional laboratories in the sciences. Gilman (2006) conducted a study to discover whether offering an online virtual lab on cell division would "short-change" (p. 131) students or be just as effective as traditional labs. The researcher discovered a statistically significant difference ($p = 004$) among students that performed the virtual lab assignment online compared to the students that performed the activity in class, although the difference was minor ($SD = 12.1$ +/- 4.5 compared to $SD = 10.8$ +/-6.4; out of 15 possible points). When students' attitudes were surveyed in respect to the virtual lab experience, there were mixed results. Of the thirty-seven respondents, twelve had very positive

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comments, fifteen were negative, and ten had mixed feelings. Gillman concluded online

or virtual labs did not "short-change" (p. 131) students in this particular study, although

this may not always be the case. Variables such as subject content and lab objectives

may affect achievement.

One study suggested a virtual lab concretely led to increased achievement in

students with disabilities (Bodzin, Waller, Santoro & Kale, 2007). Web-based activities

that included well-developed visualizations, immediate feedback to student responses,

tactile interaction with the computer, and controlling the pace of instruction allowed

students with various learning disabilities to increase comprehension of biological

concepts and processes.

With the National Research Council calling for education reform in undergraduate

education in the sciences since 1999, careful empirical evaluation of new educational

techniques must be supported. Addressing issues facing science departments such as cost

and time effectiveness, student needs, a growing enrollment, and space availability

issues, virtual laboratories may offer an alternative while maintaining the Council's

reform objectives. Continued research will add to the body of knowledge needed to test

the efficacy of virtual labs and determine if its use should continue.

Comparisons of Student Attitude in Virtual and Traditional Laboratories

Some research indicated student attitudes with regard to virtual labs are more

positive towards those in face-to-face lab instruction. Sommer and Sommer (2003) found

from a rating survey that students preferred the convenience and flexibility of on-line labs

compared to students enrolled in traditional labs ($p < .05$). Dalgarno, Bishop and

Bedgood (2003) used virtual 3-D labs as a pre-lab tool for familiarizing students enrolled

in a chemistry lab with laboratory protocol, layout, and equipment before they entered the actual lab. Results from a formative evaluation that included observing students followed by a questionnaire and an interview found students felt the pre-lab component useful. Mason and Brand (2000) developed a virtual plant walk to assist students in plant identification. Eighty percent of students in the treatment group believed the website improved their test scores in addition to the regular instruction and students also favored the web activity because it decreased their overall study time.

Finally, Campbell et al. (2004) found students in an in-class electronics lab requested to be transferred to the virtual labs because of the time flexibility. Conversely, in an exploratory study that utilized both face-to-face laboratories and virtual laboratories in a non-majors biology course, Stucky-Mickell and Stuckey-Danner (2007) found 87% of students felt face-to-face laboratories were more effective in increasing comprehension of course content to student learning as compared to virtual labs. The authors attempted to tease out the complex issues which possibly influenced the students' perceptions of efficiency. They suggested the specific design of the learning experience, the virtual laboratory itself, and/or online collaboration tools may have an effect on students' perceptions of the laboratory type. There were several limitations to this study, including sample size and several of the virtual labs were older and therefore not as engaging, but had both strengths and weaknesses. However, the authors felt there was a great deal of research that needed to be conducted to further elucidate the effects on student learning as virtual laboratories increase in popularity.

Ma and Nickerson (2006) conducted a literature review and found there was no standard of evaluation of student achievement among researchers of online learning. For

one, the literature was spread across many different disciplines which typically have different learning objectives. The authors noted even terminology used in online pedagogical research is varied. For example, remote and virtual laboratories are defined in varying ways within the literature and these irregularities lead to misunderstanding.

It appears from the literature, student attitude was dependent on specific variables like lab design, amount of interaction among teachers and other students, and occasionally student's perceived self-efficacy. Continued evaluation of student attitudes should continue to understand the factors that affect achievement in online learning.

Other Predictors of College Student Success in the Sciences

Traditional predictors of student success have typically been GPA and ACT scores (Burton & Ramist, 2001). However, Robbins, et al. (2004) found the best predictors of student success, as measured by GPA, in postsecondary education, are self-efficacy and achievement motivation, although high school GPA and ACT scores did play a small role. The authors conducted a meta-analysis on 109 studies and using educational motivational theories, categorized nine over-arching frameworks: achievement motivation, academic goals, institutional commitment, self-concept, academic-related skills, contextual influences, academic self-efficacy, perceived social support, and social involvement. Of all of the preceding constructs, only two were statistically significant in determining student achievement: self-efficacy and achievement motivation. However, the authors ran a regression analysis and found high school GPA and ACT scores did account for a small percentage of the variability (25%).

Other studies have examined sex and race as predictors in college success, specifically in the sciences. Kahle (2004) looked at data from the National Assessment

of Educational Progress (NAEP) since 1990 and concluded Whites outperformed minority students, typically African American and Hispanics. In 1988, the NAEP summarized the outcomes of their first science assessments (1970-1986) and found discrepancies in sex and race in the sciences. They found boy's outperformed girls consistently in science achievement and Whites significantly outscored African Americans and Hispanics. Since then, continued assessment from the NAEP has shown the gap between sex and race has only slightly narrowed (Kahle, 2004).

Obrentz (2012) specifically looked at predictors of success in an introductory chemistry course to discern differences in sex and race. The researcher found females earned lower final course grades than their male counterparts. Using educational motivation constructs to examine differences, Obrentz found males had higher intrinsic motivation and they also had lower test anxiety compared to females, which might account for the differences in final grades. The researcher did find that final course grades were lower for all ethnic groups compared to Whites and Asians. Surprisingly there were fewer differences in motivation compared to males and females. As researchers continue to evaluate student achievement in science and particularly science laboratories, careful attention to varying groups should be also be addressed.

Conceptual Framework

The Community of Inquiry (CoI) model, developed by Garrison, Anderson and Archer (2000) (Figure 1) is a framework that has been repeatedly used in assessment of online learning. The CoI model provides a framework for teachers involved in online instruction to better serve students and enhance educational practices. There are three elements to the CoI model: teaching presence, cognitive presence, and social presence.

Community of Inquiry

SOCIAL PRESENCE

COGNITIVE PRESENCE

Supporting Discourse

EDUCATIONAL EXPERIENCE

Setting Climate

Selecting Content

TEACHING PRESENCE (Structure/Process)

Communication Medium

Figure 1   The Community of Inquiry Framework

The first element, cognitive presence can be defined as the student's ability to construct knowledge through online communication (Garrison, Archer & Anderson, 2000). Cognitive presence is vital to deeper student learning, an obvious goal of higher education. Its role in the model is an essential component to student success in online classes. Huang (2011), however, posited that students' motivational processing has a significant impact on cognitive presence, especially in complex online learning environments, and further studies in this area are warranted. To illustrate this need, the researcher evaluated the motivation of undergraduate students that voluntarily participated in an online gaming experience specifically developed to test cognition. After the game, the students were surveyed to determine motivational factors that influenced deeper cognitive processing and Huang discovered a statistically significant connection among the two.

The next element, social presence can be viewed as the ability of a student to connect to the online community through social and emotional means (Garrison, Archer & Anderson, 2000; Whipp & Lorenz, 2009). Social presence appeared to be closely tied with a student's feeling of "community" through building relationships with the instructor and/or fellow students (Hughes, Ventura & Dando, 2007). It has also been directly linked to a student's feeling of satisfaction in online learning environments. Whipp and Lorentz (2009) conducted a cross-case study to determine at what level social and cognitive presence affect a student's perception of support and guidance in an online course. The authors found a direct link among a student's feeling of satisfaction and the amount of social support. Zhan, Xu and Ye (2011) found students that are actively engaged in discussions and group participation in an online learning community (OLC) had significantly higher scores than those that were in passive learning treatment groups. The passive treatment group was enrolled in a face-to-face course and did not participate in any engaging activities online.

The last element, teacher presence, has also been termed "teacher immediacy." It has two functions. The first function is the teacher's instructional design of the course; including how the material is presented and how learning is assessed. The second function is simply the facilitation of the online course. This is also considered to be both the responsibility of the teacher and the learner (Garrison, Archer, & Anderson, 2000). Some research suggests teacher presence has the greatest effect on student satisfaction and learning gains. In contrast, Arbaugh (2010) found teacher presence in an online MBA program had little to do with student satisfaction although it appears to be a predictor. Using a survey at the end of two years of online coursework, the researcher discovered no

matter the degree of teacher presence, students were not influenced to feel self-satisfaction. Arbaugh concluded the CoI model was developed to assess student learning gains rather than satisfaction with an online course and thus cannot be applied.

A possible fourth element, self-efficacy, has been proposed but currently is not included in the original model (Shea & Bidjerano, 2010). Each element and the relationship among them have been the focus of much research. Teacher presence has been shown to have the largest impact on student learning gains and it also has the largest influence on the other two elements. The implications of such research could enable instructors at the higher education level to develop and implement virtual labs that provide opportunities for optimum student success. Although it appears the CoI model could also fit for face-to-face instruction, the instruments used for measurement of the framework are specifically designed for online instructional learning.

CHAPTER III

METHODOLOGY

Overview

The main purpose of this study was to discern differences in achievement attributable to laboratory instruction type, i.e., traditional and virtual laboratories, in a non-majors' biology course at Mississippi State University. To achieve this, an ex post facto design was used. Randomization for this study was not feasible and therefore control for possible extraneous variables was attempted by statistical analysis techniques and building variables into the design.

Final laboratory averages in each laboratory type and course lecture averages were both used as dependent variables. Webster's dictionary defines achievement as a result gained by effort of some task or performance (Merriam-Webster, 2012). In this context, laboratory achievement is operationalized on a subject's final average on mini-quizzes given throughout the course of the semester. Lecture achievement is operationalized as a subject's final average on four lecture exams. Each lecture exam consisted of 50 multiple choice questions and covered approximately one-fourth of lecture content.

Virtual and traditional laboratories are both the main independent variables. Course content in the lecture is the same for both groups, however, virtual and traditional labs cover different content (Table 1) and could not be standardized. Tables 1 displays

the similar topics covered in each of the ten labs for traditional and virtual labs, as well as the differing topics. Another limitation to this study is the differences in assessment in traditional versus the virtual labs. The number of questions on quizzes is not similar (i.e., five questions on the quizzes in the traditional lab and eight questions in the virtual lab along with data reports). And finally, GPA and ACT scores will be used as covariates to equalize groups in order to control for differences among students.

Table 1   Content comparison in traditional and versus virtual labs

Traditional Lab	Virtual Lab
Similar content:	
Microscope Use: students learn parts of microscope, understand magnification, actual focusing	Virtual microscope: prepared slides of cells undergoing mitosis
Rainforest ecosystems (video)	All ecosystems including rainforests
Photosynthesis (video)	Mapping stages of photosynthesis after reading about the process
Transport of nutrients through plant (video)	Plant transpiration: students manipulate different variables that affect transpiration rates
Other content:	
Bacteria, Fungi, Bryophytes, Gymnosperms	Dependent/Independent variables, enzymes
Plant reproduction, pollination, plant anatomy	Cell respiration, cell reproduction, population biology, trophic levels, communities/biomes, punnett squares

Tables 3 and 4 show actual topics covered in each lab type. This table attempts to show only similar topics covered in both lab types.

Research Objectives

Research Objective 1

To compare laboratory achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken at a four-year university with students enrolled in the virtual laboratory at the same university.

H_0: There is no difference in laboratory achievement rates of traditional versus virtual laboratory enrollment.

Research Objective 2

To compare lecture achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken at a four-year university with students enrolled in the virtual laboratory at the same university.

H_0: There is no difference in lecture achievement rates of traditional versus virtual laboratory enrollment.

Research Objective 3

To describe student achievement rates based on descriptive variables in the traditional and virtual laboratory achievement types.

Participants and Setting

Mississippi State University students enrolled in BIO 1023 (Plants and Humans), a non-majors science course and general education requirement will be used for this study.

Catalog description

BIO 1023. Plants and Humans. (3) Two hours lecture. Two hours laboratory. For non-science majors. Students may not have credit for both BIO 1023 and BIO 2113 nor for both BIO 1023 and general biology courses transferred from other institutions. A survey of botany intended to introduce students to the world of plants, particularly emphasizing their relationships with humans and society (Mississippi State University, 2010).

Table 2 shows the semester, year, and specific laboratory-type from which data will be analyzed

Table 2   Lab type by semester and year

Year	Spring	Fall
2006	---	Traditional
2007	Traditional	Traditional
2008	Traditional	Virtual
2009	Virtual	Virtual
2010	Virtual	---

Lab content delivered in traditional labs is identical every semester taught with the exception of the graduate student conducting the lab. Measures are taken to standardize content and quizzing. Lab content delivered in virtual labs is identical same every semester taught. Measures are taken to standardize content and quizzing.

Description of the Independent Variables: Traditional Laboratories

Prior to fall 2008, BIO 1023 laboratories were taught in the traditional laboratory format. Each week, students watched a short video on a particular topic at the beginning of the laboratory period. Students were given a series of questions to answer from the video. Following the video, students performed a specific activity such as describing

various specimens viewed under the microscope, observing a demonstration, dissecting

plant organs, or viewing biological models. Students were then given approximately 10

minutes to review the objectives of the laboratory and immediately administered a five-

question quiz with two questions coming from the short video. Approximately twelve

laboratories were given with the lowest two grades dropped. The final lab grade was

calculated from totaling the lab quizzes and multiplying by two. This final lab grade will

be used for purposes of this study. Table 3 outlines the subject content for the traditional

lab

Table 3   Topics covered in traditional laboratory

Film	Lab Topic
Rain Forests	Lab #1 Use of the Microscope
Bacteria	Lab #2 Kingdom Monera
Euglena; Protista: Giant Sequoia	Lab #3 Kingdom Protista
World of Fungi	Lab #4 Kingdom Fungi
Baobab Tree	Lab #5 Kingdom Plantae: Bryophtes/Pterophytes
Power of Plants	Lab #6 Kingdom Plantae: Gymnosperms
Plant Nutrition; Transport/Movement	Lab #7 Kingdom Plantae: Roots
Death Trap	Lab #8 Kingdom Plantae: Stems
Photosynthesis; Bonsai	Lab #9 Kingdom Plantae: Leaves
Sexual Encounters of the Floral Kind	Lab #10 Kingdom Plantae: Flowers
Plant Reproduction; Grass/Highlands	Lab #11 Kingdom Plantae: Fruits

Description of the Independent Variables: Virtual Laboratories

For purposes of this research, virtual laboratory describes a computer simulation
that allows key procedures of laboratory experiments to be carried out on a computer.
For example, a student may "virtually" pipette a solution from a beaker into a test tube to

observe changes in pH concentrations from his or her computer or "virtually" manipulate physical situations to determine changes in transpiration rates of plants.

In fall 2008, the Department of Biological Sciences, due to limited laboratory space, switched from traditional laboratories to virtual labs in all of non-majors science course offerings. The virtual lab consisted of ten pre-fabricated "virtual" experiments created by McGraw-Hill publishing company (available online: http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/). Figure 2 shows a screenshot of one of the virtual labs conducted in BIO 1023. This particular lab teaches students the concept of independent and dependent variables used in research by having students grow two different types of corn: one is resistant to corn borers and one is not. Then students compare yields of the two different varieties.

Figure 2   Screenshot of a virtual experiment using a biotechnology experiment as an
example of experimental design, including independent and dependent
variables

(http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/)

In this laboratory type, students complete each of the ten virtual labs required for

the conclusion of the course in their own time, one per week, either at home or at a

computer lab on campus. Each week's laboratory typically includes manipulation of

variables in a virtual experiment, data collection, and answering a series of questions on

concepts and findings. Students then attend a face-to-face lab at a designated time the

following week to hand in their results and answers to the specific lab questions. These

assignments turned in are worth two points. Students then take an 8 question mini-quiz on the laboratory. The total lab is worth 10 points. Ten labs are required throughout the semester with the lowest score dropped. At the end of the semester, all points are totaled and this multiplied by 1.112 in order to make the total lab grade 100 points. Table 4 shows the topics covered in the virtual laboratory.

Table 4   Topics covered in the virtual lab

Laboratory	Topic Covered
Lab #1	Dependent & Independent Variables
Lab #2	Enzyme Controlled Reactions
Lab #3	Ecosystems, Organisms & Trophic Levels
Lab #4	Model Ecosystems
Lab #5	Population Biology
Lab #6	Communities & Biomes
Lab #7	Plant Transpiration
Lab #8	Cell Reproduction
Lab #9	Punnett Squares
Lab #10	Energy in the Cell

Virtual Labs in the Context of the COI Model

According to Garrison, Archer and Anderson's (2000) Community of Inquiry model, there are three elements necessary in online learning to maximize student achievement: teacher presence, cognitive presence, and social presence. Teacher

presence is defined by the design of the course, presentation of the content, and how assessment of learning is conducted. For purposes of this study, teacher presence refers to the design of the virtual lab itself. Each lab is interactive and engaging. Step-by-step instructions are given to students on how to perform each virtual lab. Assessment is given through discussion questions – given as "open-book" – and a multiple choice quiz after the completion of each lab.

The next element, cognitive presence, is defined as the ability of a student to construct knowledge from online learning. For the virtual labs used in this study, cognitive presence will be assessed through the discussion questions and multiple choice questions presented after each lab. Student achievement will be defined as the final lab average for each student.

And finally, social presence is defined as the ability of a student to connect socially and emotionally to other students and the instructor. In this study, students will meet with the teaching assistant weekly for quizzes and information about performing the next week's lab. Students engage in social interaction during this time with the teaching assistant and with other students during the face-to-face time.

Data Sources and Collection

The following demographic data was analyzed to observe relationships, if any, among lab type and lab grade: sex and race. Other data was also collected: GPA at time of enrollment in BIO 1023, cumulative ACT score, lecture grade average (i.e., average of all four lecture exams given during the semester), laboratory instruction type (i.e., traditional versus virtual), and semester (i.e., fall or spring) and year of enrollment (2006, 2007, 2008, 2009, or 2010). Names and other identifying information was omitted to

maintain the privacy of students and to adhere to FERPA regulations. Under Mississippi State University's Institutional Review Board for the Protection of Human Subjects requirement, research docket #12-017 was reviewed and approved via administrative review on 1/31/2012 in accordance with 45 CFR 46.101(b)(1).

The described data were analyzed using various techniques in the Statistical Package for the Social Sciences (S.P.S.S.). Multivariate Analysis of Variance (MANOVA) was used, as was Multivariate Analysis of Covariance (MANCOVA) to look for possible extraneous variables. Pearson's correlation was used to discern relationships between variables. These correlations help predict and further justify the regression analysis.

CHAPTER IV

RESULTS

This chapter begins with a description of the treatment group and data collection, including demographic data. After this brief description, statistical methods for each hypothesis and the results of the analyses are presented.

Treatment Group and Data Collection

The target population for this study were students pre-enrolled in BIO 1023 (Plants and Humans), a non-science majors course that included a laboratory at Mississippi State University during the semesters of fall and spring of 2006 – 2010. Majors of students enrolled in BIO 1023 varied (i.e., art, history, business, physical education, etc.).

Laboratory quiz averages and lecture exam averages were collected from students enrolled in the two varying laboratory types, traditional and virtual, in this non-majors biology course. To control for ability, a possible extraneous variable, GPA and ACT were used as covariates.

Descriptive Variables

Table 5 summarizes descriptive variables of students enrolled in BIO 1023 for all semesters specifically collected for this study. These descriptive variables were used to discern if differences in achievement exist among race and sex in the differing laboratory

types: Is one sex or race's academic performance affected more than another in virtual labs compared to traditional labs?

Table 5   Race of students in both laboratory instruction types (N = 1479)

Race	Traditional Lab	Virtual Lab	Total
White	391	754	1145
Black	74	212	286
Hispanic	5	14	19
Asian	6	12	18
Multiracial	1	2	3
American Indian	2	5	7
Pacific Islander	0	1	1

Table 6   Number of male and female students enrolled in both laboratory instruction types (N = 1479)

Sex	Traditional Lab	Virtual Lab	Total
Male	219	434	653
Female	260	566	826

Results

Research Objective 1

To compare laboratory achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken at a four-year university with students enrolled in the virtual laboratory at the same university.

H$_0$: There is no difference in laboratory achievement rates of traditional versus

virtual laboratory enrollment.

Among the two laboratory types, students enrolled in the traditional laboratory

scored, on average, higher ($M = 90.46$, $SD = 10.28$, $n = 479$) on final lab averages than

students enrolled in the virtual laboratory ($M = 79.66$, $SD = 14.49$, $n = 1000$). Table 7

displays these results. To determine if there was a statistically significant difference, data

were analyzed using analysis of variance (ANOVA) in SPSS 19.0. There was found to be

a statistically significant difference among the two treatment groups, $F(1,1477) = 214.36$,

$MSE = 176.31$, $p < .001$, at the .01 alpha level. Levine's check of homogeneity yielded

problems, $p < .001$. Normality checks showed marginal negative skewness.

Transformations using square root, logarithms and inverse methods were unsuccessful at

negating this affect. However, SPSS calculated a large effect size, $\eta^2 = .13$. Table 8

summarizes the ANOVA findings. For the first research objective, we fail to accept the

null hypothesis. Students enrolled in the traditional laboratories, on average, score higher

on lab quizzes than students enrolled in the virtual laboratories.

Table 7   Mean differences between traditional and virtual lab averages

	Traditional Lab			Virtual Lab		
	M	*SD*	*N*	*M*	*SD*	*N*
Lab Average	90.5	10.28	479	79.66	14.49	1000
Lecture Average	81.0	11.23	479	79.38	11.75	1000

Table 8   ANOVA summary of lecture and laboratory averages

Source	*SS*	*df*	*MS*	*F*
Lab Average				
Between groups	37793.10	1	37793.10	214.36
Within groups	260403.50	1477	176.31	
Total	298196.60	1478		
Lecture Average				
Between groups	2026.52	1	2026.52	15.10
Within groups	198259.63	1477	134.23	
Total	200286.15			

Means were calculated for fall and spring semesters to determine if differences in achievement exist between the two semesters. Table 9 summarizes the findings. Differences in fall and spring semesters for traditional labs were marginal (mean difference = .98) where differences in fall and spring for virtual labs were slightly greater (mean difference = 2.91).

Table 9   Achievement differences in fall and spring semester based on laboratory
            type (N = 1415)

	Lab Type					
	Traditional			Virtual		
	M	SD	N	*M*	*SD*	*N*
Fall	87.54	14.12	272	80.20	16.75	792
Spring	86.56	13.57	407	77.29	16.01	623

Research Objective 2

To compare lecture achievement rates of students in the traditional laboratory of a non-

major's introductory biology course taken at a four-year university with students enrolled

in the virtual laboratory at the same university.

H_0:There is no difference in lecture achievement rates of traditional versus

virtual laboratory enrollment.

Among the two laboratory types, students enrolled in the traditional laboratory

scored, on average, higher ($M = 81.0$, $SD = 11.23$, $n = 479$) on final lecture averages than

students enrolled in the virtual laboratory ($M = 79.38$, $SD = 11.75$, $n = 1000$). Table 7

displays these results. To determine if there was a statistically significant difference, data

were analyzed using analysis of variance (ANOVA) in SPSS 19.0. There was found to be

a statistically significant difference among the two treatment groups, $F(1,1477) = 15.10$,

$MSE = 2026.52$, $p < .001$, at the .01 alpha level. Levine's check of homogeneity yielded

no problems at the .01 level, $p = .05$. Mean difference between lecture averages among

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laboratory types was marginal (mean difference = 1.62), however, SPSS still detected a significantly significant difference. Distinctions in N of the treatment groups may account for this: number of students sampled in traditional labs = 479, number of students sampled in virtual labs = 1000.

Research Objective 3

To describe student achievement rates based on descriptive variables in the traditional and virtual laboratory achievement types.

A Multivariate Analysis of Covariance (MANCOVA) was conducted using sex and race as covariates. For the variable of sex, there was no statistically significant differences among males and females, $F(1, 0.32) = 0.72$, $MSE = 0.32$, $p = 0.40$, at the .01 alpha level. Race also was not statistically significant: $F(1, 0.05) = 0.10$, $MSE = 0.05$, $p = 0.75$, at the .01 alpha level. Table 10 summarizes the findings.

Table 10   MANCOVA summary of effect of lab type with GPA as a covariate

Source	SS	df	MS	F
Covariate (G.P.A)				
Lab average	81173.89	1	81173.89	668.49
Lecture average	93369.72	1	93368.72	1313.86
Lab Type				
Lab average	34420.53	1	34420.53	283.46
Lecture average	1265.54	1	1265.56	17.81
Residual				
Lab average	179229.61	1476	121.43	
Lecture average	104890.91	1479	71.06	
Total				
Lab average	10525728.10	1476		
Lecture average	9711942.04	1479		

Although no hypothesis was proposed to predict relationships, an analysis was run in order to see if any relationships did exist among other variables (i.e., semester, GPA, lecture averages, sex, ACT, or race), including the relationships with both virtual and traditional lab grades. A linear regression analysis in SPSS was conducted using backward criterion. The model omitted race, sex, and ACT scores. Remaining variables were lab type, lab grade, GPA, and ACT scores in the model, $F(4,1478) = 275.79$, MSE =31911.25, $p < .001$, at the .01 alpha level. Removal of race, sex, and ACT scores resulted in an adjusted $R^2 = .43$, however, this was not different than the original model

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which included all variables. Pearson correlations confirmed similar results (Table 11). Pearson's correlations also confirmed GPA (.69) and ACT (.53) are extraneous variables for lecture averages and GPA (.47) and ACT (.26) for laboratory averages. Students with a high GPA and ACT score performed higher on exams and lab quizzes no matter the laboratory type.

Table 11   Pearson correlations looking at relationships among differing variables

	Lab Type	Semester	G.P.A.	Lecture average	Gender	ACT	Ethnicity	Lab Grade
Lab Type	1.00	.13	-.03	-.10	.02	-.01	.05	-.36
Semester	.13	1.00	-.01	-.03	-.01	-.02	.03	-.11
GPA	-.03	-.01	1.00	.69	.15	.47	-.13	.53
Lecture average	-.10	-.03	.69	1.00	.13	.46	-.03	.51
Sex	.02	-.01	.15	.13	1.00	.01	.03	.06
ACT	-.01	-.02	.47	.16	.01	1.00	-.19	.26
Race	.05	.03	-.13	-.03	.03	-.19	1.00	-.10
Lab Average	-.36	-.11	.53	.51	.06	.26	-.10	1.00

CHAPTER V

CONCLUSION

This chapter summarizes the purpose of this study, outlines the limitations, and describes the findings. Then the theoretical implications of this research will be presented, as well as areas of future research. Finally, recommendations for practice will be outlined.

Summary

This dissertation has investigated laboratory type on student achievement rates in a non-majors biology course at Mississippi State University. The following laboratory types were examined: *traditional laboratories* that included a more "hands-on" approach to learning scientific concepts with use of models, dissections, etc. in a face-to-face environment and *virtual laboratories* whereby scientific concepts are learned online, outside of the classroom in the student's own time, using a computer-generated virtual laboratory created by a specific publishing company. An ex post facto design was used. Although randomization was not possible for this study, statistical analysis techniques were used to control for extraneous variables as well as building the variables into the design. The study also sought to determine if differences in achievement on lecture exam averages exist due to laboratory instruction type. And finally, descriptive variables were examined to see if achievement by students of different sex or race was impacted by

laboratory instruction type. With much of the literature conflicted on the potential effect of using virtual laboratory instruction in the STEM fields, this study sought to further give evidence of its continued use or disuse in educational practices.

Limitations

There were many limitations to this study other than the inability to randomize students. Measurements of achievement outcomes were not standardized among the two differing laboratory types. Students in the traditional labs were given a five question quiz immediately after conducting the lab, whereas students in the virtual lab where given an eight question quiz, delivered at the beginning of the lab the following week, and two points for turning in a hard-copy of their data results, for a total of ten points rather than five points in the traditional lab. Furthermore, nearly 50% of the content covered in virtual and traditional labs varied. For example, understanding research methods (i.e., independent versus dependent variables) in scientific experiments was covered in the virtual labs but not in the traditional. A reasonable comparison of student achievement rates was still attempted in this study, nevertheless.

Findings

The first research objective sought to compare laboratory achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken at a four-year university with students enrolled in the virtual laboratory at the same university.

H₀: There is no difference in laboratory achievement rates of traditional versus virtual laboratory enrollment.

The data showed that there was a statistically significant difference of student achievement rates in virtual labs versus traditional labs in this experiment ($p < .001$ at the .01 alpha level). Students enrolled in the traditional laboratory had better scores ($M = 90.46$, $SD = 10.28$, $n = 479$), on average, than those enrolled in the virtual labs ($M = 79.66$, $SD = 14.49$, $n = 1000$) with a mean difference of 10.8 (Table 7). Therefore we reject the null hypothesis for research objective one.

This data may indicate that students enrolled in the virtual laboratory did not have a sound understanding of biological concepts when they performed "virtual experiments" on their own. The question remains whether this difference of achievement was due to the absence of a teaching instructor to guide students through the laboratory process or whether the virtual labs did not do a good job assisting students to understand biological concepts. According to Garrison, Archer, and Anderson (2000) Community of Inquiry framework, teacher presence influences cognitive presence which is the ability to understand scientific concepts. Students enrolled in the virtual labs, in this research study, had limited contact with a teaching instructor and therefore possibly affected cognitive presence. Without standardized grading criteria and differences in concepts covered between the two laboratory types, understanding the true cause of the disparities in student achievement rates can only be inferred.

The second research objective sought to compare lecture achievement rates of students in the traditional laboratory of a non-major's introductory biology course taken

at a four-year university with students enrolled in the virtual laboratory at the same university.

        H$_0$: There is no difference in lecture achievement rates of traditional versus virtual laboratory enrollment.

        The findings also showed there was a statistically significant difference in lecture averages among the two laboratory types ($p < .001$ at the .01 alpha level). Therefore, we reject the null hypothesis for the second research objective. Lecture exam averages based on test scores were only nominally higher for students enrolled in the traditional labs ($M = 81.0$, $SD = 11.23$, $n = 479$) than the virtual laboratories ($M = 79.38$, $SD = 11.75$, $n = 1000$) with mean difference = 1.62. Although statistically there were found to be differences, the raw data appear to say otherwise. One possible explanation may be the disparity in the number of students in the two treatment groups. Students sampled in the virtual lab were nearly double the number in the traditional lab, and therefore, the statistical differences may be due to this contrasted sample size.

        If scores on exams indicated whether concepts were learned and understood by students, as is reasonable to expect, then the findings can only conjecturally indicate traditional labs do a better job in facilitating comprehension of scientific concepts (Hofstein & Lunetta, 2003). Similarly, one can only surmise, students who are required to physically perform an experiment, touch models, or some other participative approach, have better information transfer of scientific concepts, and thus, appear to have deeper learning which resulted in higher lecture exam scores.

        The third research objective sought to describe student achievement rates based on descriptive variables, specifically race and sex, in the traditional and virtual laboratory

achievement types. For this research study, no statistically significant difference was found for either race ($p = 0.75$) or sex ($p = 0.40$) at the .01 alpha level (Table 10).

A small amount of research has indicated that males and females do differ in achievement in the sciences (Kahle 2004; Obrentz, 2012). However, in analyzing descriptive variables for this study, there was not a statistical significant difference in achievement for both lecture and laboratory averages between males and females in the differing laboratories ($p = 0.42$ at the .01 alpha level).

These analyses were accomplished simply to attempt to further elucidate and possibly describe whether differences existed among race and sex in student achievement rates for this specific course at Mississippi State University. Since no such differences were found, then these specific descriptive variables can be ruled out as possible extraneous variables.

Theoretical Implication

The Community of Inquiry model (CoI), designed by Archer and Anderson (2000) set out to create a framework for online learning situations. The authors proposed three main elements are all factors that influence student learning in online environments: teacher presence, social presence, and cognitive presence. As indicated in the model, teacher presence seems to have the biggest influence on the social and cognitive presence. However, all three must be present for meaningful learning to occur.

Community of Inquiry

Supporting Discourse

SOCIAL PRESENCE

COGNITIVE PRESENCE

EDUCATIONAL EXPERIENCE

Setting Climate

Selecting Content

TEACHING PRESENCE
(Structure/Process)

Communication Medium

Figure 3   The Community of Inquiry Framework

In the context of the CoI Model, the virtual laboratories appear to lack elements of the framework. Teacher presence was definitively minimal in this context. A teaching assistant gave preliminary instructions on how to conduct the virtual lab, but students were ultimately left alone to carry out the laboratory assignment. No teacher contact was provided for students during the virtual experiment except via email if the student had a question. Teacher presence also includes the instructional design of the online course. Since the virtual laboratories were pre-fabricated by a publishing company for free use by the university, there was no input to the instructional design by the teacher of record. Therefore, laboratory content and delivery was not specifically tailored to the particular course used in this study.

Social presence also was minimal. Students were given initial instructions and then dismissed to perform the lab assignment on their own time over the course of a

week. Students could use their own computers or the university's computer labs to complete the task. Therefore, there was little or no social presence unless students coordinated a time to collaboratively work together.

Finally, cognitive presence, as defined by the student's ability to construct knowledge from online learning, appeared to be missing as well. If lab averages were indicative of cognitive presence, then students fell short compared to students enrolled in the traditional labs.

The specific virtual laboratories used in this study seemed to lack the elements of the CoI model. Since this study was of ex-post facto design, the instruments developed by the authors to test the model were not employed. For this reason, the study was not able to further elucidate each of the three presences on student achievement in virtual laboratories.

Recommendations for Future Research

Science laboratory instruction continues to be strongly supported by educators as vital to science education because it facilitates understanding of scientific concepts, teaches practical skills and creates an interest in the sciences (Lunetta, 1998; McComas, 1997). Thus, it has been required in some form in all science curricula. Varied research on the benefits has been reported in the literature with no conclusive evidence that concretely points to a best-practice methodology. Use of virtual laboratories is a relatively newer concept in science education. Its utilization was conceived to alleviate many issues universities face such as enrollment constraints, space concerns, and cost (Campbell, et al., 2004; Minasian-Batmanian & Jayachandran, 2003; Scheckler, 2003). However, research on its effectiveness in student achievement is in its infancy.

As universities look for ways to elevate increased student enrollments with limited budgets while maintaining high educational standards, research on the effectiveness of virtual laboratories is critical (Campbell, et al., 2004; Minasian-Batmanian & Jayachandran, 2003; Scheckler, 2003) . What appears to be significant to this circumstance is preserving the central objectives to *why* we teach laboratory, no matter the instruction type.

Understanding the influence of virtual laboratories on student achievement at the higher educational level is important if the use of virtual labs continues to be utilized on college campuses as a means of saving money and/or dealing with enrollment constraints (Campbell, 2004; Sommer & Sommer, 2003; Walker, Altemus, Allen, Klinkhachorn, & Kraszpulska, 2007). As science and technology progressively becomes more and more a part of all our lives, then a strong educational foundation in the STEM fields is imperative to our future generations so we are competitive in the global market, but also because as citizens, we have a moral obligation to be educated consumers and voters (Sanders, 2009).

There are other types of laboratory instruction that have been attempted such as problem-based learning (Hicks & Bevsek, 2011; Sandi-Urena, Cooper, Gatlin & Bhattacharyya, 2011) and "hybrid" labs which incorporate both virtual and hands-on elements (Beck & Ferdig, 2008). Developing and implementing other laboratory instruction types, like the ones mentioned previously, for BIO 1023 at Mississippi State University and analyzing the achievement or impact of these differing instructional types would potentially benefit students at this institution. But empirical evidence is necessary to soundly conclude that one laboratory instruction type is better than another in

impacting student achievement rates. One way to accomplish this would be to standardize measurements of student achievement rates and concepts covered in both lab types. Also, use of the instruments designed and validated in the CoI model by Garrison, Archer, and Anderson (2000) would be implemented to better elucidate the variable or variables that have the greatest effect on student achievement rates in an instructional laboratory design. These instruments measure the effect of social, teacher, and cognitive presence on student achievement.

The research findings described in this dissertation point to the fact that continued evaluation of laboratory instruction, especially the use of virtual laboratories, needs to be better quantified. Laboratory instruction that has empirical-based positive achievement for students should be utilized. Therefore, future research would be geared towards this goal and the theoretical framework would be implemented a priori, as stated previously.

Recommendations for Practice

Wilson and Stensvold (1991) described, in their opinion, the goals of science laboratory instruction:

1. Develop applied proficiencies in a laboratory setting. These include developing proper laboratory techniques and safety methods.

2. Practice and study about the natural world using available materials.

3. Understand, demonstrate, describe, and synthesize scientific concepts and theories.

4. Use critical thinking along with resourceful and investigative skills to apply scientific facts and principles to any situation.

5. Accept new ideas and make judgments and decisions based on tested knowledge that has used proper analyses and to support scientific thinking and approaches.

If the previous listed are goals important for science instruction, then educators need in ensure these objectives are being met within a laboratory setting, no matter the laboratory type. This can be accomplished by utilizing various instruments used to quantify student achievement. This research study used only limited methods to assess whether student achievement rates in virtual labs compared to student achievement rates in traditional labs for BIO 1023 taught at Mississippi State University. Although statistical significant differences were found for this study, due to the many limitations, it is not conclusive to say virtual labs used for BIO 1023 are any better or worse than traditional labs in positively impacting student achievement rates.

There are many advantages of virtual labs including easing enrollment constraints (Nedic, Machotka & Nafalski, 2003), allowing students to conduct experiments that could not be feasibly carried out in a restrained time frame (Scheckler, 2003), repetition until concepts are understood (Scheckler, 2003), as a pre-laboratory prep for greater student success (Dalgarno, Bishop & Bedgood, 2003) and saving the university money due to the cost of lab supplies (Campbell et al., 2004; Minasian-Batmanian & Jayachandran, 2003). However, traditional labs also have advantages, such as a "hands-on" approach to understanding scientific concepts, direct guidance of the lab by a teaching instructor (Scheckler, 2003), and peer-learning through lab partners (Bourne, McMaster, Rieger & Campbell, 1997; Goldsmith, Stewart & Ferguson, 2005; Keppell,

Au, Ma & Chan, 2006). Weighing the advantages and disadvantages is difficult simply because analyzing the process can be, in part, subjective and course dependent.

If virtual labs and traditional labs both offer worthwhile benefits, perhaps use of "hybrid" labs may offer a viable solution. These labs could utilize the best of both laboratory instructional types: selected virtual labs and traditional labs. Some virtual labs seem better than others and those could be included in the "hybrid" lab. For the virtual labs that possibly lack appropriate content or do not connect with the lecture material in a robust way, demonstrations, models, observation, etc., may be added to the hybrid lab instruction. The traditional side of the hybrid laboratory would not have to be time consuming or incur huge costs. Use of plastic models, bringing in specimens for observation, or demonstrating biological concepts (e.g., using pipe cleaner chromosomes to manipulate different stages of mitosis) are all cost effective ways to bring in a more "hands-on" approach and have a positive impact on student achievement.

Due to the limitations of this study, disuse of virtual labs for BIO 1023 is inconclusive. It is recommended that further research be exercised to effectively determine if there is any effect on student achievement, whether positive or negative. Another recommendation is to look at other models of laboratory instruction developed by other institutions of higher learning and create something similar at Mississippi State University. Assessment and evaluation of students' achievement rates would need to be completed to ensure the model created by Mississippi State University is effective.

In conclusion, science educators have discovered ways to utilize technology in laboratory instruction in the form of "virtual" labs. Understanding the impact on student achievement of this type of lab instruction is important. Through theoretical frameworks,

like the CoI model developed by Garrison, Archer and Anderson (2000), educators can better answer these questions. This research study had several limitations, but what can be conclusively stated is that a good research design and theoretical framework would have helped to clarify whether virtual laboratory instruction affects student achievement rates.

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