AN INSTRUCTIONAL DESIGN FOR ONLINE COLLEGE PHYSICS LABORATORIES

by

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has been approved

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Abstract

Online learner-centered self-directed educational opportunities are growing in scope and acceptance across the academic curriculum because of the flexibility for the learner and cost-effectiveness for the institution. However the offering of online science courses and particularly physics instruction has lagged behind due to the challenge of re-creating the hands-on laboratory learning experience. This research examines the effectiveness of the design of a series of physics laboratory experiments for potential online delivery which provide learners with hands on experiences. Two groups of college physics learners conducted physics experiments inside and outside of the physical laboratory using instructions and equipment provided in a kit. Learning outcomes as determined by pretest, written laboratory report, and posttest assessments and learner reactions as determined by a questionnaire were utilized to compare both types of laboratory experiences. The research findings indicated learning outcomes achieved by learners outside of the physical laboratory were statistically greater than the equivalent face-to-face instruction. Evidence from learner reactions comparing both types of laboratory formats indicated learner preference for the online laboratory format. These results are an initial contribution to the design of an entire sequence of experiments that can be performed independently by online learners outside of the laboratory satisfying the laboratory requirement for the two semester college physics course.
Dedication

My parents Gerald H. and Beatrice A. Grambau knew the significance of higher education and instilled in me a desire to learn and pursue my educational goals. My husband William P. Ruby has been supportive and encouraging of my professional development throughout our marriage and was vital during my doctoral journey. This dissertation is dedicated to them with appreciation and gratitude.
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Completing a doctoral dissertation requires the joint effort of the learner, their family, study participants, mentor, committee, and school. My husband William P. Ruby and my parents Gerald H. and Beatrice A. Grambau are acknowledged for their help in obtaining and assembling the experiment kits required for this research study. The important contributions of the college physics learners at LeTourneau University, the field testers of the physics experiments, Dr. Amar Almasude, Dr. Glenn Shepherd, Dr. Victor Klimoski, LeTourneau University, and Capella University are likewise acknowledged. This dissertation would not have been possible without their involvement and I am thankful for their efforts, input, assistance, and support.
Table of Contents

Acknowledgments iv
List of Tables ix
List of Figures x

CHAPTER 1. INTRODUCTION 1
Introduction to the Problem 1
Background of the Study 3
Statement of the Problem 4
Purpose of the Study 5
Rationale 6
Research Questions and Hypotheses 7
Significance of the Study 8
Definition of Terms 9
Assumptions and Limitations 10

CHAPTER 2. LITERATURE REVIEW 13
Introduction and Structure of the Literature Review 13
Literature on Learner-Centered Theory and Application 13
Application of Behaviorism to Physics Instruction 15
Instruction in the Psychomotor Domain 18
Literature Comparing Online Instruction to Face-to-Face Instruction 19
CHAPTER 3. METHODOLOGY

Research Methodology
Research Methods
Research Procedures
Analysis
Anticipated Outcomes
Reducing Experimental Bias

CHAPTER 4. DATA COLLECTION AND ANALYSIS

Summary of Research Design and Methods
Learner Characteristics
Research Question 1
Research Hypotheses 1
Two Dimensional Motion Investigation
Newton’s Third Law Investigation
Newton’s Second Law Investigation
Determining the Coefficient of Friction Investigation
Research Question 2
Research Hypothesis 2
Learner Reaction Data
<table>
<thead>
<tr>
<th>Analysis of Learner Reaction</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAPTER 5. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS</td>
<td>84</td>
</tr>
<tr>
<td>Summary and Discussion of Results</td>
<td>84</td>
</tr>
<tr>
<td>Summary of Findings for Research Question and Hypotheses 1</td>
<td>97</td>
</tr>
<tr>
<td>Summary of Findings for Research Question and Hypothesis 2</td>
<td>99</td>
</tr>
<tr>
<td>Conclusions</td>
<td>100</td>
</tr>
<tr>
<td>Recommendations</td>
<td>105</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>110</td>
</tr>
<tr>
<td>APPENDIX A. CONSENT FORM</td>
<td>113</td>
</tr>
<tr>
<td>APPENDIX B. BACKGROUND INFORMATION SURVEY</td>
<td>115</td>
</tr>
<tr>
<td>APPENDIX C. TWO DIMENSIONAL MOTION INVESTIGATION</td>
<td>116</td>
</tr>
<tr>
<td>APPENDIX D. GRADING RUBRICS FOR THE TWO DIMENSIONAL MOTION INVESTIGATION</td>
<td>128</td>
</tr>
<tr>
<td>APPENDIX E. NEWTON’S THIRD LAW INVESTIGATION</td>
<td>135</td>
</tr>
<tr>
<td>APPENDIX F. GRADING RUBRICS FOR THE NEWTON’S THIRD LAW INVESTIGATION</td>
<td>147</td>
</tr>
<tr>
<td>APPENDIX G. NEWTON’S SECOND LAW INVESTIGATION</td>
<td>153</td>
</tr>
<tr>
<td>APPENDIX H. GRADING RUBRICS FOR THE NEWTON’S SECOND LAW INVESTIGATION</td>
<td>164</td>
</tr>
<tr>
<td>APPENDIX I. DETERMINING THE COEFFICIENT OF FRICTION INVESTIGATION</td>
<td>171</td>
</tr>
<tr>
<td>APPENDIX J. GRADING RUBRICS FOR DETERMINING THE COEFFICIENT OF FRICTION INVESTIGATION</td>
<td>184</td>
</tr>
</tbody>
</table>
List of Tables

Table 1: Gender and Class Demographics of Learners by Group 49
Table 2: Prior Physics Courses and Online Experience of Learners by Group 50
Table 3: Academic Majors of Learners by Group 51
Table 4: Descriptive Statistics for Two Dimensional Motion Investigation 55
Table 5: Two Dimensional Motion Investigation $t$-tests 57
Table 6: Descriptive Statistics for Newton’s Third Law Investigation 59
Table 7: Newton’s Third Law Investigation $t$-tests 61
Table 8: Descriptive Statistics for Newton’s Second Law Investigation 63
Table 9: Newton’s Second Law Investigation $t$-tests 65
Table 10: Descriptive Statistics for Determining the Coefficient of Friction Investigation 67
Table 11: Determining the Coefficient of Friction Investigation $t$-tests 69
List of Figures

Figure 1: Frequency Distribution of PreTest versus PostTest Differences for the Two Dimensional Motion Investigation 56

Figure 2: Frequency Distribution of Laboratory Report Scores for the Two Dimensional Motion Investigation 56

Figure 3: Frequency Distribution of PreTest versus PostTest Differences for the Newton’s Third Law Investigation 60

Figure 4: Frequency Distribution of Laboratory Report Scores for the Newton’s Third Law Investigation 60

Figure 5: Frequency Distribution of PreTest versus PostTest Differences for the Newton’s Second Law Investigation 64

Figure 6: Frequency Distribution of Laboratory Report Scores for the Newton’s Second Law Investigation 64

Figure 7: Frequency Distribution PreTest versus PostTest Differences for the Determining the Coefficient of Friction Investigation 68

Figure 8: Frequency Distribution Laboratory Report Scores for the Determining the Coefficient of Friction Investigation 68

Figure 9: Analysis of Responses from the Learner Reaction Questionnaire 81
CHAPTER 1. INTRODUCTION

Introduction to the Problem

Many learner-centered pedagogies like simulations, problem based inquiry, reciprocal teaching, goal based instruction, open learning environments, and cognitive apprenticeships have surfaced in recent years encompassing different technologies and approaches; but all are based on similar foundations about the nature of understanding and how to facilitate learning (Jonassen & Land, 2000). The objective of learner-centered instruction is to empower learners to pursue individual goals and interests through conceptual teaching practices and technology (Jonassen & Land, 2000).

The online learning environment offers promise that learner-centered instruction can be designed and implemented removing the learner from the traditions of face-to-face instruction and placing them in a virtual classroom where learning is self-directed and self-paced. However the lack of online courses in science and particularly in physics limits learners desiring the flexibility and independence of learning opportunities offered online.

Online learning is growing in scope and acceptance across the academic curriculum. According to the United States Department of Education National Center for Educational Statistics (2003), during the 2000–2001 academic year 90 % of public two-year institutions, 89 % of public four-year institutions, 16 % of private two-year institutions, and 40 % of private four-year institutions offered distance education courses at either the elementary, secondary, college, adult, or professional level.

During the next three years 12 % of all institutions whether or not they were currently offering distance education courses indicated plans to begin or increase distance
education offerings (United States Department of Education National Center for Educational Statistics, 2003). Several factors are involved in the growth of distance learning as expressed by Belanger and Jordan (2000) who state that "distance learning opens up new opportunities for students that might otherwise be excluded from participating in the learning process" (p. 4). This might include individuals with limited mobility or those living in remote areas where educational opportunities are limited as well as working adults who require the scheduling flexibility offered by online learning.

Offering instruction online is a cost-effective means of delivering higher educational programs to large numbers of learners as these programs reduce the need for infrastructure such as classrooms and furnishings as well as the overhead associated with building maintenance (Belanger & Jordan, 2000). Learner-centered self-directed educational opportunities with flexibility for the learner and cost-effectiveness for the institution have promoted the growth of online learning. However the offering of science courses and particularly physics instruction has lagged behind. This is evidenced by searching the Internet for physics courses which were offered online.


Online conceptual math-based physics course with lecture but no laboratory component was found to be offered by Ellis College (2005).

Learners seeking degrees which require an undergraduate physics course with a lecture and laboratory component cannot complete their degrees online because online physics courses are very limited. This lack of online physics course offerings with both lecture and laboratory components may be due to the lack of research into the effective design of such courses.

Background of the Study

The undergraduate physics course is an introductory survey course designed to provide a foundation for the learner’s continuing course of study. The physics course consists of a lecture and laboratory component that builds the scientific literacy of learners. Learners study the development of scientific knowledge through empirical and experimental evidence as well as connecting physics with other sciences. The impact of physics on everyday life is examined in order to develop an understanding of the place physics holds in history, other disciplines, and society.

The college physics course is required in many pre-professional, engineering, and technical programs where the laboratory component is considered an essential element. The physics laboratory provides learners with the opportunity to gain, apply, and test their theoretical knowledge using a hands-on approach.

This traditional approach to the physics laboratory has limited its offering as a distance learning course as learners are required to perform experiments in a physical
laboratory. The physics laboratory must be accessible to the learner when experiments are scheduled thereby limiting the flexibility of time and place offered by distance learning.

Statement of the Problem

Distance learning provides learners with an opportunity to further their educational goals while being free of the restrictions of time and place. However this “powerful educational tool” (Alhalabi et al., 2004, p. 1) is not being fully utilized for physics instruction. Offering the lecture component through a distance delivery mechanism is being accomplished however re-creating the hands-on laboratory has proven more challenging.

This entails designing a physics laboratory that provides learners “with the experience of manipulating real inputs to observe real responses of real physical elements” (Alhalabi et al., 2004, p. 1). The two approaches which have been proposed include simulated laboratories (Meisner & Hoffman, 2001) and remote laboratories (Alhalabi et al., 2004; Faltin et al., 2002).

Meisner and Hoffman (2001) created a simulated physics laboratory called Learn Anytime Anywhere Physics (LAA Physics) funded in part by the United States Department of Education’s Fund for the Improvement of Post Secondary Education. LAA Physics is an online program developed to replicate the experience of taking an interactive laboratory course (Meisner, 2002). The LAA Physics system uses open exploration and guided discovery as the basis for a laboratory-based physics course that can be completed entirely online.

In some instances simulations do not provide the same experiences that can be garnered through physically manipulating equipment. Simulations may also limit the possible
outcomes because explorations beyond the initial experiment are typically not allowed (Alhalabi et al., 2004). Surveys conducted by Alhalabi et al. (2004) of online courses, distance education, virtual universities, and electronic online universities for currently available educational modalities found none discussing or investigating the concept of real laboratories or remotely accessed laboratories.

This prompted Alhalabi et al. (2004) to create a remote physics laboratory at the Center for Innovative Distance Education Technology which allows learners to manipulate real equipment and conduct real experiments using a software interface. Remote laboratories are more costly to create and maintain than simulations because actual equipment and instrumentation must exist in the accessed laboratory.

Simulations and remote laboratories offer interactive engagement based on a constructivist learning philosophy; however while each of these distance laboratory experiences has benefits there are still drawbacks. Neither system provides learners with the opportunity to physically put their hands on equipment. In order to re-create the traditional hands-on laboratory experience, a third option will be presented. Learners will conduct hands-on physics experiments outside of the physical laboratory using real equipment supplied in a kit.

Purpose of the Study

This research proposes to investigate the effectiveness of a series of physics laboratory experiments designed for incorporation into an online college physics course which would satisfy the laboratory requirement of the course. These experiments employ a hands-on approach and can be performed by physics learners outside of the physical
laboratory using instructions and equipment provided in a kit. The materials in the kit will be purchased from local retail stores and would be readily available to learners participating in an online physics course.

Learners will conduct experiments outside of the physical laboratory simulating an online physics laboratory and inside the physical laboratory using the traditional or face-to-face approach of physics laboratory instruction. The effectiveness of both instructional approaches will be measured by pretest, written laboratory report, and posttest assessments. Learner reaction to both types of laboratory experiences will be determined using a questionnaire.

The purpose for conducting this research is to determine the efficacy of delivering physics laboratory instruction outside of the physical laboratory. This study will determine what difference in learning outcome and learner reaction occur when the learner must work independently on a physics experiment and communicate with the instructor by means other than face-to-face. The results from this research study can be utilized to design additional experiments for learners to perform independently outside of the physical laboratory. The objective is to design an entire sequence of experiments that can be performed independently by online learners outside of the laboratory satisfying the laboratory requirement for the two semester college physics course.

Rationale

Learner-centered self-directed educational opportunities with flexibility for the learner and cost-effectiveness for the institution are promoting the growth of online learning. The undergraduate physics course’s transition to the online environment is lagging behind
because there is minimal evidence showing an online laboratory’s effectiveness in producing the desired learning outcomes and positive learner reactions. This research study will evaluate the effectiveness of a learner-centered online physics laboratory designed to be performed by learners individually in their homes with equipment from a kit.

The review of research in this area indicates an investigation into this approach to online laboratory delivery has not been performed with physics learners. There is a gap in the knowledge with regard to physics instruction as well as the evaluation of such a laboratory using a learner-centered approach. This study proposes to fill that gap with an investigation of outcomes and reactions of learners to physics laboratory experiments designed using a learner-centered philosophy for both the traditional and online delivery.

Research Questions and Hypotheses

This research study will focus on learning outcomes and learner reaction as described in the following questions. How effectively will learning outcomes as measured by a pretest, written laboratory report, and posttest be realized for an online physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in their home as compared with a physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in a physical laboratory? What reactions will learners express on a questionnaire regarding their experiences with the online physics laboratory designed using the learner-centered approach to instruction and completed by the learner in their home as compared with a physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in a physical laboratory?
When learners conduct experiments outside of the physical laboratory, time constraints and pressure from peers are removed allowing for self-directed and self-paced investigations which promote learning. It is hypothesized that the learning outcomes for the physics experiments performed outside of the physical laboratory will be at a level equal to or greater than the physics experiments performed inside the physical laboratory. It is further hypothesized that the convenience and flexibility offered by the physics experiments performed outside of the physical laboratory will result in a majority of learners indicating a positive reaction to these experiments. Learners are expected to express satisfaction with their learning experiences outside of the physical laboratory because the independence offered by performing physics experiments outside of the physical laboratory will increase their level of confidence in their ability to understand physics.

Significance of the Study

As more online courses are offered, it is essential to be cognizant of the quality of learning being provided by these courses. Research studies have been conducted which compare the learning outcomes of instruction delivered in the face-to-face environment and the distance learning environment. One example is an investigation of learner performance and learning outcomes between the face-to-face and distance delivery of a graduate course involving technology management (Ouellette, 2000).

In a survey of research comparing learning outcomes in traditional and distance courses, Zhao et al. (2005) found the aggregate data showed no significant difference in outcomes between face-to-face and distance education. The result of Zhao’s et al. (2005) investigation led to consideration of theoretical, analytical, and conceptual frameworks for
understanding distance education. Zhao et al. (2005) suggests using Schwab’s four common places - the instructor, learner, content, and milieux of teaching-learning - as a framework for studying distance education. The milieux of teaching-learning is described as the format and method of delivery (Zhao, et al., 2005).

McCombs and Vakili (2005) indicate that many researchers and practitioners decry the lack of a research validated framework which could guide their design. The four research validated domains include cognitive and metacognitive, motivational and affective, developmental and social, and individual differences (McCombs & Vakili, 2005).

These domains and their associated principles of learning form the framework which McCombs and Vakili (2005) explain is needed to understand and create learner-centered experiences for all delivery mechanisms including distance learning. Therefore, this research study seeks to contribute knowledge to the field of educational research by designing learner-centered physics laboratory experiments based on cognitive and metacognitive principles.

The proposed physics experiments will be performed in both the hands-on laboratory and independently by physics learners outside of the laboratory. Schwab’s four common places - the instructor, learner, content, and milieux of teaching learning - will be examined to address the gaps in previous research investigations. The results of this inquiry will also advance knowledge in education and physics filling in an existing gap in the knowledge regarding the efficacy of asynchronous delivery of physics laboratories.

Definition of Terms

For this study the term online indicates that the instructor and learner are separated by both time and place as the experiments performed outside of the physical laboratory will be
conducted asynchronously with the learner in control of the speed, sequence, and progression of their learning. The experiments performed in the physical laboratory will be synchronous; however, learners will be encouraged to work independently with the instructor acting as a facilitator.

Assumptions and Limitations

The sample, instructors, and scope of the analysis can potentially limit the findings of this study. There are concerns about the size of the sample being too small and the diversity of its composition. According to Triola (2005), learning outcome differences between independent groups can be compared using a $t$-test when the number in each group is greater than 30.

Participants in the research study may be limited because participation will be voluntary. The non-random selection procedure may contribute to a sample non-representative of the physics learner population. The full range of academic majors for which college physics is a requirement may not be represented in the sample due to the number and type of programs offered at the host university.

Limitations may also arise from uncontrolled variables such as the course instructors and their ability to fulfill the online role of facilitator and guide. Therefore the laboratory instructors may request information regarding their facilitator role for the online portion of the study. This information will be limited to online pedagogy and will not include discussion of expectations for the outcomes of the study.

There will be moderate gender diversity in the prospective sample for this research study. College physics courses are typically composed of significantly more males than
females. This study will not make an analysis of learning outcome differences with respect to gender due to the probable lack of a statistically significant female sample.

The learner population at the host university has minimal racial and ethnic diversity. This limitation in the sample means an analysis of learning outcome differences with respect to race or ethnicity is not viable.

Learners with pre-existing self-regulatory learning skills and preference for self-directed learning are more likely to succeed in the simulated online physics laboratory. This research study will not analyze learning outcome differences between self-directed learners and learners preferring classroom instruction. However as part of the learner reaction questionnaire learners will indicate whether face-to-face interaction with the instructor and other learners was important to their successfully completing any of the experiments.

Nature of the Study

This study will compare the learning outcomes achieved by physics learners performing hands-on experiments outside of a physical laboratory and inside a physical laboratory using pretest and posttest scores as well as scores on written laboratory reports. The use of these quantitative measurements will provide an understandable means of comparison between the two types of physics laboratory experiments.

Learner reaction to both types of experiments will be measured using a questionnaire. This qualitative feedback will be used to determine learner preferences and level of satisfaction with the learning experiences outside and inside of the physical laboratory. These reactions and the level of satisfaction will be clearly articulated using the learner’s own words.
Organization of the Remainder of the Study

Literature related to the key elements in this study will be reviewed in the next chapter followed by a detailed examination of the research methodology in chapter three. The methodology will describe the research design, sample population, data collection, and methods of data analysis. Chapter four contains the presentation of the data, analysis, interpretation of the analysis, and the findings of the study relative to the research questions. The concluding chapter presents a summary and discussion of the research results, conclusions, recommendations from this study, and suggestions for future research.
CHAPTER 2. LITERATURE REVIEW

Introduction and Structure of the Literature Review

The research proposed herein is an integration of theory and application for a specific instructional situation. This study will investigate the efficacy of a learner-centered theoretical framework incorporated into the instructional design of undergraduate physics experiments for online delivery.

Literature reviewed in preparation for this study reflects the learner-centered theoretical framework and its application in online learning, application of behaviorism to physics instruction, instruction in the psychomotor domain, the examination of studies comparing online instruction to face-to-face instruction, the investigation into existing methods of delivering science laboratories online, and possible future trends in online learning.

Literature on Learner-Centered Theory and Application

McCombs and Vakili (2005) provide a definition of learner-centeredness in an e-learning environment, offer a framework to guide distance learning efforts, and provide principles for the utilization of educational technology for the support of learner-centeredness. McCombs and Vakili (2005) indicate the learner-centered online environment must meet the learner’s need for interpersonal relationships; acknowledge individual differences and the diversity of learner needs, abilities, and interests with different learning strategies; and assess the efficacy of technology to meet the needs of a diverse learning community.
McCombs and Vakili (2005) conclude with a significant charge which states “it is necessary to look for not only the match or mismatch of technology [utilization] with learning principles, but also its match or mismatch with learners and their diverse needs” (p. 1595). The tone of this research study into online physics laboratories is set as an effort to develop more effective learner-centered online instruction as exemplified by the framework of McCombs and Vakili (2005).

Evidence the learner-centered philosophy is not being applied in online education is offered in a study by Cox (2005). Cox presents the findings of an investigation of online education at 15 community colleges in diverse geographical settings throughout the United States. The purpose of the study was to determine the approaches being utilized to structure online courses and programs. Instruction in an online environment is different from instruction in the traditional face-to-face classroom as the delivery of online learning has implications for the design, development, and implementation of courses.

Cox (2005) found the approach taken for the development of online courses at community colleges was not dramatically different from face-to-face courses. Bransford, Vye, and Bateman (as cited by Cox, 2005) assert when instructors are asked to redesign their courses for online delivery they do not re-think the lecture driven format which results in most online courses looking like the traditional classroom transported to the Internet.

This disconnect between learner-centeredness, what is known about learning processes, and actual online practices may have been in response to external pressures on community colleges to adopt online education (Cox, 2005). The forces that have driven online education at community colleges have created inconsistencies between the “visible
enactment of the online education and the actual practices of the college’s online program” (Cox, 2005, p. 1778). This perspective on online learning is unlikely to improve without changing the thinking in the present environment. The impetus for a change might be research that instead of indicating online courses are equivalent to face-to-face courses demonstrates a design which makes online instruction superior.

Application of Behaviorism to Physics Instruction

The behaviorist considers learning in terms of change in conduct, actions, or performance rather than mental processes. Change might consist of developing a previously unobserved behavior or extinguishing an observed but undesirable behavior (Driscoll, 2000). Behaviorism places emphasis on visible, perceptible, and quantifiable behaviors performed in response to environmental stimuli and the administering of negative or positive reinforcement. The connection between the stimulus and the response establishes a cause and effect relationship (Hung, 2001).

In a learning environment, detectable change in the frequency of an observed behavior or a reduction in the time between the stimulus and response indicates learning is occurring (Gredler, 2004). During this process learners are considered passive (Zemke, 2002) even though a response requires some action on the part of the learner (Driscoll, 2000). The shaping of behaviors can take place in increments by breaking down the goal behavior into steps and reinforcing the achievement of individual and accumulated steps.

The external environment described as the array of stimuli and consequences is an important contributor in the learning process (Jackson, 2005). This environment usually controlled by the instructor is the basis for developing and strengthening the learned
relationship between instructional prompt and correct learner response (Gredler, 2004). Generalization or the recognition of similar features in another environment and the transference of learned responses is another important learning outcome (Gredler, 2004).

Behavioral change starts with a task analysis which determines the actions required to complete a specific task. Learning events are sequenced which guide the learner toward the target behavior and instructional prompts are supplied to elicit the correct behavior. Reinforcement is awarded when correct responses or a sequence of correct responses is observed typically followed by additional opportunities for the learner to practice making the proper responses.

In the classroom the fundamental procedure utilized by behaviorists to achieve learning and the transference of correct responses to similar situations are achieved by stating objectives, breaking down objectives into steps, providing cues to guide learners to the desired behavior, and administering consequences to reinforce the desired behavior (Driscoll, 2000). The learner receives reinforcement when one step or a sequence of steps is accurately reproduced and reinforcement is removed if the learner does not accurately reproduce a step or sequence of steps. This process must be repeated until the goal behavior becomes an automatic response (Gredler, 2004).

The instructional strategies employed by behaviorists include directed instruction, programmed instruction, drill and practice, or individualized instruction (Zemke, 2002). Directed instruction utilizes low-level to high-level sequencing and emphasizes traditional methods such as lecture, homework, and tests. Programmed instruction presents information in steps or units with frequent testing requiring the learner to complete one step before
proceeding to the next. Drill and practice uses a cycle of repetition and feedback to strengthen the generation of target responses. Designing a program to accommodate the learning styles and preferences of specific learners as a means of challenging them is the basis for individualized instruction (Zemke, 2002).

While behaviorism does not explain how some skills are learned (Gredler, 2004) such as higher level and critical thinking skills, it is easily implemented and provides learners with clearly stated objectives, achievable behavioral expectations, and measurable success criteria (Zemke, 2002). Learners focus on developing proper reactions which are automatically displayed when the stimulus is presented. Evaluation is objective based on predetermined criteria which are uniform for all learners.

Behavioral classrooms are primarily instructor centered with the instructor responsible for creating, directing, and controlling the learning environment. The instructor determines the performance objectives, establishes the prompts for guiding learners toward the development of correct responses, and structures the practice situations (Zemke, 2002). Learners receive the stimulus for behaviors and the consequences for appropriate and inappropriate behaviors from the instructor.

In an online environment learners must receive objectives, expectations, stimuli, and reinforcement without the assistance of a face-to-face instructor. The instructional designer must develop a virtual behaviorist environment which employs individualized instruction with the drill and practice process of repetition and feedback to generate the desired responses.
In the virtual classroom the learner can work at their own pace to understand the requirements of the learning objectives and examine new material. Learners can be guided through the learning process in steps by prompts which elicit inputs followed by reinforcing feedback. Multiple opportunities for practice and assessment can be provided until learners become proficient. Learners are then directed to the next step in the sequence until the performance requirements of all objectives has been achieved.

The stimulus response learning which occurs with behaviorism is effective when learners need to remember and repeat information (Hung, 2001). The foundational nature of the physics course requires certain knowledge be consistently repeated in subsequent courses such as systems of units, unit conversions, significant figures, vector arithmetic, conservation of energy, and conservation of momentum. To build the learner’s ability to respond correctly, drill and practice with immediate and reinforcing feedback must be available. These practice activities should increase in difficulty and complexity for completion on the learner’s schedule and be repeatable until the learner achieves proficiency.

Instruction in the Psychomotor Domain

The psychomotor domain describes a hierarchy for learning physical behaviors primarily through practice and repetition. The level of a learner’s motor skill development is important in the physics laboratory as learners are required to perform specific physical movements when collecting data. The learner’s ability to make physical measurements affects the accuracy of the data and the reliability of the results.

The method proposed by Romiszowski (1999) for the development of physical skills is intended for application in all psychomotor learning situations. According to
Romiszowski’s (1999) theory, there are three phases in the development of psychomotor skills. First, the learner acquires knowledge of the purpose, sequence, and means for performing the activity through demonstration. Next, the learner develops basic skills through controlled practice of each step or sequence of steps. Finally, through repetition the learner becomes proficient and is able to automatically perform the required physical movements.

Romiszowski (1999) suggests a progression from lower level to higher level skills with corrective feedback or debriefing. By varying the practice opportunities, learners can generalize their knowledge and more readily transfer skills to a wider range of applications.

It is anticipated college physics learners are equipped with certain laboratory skills such as the ability to make measurements and construct graphs. Physics laboratory experiments initially utilize these basic activities as the foundation for developing more complex movements required in subsequent experiments.

Whether the physics laboratory is online or face-to-face, corrective and encouraging feedback from the instructor is vital to the development of the required psychomotor skills. The physics laboratories designed to be performed by learners in their homes will apply Romiszowski’s (1999) instructional methods for the development of physical skills.

Literature Comparing Online Instruction to Face-to-Face Instruction

There are numerous studies comparing online instruction to face-to-face instruction, therefore it is prudent to examine a sampling of these studies to compare and contrast them with this study. Ouellette (2000) presents a research study examining the characteristics and behaviors of learners in the same technology management course delivered face-to-face and
online at the University of Maryland University College. Comparisons of population characteristics, learner attitudes, time utilization, learner contact with the instructor, learners’ preference for activities, learner satisfaction, and learning styles between the face-to-face and distance delivered course were measured with pre-course and post-course surveys (Ouellette, 2000).

The face-to-face and online populations in the Ouellette (2000) study were comparable in terms of age, ethnic origin, gender, and access to computer technology. The majority of learners in both courses indicated a preference for working alone rather than in groups (Ouellette, 2000). There was virtually no difference in time utilization between the face-to-face and online course as indicated in the categories of writing, communicating, reading, and researching (Ouellette, 2000).

More contact with the instructor was recorded for the face-to-face class and the learners indicated a higher level of satisfaction with and preference for the activities presented in the face-to-face course (Ouellette, 2000). It should be noted the elements and materials of the face-to-face course were transferred to the online environment therefore a learner-centered instructional design was not applied to the online course.

The interesting aspect of the Ouellette (2000) study was the integration of learning style testing. Ouellette (2000) recommended courses for delivery in either medium be designed based on active learning techniques and focus on the learning styles favored by the learners.

Zhao et al. (2005) conducted a study which analyzed a significant body of research to highlight the factors that determine the effectiveness of distance education programs. The
motivation for Zhao et al.’s (2005) research study was the “pressing need for practical
guidance for improving distance education and the dismissive criticism of the immense body
of literature in distance education” (p. 1860). There were variations in the effectiveness of
distance education programs; however it appears that factors impacting the effectiveness of
distance education would have a similar affect if applied to traditional programs (Zhao et al.,
2005).

For example, interaction with other learners and the instructor seemed to produce
quality learning outcomes in either environment. The aggregate data from this study showed
there were no significant differences in outcomes of the face-to-face and distance education
programs; however individual differences were apparent. Zhao et al. (2005) points out that
variation in learning outcomes will occur in distance education programs as well as
traditional programs.

In addition to learning outcomes Zhao et al. (2005) investigated whether new
theoretical, analytical, and conceptual frameworks were required for the development of
distance learning instruction. Zhao et al. (2005) found support for the argument that another
conceptual and theoretical framework for distance education was unnecessary as learning is
fundamental to both distance and traditional education. Zhao et al. (2005) suggests using
Schwab’s four common places which include the instructor, learner, content, and milieux of
teaching-learning as a framework for studying distance education. The milieux of teaching-
learning is described as the format and method of delivery (Zhao, et al., 2005). These
suggestions deserve consideration in light of the desire to measure learning outcomes and
effectiveness in the online physics laboratory.
Interaction appears to be an important contributor to effective learning outcomes for online courses. Farahani (2003) researched the importance of online interaction from the learner and instructor perspective in online courses at Mid-Atlantic Community College. Learner to instructor, learner to learner, and learner to content interactions were reported to be available at a high level by the learners. Communication with the instructor through email was most prominent and along with feedback on assignments was considered very important to the learners. Interaction with other learners, group projects, and interaction with content were perceived by learners to be less important (Farahani, 2003).

Instructor perceptions of interaction were quite different from the learners. The instructors rated direct interaction with learners through email or for feedback as less significant in the online teaching experience (Farahani, 2003). Online instructors in this study appeared not to value the majority of the interactivity criteria listed in the survey as they indicated most criteria were not available and not perceived to be important for online learning (Farahani, 2003). Farahani (2003) indicated instructors in this sample may not have been familiar with online instruction practices and consequently did not utilize them in these courses.

Farahani’s (2003) study provides evidence that online interactions might be affected by the perceptions of the instructor, therefore Koory’s (2003) study controlled both the instructor and the course content while examining the same course offered online and face-to-face. This was accomplished using an extended experimental comparison of learning outcomes in both courses and the investigation of effective course design and teaching practices (Koory, 2003).
Rather than transferring an existing face-to-face course to the online medium, the online version of the “Introduction to Shakespeare” course incorporated several communication modes with an online pedagogy (Koory, 2003). The communication modes as described by Koory (2003) included one-alone meaning self-paced, self-directed learner to content interaction; one-to-one meaning exchanges between individual learners and the instructor; one-to-many meaning instructor communications with the entire class; and many-to-many meaning the discussions between learners, between learners and the instructor, and small group discussions.

Koory’s (2003) results showed consistently better learning outcomes in the online course compared to the on-campus versions using grade comparisons and learner satisfaction. The satisfaction indicated 100% of online learners would recommend the online version of the course to others. When the design of an online course and the instruction are based on an online pedagogy the result is more effective learning outcomes and higher learner satisfaction.

Literature on Online Laboratories

The future potential for online physics laboratories is being shaped by these studies. Dowd et al. (2005) reports the results of an investigation into learner perceptions of web based course components. Of particular interest to this study is the inclusion of lab activities in the instructional modules. Qualitative and quantitative data on learner’s perceptions were collected for two modules consisting of six lectures and three online lab activities placed on a web site (Dowd et al., 2005).
The online lab activities allowed learners to investigate phenomena and learn about the techniques and challenges of scientific inquiry (Dowd et al., 2005). Learners reported the progression from simple to complex lab activities as “increasingly more interesting and informative, but also more difficult to navigate” (Dowd et al., 2005, p. 1748). Learners considered the site an enhancement to their learning, a valuable addition to their learning, and a good addition to the course (Dowd et al., 2005). This study represents a successful transference of a science course’s lab component to an online environment.

Reeves and Kimbrough (2004) sought to remove a barrier to online learning in science courses at the University of North Carolina at Wilmington (UNCW) by making a laboratory science course accessible to distance learners. Reeves and Kimbrough (2004) describe an undergraduate chemistry course for science and non-science majors featuring laboratory experiments conducted by learners in their homes using materials typically available from local stores.

The laboratory course consisted of nine experiments carried out individually by learners in their kitchens. The experiments providing hands-on experience with chemical principles were closely aligned with the experiments performed in the traditional laboratory course at UNCW (Reeves & Kimbrough, 2004). Learners found the kitchen chemistry experiments “enhanced their appreciation of the relevance of chemistry in their lives because they involved familiar materials and measurements done in familiar surroundings” (Reeves & Kimbrough, 2004, p. 50).

Based on the distribution of final course grades, the learners in the distance learning laboratory outperformed their traditional counterparts indicating the well-organized calendar,
links to lessons, assignments, laboratory quizzes, and accessibility of the course instructor as contributors to their success (Reeves & Kimbrough, 2004). Reeves and Kimbrough (2004) concluded the distance laboratory experiments were found to be suitable replacements for the traditional laboratory. This study demonstrates undergraduate chemistry laboratory experiments can be performed successfully by learners in their homes with positive results.

Sethi and Antcliffe (2002) describe a set of physics experiments developed at Devry University in Pomona, California which utilize selected Java and Shockwave Applets accessible over the Internet. The project supports a learner-centered approach to education and opens up the possibility for science based courses to be offered online.

This method presents experiments through a visually-based interface which uses graphical representations of physics experiments. Rather than manipulating equipment the learners see and understand the physics principles as the effect of changing one parameter is reflected in the other parameters (Sethi & Antcliffe, 2002).

To optimize the learning experience questions from basic through challenging are presented to the learner during the experiment (Sethi & Antcliffe, 2002). Learners tested a prototype and a majority of learners provided substantially positive responses (Sethi & Antcliffe, 2002).

Meisner and Hoffman (2001) tested their design for a standalone distance learning course for introductory physics which incorporates open exploration and guided investigations called Learn Anywhere Anytime Physics (LAAPhysics). LAAPhysics is a virtual laboratory where learners perform experiments using simulations.
Meisner and Hoffman (2001) indicate the important contribution of the LAAPhysics system is not the technology but rather its ability to actively engage learners. The LAAPhysics experiments are interactive simulations where students are allowed to manipulate variables, make decisions independently, make mistakes, and determine measurement errors simulating real experiments (Meisner & Hoffman, 2001).

Portfolios of learner performance are generated for individual and aggregate analysis of conceptual understanding, expressing experimental data, and peer to peer interactions. The article provided results of beta testing with LAAPhysics (Meisner & Hoffman, 2001). Learners indicated they would choose LAAPhysics over a traditional laboratory course and they were stimulated by the opportunity to work independently (Meisner & Hoffman, 2001). Meisner and Hoffman (2001) indicated testing continues as more learners utilize LAAPhysics for their undergraduate physics laboratory course.

Alhalabi et al. (2004) presents remote laboratories as an alternative to simulations for online physics laboratories. The remote laboratory concept is still under development for electrical engineering and physics. The remote laboratory is a real physical laboratory accessed through an interface using the Internet (Alhalabi et al., 2004). According to Alhalabi et al. (2004), the remote laboratory provides learners with real responses to inputs from physical elements and stimulation of higher order thinking skills by involving the learner’s individual senses with the element of reality.

The remote laboratory concept is based on the Instructional Systems Design process of cyclic needs analysis, design and development, and evaluation and revision (Alhalabi et al., 2004). Accessing a remote laboratory provides learners with convenience, no time
constraints, and the opportunity to explore beyond the initial experiment (Alhalabi et al., 2004). Prototypes of a few experiments have been produced and as of this report no testing of the learning outcomes or learner reactions had been completed.

Faltin et al. (2002) presents a remote laboratory concept providing access to real laboratories with the additional distributed learning support of a tutorial assistant. The Internet assisted Laboratories (I-Labs) is a collaborative effort between the Stanford Center for Innovations in Learning in California and the Learning Lab Lower Saxony in Germany (Faltin et al., 2002). I-Labs learning strategies are based on self-directed and collaborative learning in online laboratories with tutorial assistance (Faltin et al., 2002).

There is a potential with I-Labs for a network of participating educational institutions sharing remote laboratories or commercial laboratories providing learners with the opportunity to access multiple facilities (Faltin et al., 2002). This technology and networking are under development as well as plans for testing of learning outcomes and learner reactions. This type of report illustrates physics laboratories are being designed for online delivery and will become a reality in the near future.

Adams (2003) describes the introductory physics course taught online through the Kentucky Virtual University in Paducah, Kentucky. This course includes lecture and laboratory components completed entirely online. The online laboratory includes the same combination of experiences learners receive in a traditional face-to-face laboratory including development of measurement skills, awareness of measurement error, analysis of data, formulating conclusions, and writing laboratory reports (Adams, 2003). Experiments were
selected that emphasized one of more of these laboratory experiences and learners were required to complete ten out of a possible 13 experiments (Adams, 2003).

Equipment for these experiments was not supplied, rather inexpensive and readily available materials in the learners’ homes or from local stores were utilized (Adams, 2003). Laboratory reports were written for each experiment and submitted through the course room. Learner success as measured by grade was comparable to the face-to-face counterpart of the course (Adams, 2003). Course evaluations were not conducted for the separate components as lecture and laboratory were evaluated together however the majority of learners rated the course materials as appropriate and the overall course as excellent (Adams, 2003). This is a significant instance of a functioning online physics course with a laboratory which is currently available.

Literature on Future Trends in Online Learning

In order for distance learning to realize its potential for achieving educational goals, the educational researcher must examine more all-encompassing possibilities. The developments occurring in technology and the market will affect distance learning requiring the researcher to be cognizant of the changing environment.

The future of distance education was postulated by Natriello (2005) with an exploration of the past developments in distance learning, characteristics of current distance learning programs, and future implications for educational researchers. Natriello (2005) identifies four fundamental changes affecting education which are currently or likely to occur (a) the shift of traditional and established packaging of education, (b) the changing role of faculty, (c) increased capital being made available to invest directly in the technology of
education, and (d) a major re-mapping of the education sector as new participants become substantial players in a global educational market (p.1892).

Natriello (2005) indicates “studying such fundamental changes presents special challenges to scholars who must begin to develop new data sources and develop new theoretical perspectives to guide inquiry” (p. 1899). As distance learning technologies stabilize, the demand for distance learning and its associated technologies will influence the practices of established educational institutions by requiring more accountability in a global market of educational services (Natriello, 2005). Learners in the marketplace will seek out the most effective educational organizations and the new entrants as well as the established institutions will be required to address the needs of that market. The future of distance learning will require providers to be responsive to the needs of learners as intended in this proposed research.
CHAPTER 3. METHODOLOGY

Research Methodology

Reviewing the research related to the comparison of online learning environments to face-to-face environments indicates a substantial body of quantitative work. The data to be collected for this study consist of background information, changes in the understanding of physics concepts, and learner reactions and level of satisfaction as reflected in quantitative measures. Background information consisting of gender, grade, academic major, prior physics courses, and prior online learning experience will be obtained by means of a learner survey. The changes in understanding of the physics content through their application in the experiments will be determined using pretest, written laboratory report, and posttest assessments as well as self-reported learner perceptions.

The quantitative methodology seems best suited to these issues under consideration; however it does not allow for the full exploration of learner reactions and satisfaction. Learner reactions and level of satisfaction relating to instructor, content, learner to learner interaction, and mode of delivery can be more accurately acquired from the learner’s written comments on a questionnaire. Therefore this study proposes to use a mixed quantitative and qualitative methodological approach.

The review of research in this area indicates a study using this approach to investigate online laboratory delivery has not been performed with physics learners. There is a gap in the knowledge with regard to physics instruction as well as the evaluation of such a laboratory using a learner-centered approach.
This study proposes to fill that gap with an investigation of outcomes and reactions of learners to physics laboratory experiments designed using a learner-centered philosophy for both the traditional and online delivery. The mixed quantitative and qualitative methodological approach combined with the evaluation technique will determine the quality of learning provided by the online physics laboratory as compared with a similar traditional approach. The review of a representative portion of the body of literature on this subject reveals a learner-centered approach to instruction combined with multiple interactions especially with the instructor contribute significantly to the efficacy of an online course.

This study will contribute knowledge to the field of education by including observations of a similarly constructed and implemented online and traditional physics laboratory. The potential findings of this research will provide information of benefit and interest to both the education and science disciplines.

Investigations examining differences between online and face-to-face learning environments encounter variables, constraints, and issues such as the role of the instructor and availability of resources for the learner. These circumstances make it impractical to design a purely experimental approach. The lack of control of environment variables means there are difficulties when using traditional experimental or even quasi-experimental methods (Mandinach, 2005).

The option to create randomly assigned treatments and control groups or ensure equivalent groups from a diverse learner population with many unknown characteristics is not available in the online learning environment (Mandinach, 2005). Additionally according to Mandinach (2005) “in an environment so open as online learning, it is
exceedingly difficult to control for extraneous and confounding influences as required by experimental design” (p 1815). Therefore two groups of learners will follow an equivalent procedure with a series of experiments in both the traditional and online settings.

Gall, Gall, and Borg (2003) suggest learner achievement can be ascertained using an objective based evaluation. The evaluation methodology is not unique to any particular learning environment and the specific challenges of an online learning environment might be balanced with the evaluation methodology (Mandinach, 2005).

**Evaluation Research Methodology**

Mandinach (2005) indicates that the emerging field of e-learning is rich with opportunities to investigate the impact of instructional activities on learning. Since e-learning is by nature different from traditional instructional mediums new and hybrid methods of evaluation are required (Mandinach, 2005). Mandinach (2005) examines the unique characteristics of e-learning and discusses potentially informative evaluation methodologies for examining the affect of e-learning on teaching and learning processes. The evaluation methodology will be proposed as the method for determining the learning impact of the online physics laboratories. The experimental method described by Mandinach (2005) is an evidence-based evaluation founded on specific research questions thereby not differentiating between research and evaluation.

The effective evaluation is based on a comprehensive understanding of the specific program, its context, and learners (Mandinach, 2005). The set of research questions should reflect the needs of the learners, methodology, measurements, data collection methods, and
designs (Mandinach, 2005). The specific questions and phenomena being investigated are the determiners of the appropriate methodology (Mandinach, 2005).

According to Mandinach (2005) “although assessment per se focuses on the individual learner, the evaluation of assessment techniques and a needs analysis can contribute to a broader understanding of the area and feed directly into development activities” (p.1828). Surveys should be constructed to evaluate the best and least effective practices while focusing on assessment techniques, capabilities of emerging technologies, innovative learning applications, improving assessments to better allow learners to demonstrate cognitive and affective processes, not translating old techniques into a different medium, the continuous and dynamic learning process, and making the feedback loop between instruction and assessment more meaningful (Mandinach, 2005).

These evaluation attributes will be incorporated into the research instruments posed to evaluate the learner-centered design of the online physics laboratory. The mixed quantitative and qualitative methodological approach will complement the evaluation design of this research study into online physics laboratories. The evaluation technique proposed for use in this study may have limitations however this technique is a valuable inclusion with the mixed methodology.

Research Methods

Educational research is an organized structured investigation accomplished using different approaches founded on precise methods. The research methods detailed by the study’s sample, instruments, variables, measurements, procedures, analysis, and anticipated outcomes have been selected to address the question of whether learning outcomes as
measured by pretests, written laboratory reports, and posttests scores for physics laboratory experiments completed by learners in their homes are as effective as the learning outcomes for physics laboratory experiments completed by learners in the physical laboratory.

It is hypothesized the learning outcomes for the physics experiments performed outside of the physical laboratory as evidenced by greater improvement between pretest and posttest scores as well as higher laboratory report scores will be equal to or greater than the physics experiments performed inside the physical laboratory due to the removal of time constraints and pressure from peers allowing for self-directed and self-paced investigations which promote learning. The use of these quantitative measurements will provide an understandable means of comparison between the two types of physics laboratory experiments. Numerical data is also well-suited to visual comparisons using graphical representations.

The responses by learners on the reaction questionnaire will address whether there is a positive learner reaction to the physics laboratory experiments performed outside of the physical laboratory. It is hypothesized the convenience and flexibility offered by the physics experiments performed outside of the physical laboratory will result in a majority of learners indicating a positive reaction to these experiments as well as a high level of satisfaction with their learning experiences outside of the physical laboratory. These reactions and the level of satisfaction will be clearly articulated using the learner’s own words.

Sample

The research presented in this proposal will be conducted at LeTourneau University in Longview, Texas during the spring 2006 semester. Five college physics laboratory
sections with an average of 17 learners per section constitute a potential sample size of 85 learners. The theoretical population for this research study is college or university learners taking an introductory physics course. The accessible sample consists of the learners at LeTourneau University who enroll in the college physics course during the spring 2006 semester. Those learners who complete both the learner-centered traditional and online physics laboratories along with the accompanying assessments and evaluations will constitute the sample.

This type of sampling is a nonrandom selection because the learners will decide to enroll in the physics course at the time and place of the study. This represents a convenient sample as these courses are in close proximity to the researcher.

There are concerns about the size of the sample being too small and its composition. Participation in the research process will be voluntary thereby reducing the sample size. The non-random selection procedure may contribute to a sample non-representative of the physics learner population.

**Instruments, Variables, and Measurements**

The instruments utilized to measure learning outcomes for the online physics laboratory will consist of similarly constructed pretests and posttests as well as written laboratory reports. The pretest and posttest will contain three to four multiple choice concept questions with four possible responses and two to three problems using simulated experimental data. The responses to the problems will be numerical requiring an explanation or calculation which illustrates how the learner determined their answer. The written
laboratory report consists of filling in data and answering questions on a prepared form provided to the learners.

The variables for measuring learning outcomes include the scores on the pretest, posttest, and the grade assigned to the written laboratory report. The pretest and posttest will be evaluated using an interval scale from zero to 15 points. The written laboratory report will be evaluated with an interval scale from zero to 20 points.

The physics experiments performed for this study will cover concepts and meet the objectives of traditional physics experiments therefore learners will receive grades for the written laboratory reports which will contribute to their final grade in the course. Each experiment the learner performs will have a cover sheet entitled grade tracking form and their name will only appear on this form. After the grade is recorded on this form it will be removed from the experiment and returned to the learner. The identity of learners will not be connected with any research data or included in any research reports as a randomly generated number code will be utilized.

Research Procedures

This research proposes to investigate the effectiveness of a series of physics laboratory experiments designed for incorporation into an online college physics course which would satisfy the course’s laboratory requirement. For this study the data collection process will consist of three segments.

During the first segment learner consent will be obtained and those learners consenting to participate in the study will be assigned random numbers. The learners will be divided into two groups identified as group one and group two. Group one will consist of
learners with random numbers less than the median number in the sample and group two will consist of learners with random numbers greater than the median number in the sample. The learners in group one will conduct two physics experiments outside of the physical laboratory and the learners in group two will conduct the same two physics experiments inside the physical laboratory. During the second segment of the data collection phase the learners in group one will conduct another two physics experiments inside the physical laboratory and the learners in group two will conduct the same two physics experiments outside of the physical laboratory. In the third segment of the data collection phase learners will complete a reaction questionnaire.

*Consent and Confidentiality*

Learners will be informed of the research study, what will be expected of them, and have their questions or concerns addressed during a traditional laboratory meeting. The learners will be asked if they consent to participate in the study and will be provided with a consent form. The consent form is included as Appendix A. Learners must indicate their consent to participate in the study by signing this form. Photocopies of the signed consent forms will be made available to the learners as soon as possible. Learners who do not consent will conduct the same experiments during their regularly scheduled laboratory time thereby maintaining consistency among all the general physics laboratory sections.

Learners who sign the consent form will be asked to provide background information consisting of gender, grade, academic major, prior physics courses, and prior online learning experience using a paper and pencil survey. This information will be supplied voluntarily and anonymously as the learner will not be identified on this form.
The background information survey is located in Appendix B. The learner’s name will not be associated with the research data or included in any research reports. The privacy and confidentiality of participants in this study will be protected as identifying information will be removed from the data prior to storage or analysis.

*Physics Experiments*

The learners signing the consent form will be given the pretests for the four physics experiments using paper and pencil forms while remaining anonymous. Learners will then be issued experiment kits containing instructions and equipment for two physics experiments. Learners in group one will complete these experiments outside of the physical laboratory and learners in group two will complete the same experiments inside the physical laboratory.

The posttest assessment will be supplied with the kit for completion after the learner has conducted the experiment. Deadlines and submission instructions for the written laboratory report and posttest assessment will be included on the grade tracking form as well as through an announcement posted on the Blackboard learning management system.

The experiments to be performed during the first segment of the data collection phase are the two dimensional motion investigation and the Newton’s Third Law investigation. Grading rubrics will be employed to ensure consistent scoring of pretests, posttests, and written laboratory reports. The grade tracking form, pretest, experiment instructions, and posttest for the two dimensional motion investigation are located in Appendix C and the grading rubrics for the two dimensional motion investigation assessments are located in Appendix D. The grade tracking form, pretest, experiment instructions, and posttest for the
Newton’s Third Law investigation are available in Appendix E and the grading rubrics for the Newton’s Third Law investigation assessments are located in Appendix F.

The learners participating in the study will perform two additional physics experiments using a similar approach. In the second data collection segment learners in group one will perform two physics experiments in the physical laboratory and group two will perform the same two physics experiments outside of the physical laboratory. Both groups will use instructions and equipment supplied in a kit. This second set of experiments will require similar psychomotor and analytical skills as utilized by learners to conduct the first two physics experiments.

The two experiments to be performed during the second data collection segment are the Newton’s Second Law investigation and the determining the coefficient of friction investigation. The grade tracking form, pretest, experiment instructions, and posttest for the Newton’s Second Law investigation are located in Appendix G and the grading rubrics for the Newton’s Second Law investigation assessments are located in Appendix H. The grade tracking form, pretest, experiment instructions, and posttest for the determining the coefficient of friction investigation are available in Appendix I and the grading rubrics for the determining the coefficient of friction investigation assessments are located in Appendix J.

The two dimensional motion and the determining the coefficient of friction investigations are typically unfamiliar concepts to the majority of college physics learners and are anticipated to reflect comparable knowledge gains. Both of these experiments will involve explorations which yield empirical results. Learners will be required to draw conclusions from experimental results rather than from experience or theory.
The Newton’s Third Law and the Newton’s Second Law investigations deal with the concept of force. Both of these investigations involve an experimental verification of a known force relationship. For these experiments learners compare their results with those predicted by Newton’s Laws of Motion. Newton’s Laws of Motion are usually familiar to the majority of college physics learners and these experimental results will reflect knowledge gained as well as reinforcement of previous knowledge.

Written laboratory reports will be submitted and posttest assessments will be completed following each of the four physics experiments. Scoring for the pretest, posttest, and written laboratory report will be consistent for all four experiments as the evaluator will not be aware of whether the learner submitting the assessment was a member of group one or group two. The only difference between groups will be the presence of an instructor for the experiments performed in the physical laboratory.

Learners will be encouraged to communicate with the course instructor if they have any questions or problems with these experiments. For learners performing physics experiments outside of the physical laboratory these communications can occur only through their university email account or by telephone to simulate the methods of communication which exist in an online course. The instructor’s email address and telephone number will be provided on the grade tracking form.

*Design of Physics Experiments*

The four experiments to be used in this study will have the same design. The type, amount, and order of information and instructions provided to the learners for each experiment follows an identical pattern. The experimental set-up, data collection, and
analysis for each experiment will require comparable levels of skill and be constructed to reflect equivalent difficulty. These experiments deal with topics studied at the beginning of the college physics course and require no previous physics knowledge or laboratory experience.

*Field Testing of Physics Experiments*

The four experiments designed for this study were field tested by college physics learners completing their second semester of a two semester physics course. In the field test evaluations learners reported all the experiments presented equivalence challenges in terms of data collection and analysis. Learners indicated the level of difficulty for each investigation was comparable with the laboratory experiments they typically perform. There was uniformity in the scores obtained by these learners on the pretests, posttests, and written laboratory reports. These results and learner evaluations indicate the experiments designed for this study are equivalent in design and level of difficulty.

*Learner Reaction*

Learner reaction to both types of laboratory experiences will be determined in the third data collection phase using a questionnaire. This questionnaire will be available as an anonymous survey through the Blackboard learning management system the day following the completion of the experiments. Learners will be given adequate time to complete the questionnaire. The learner reaction questionnaire is located in Appendix K.

*Analysis*

Learning outcomes for the four physics experiments will be determined from similarly constructed pretests and posttests as well as written laboratory reports. Grading
rubrics will be employed to ensure consistent scoring of pretests, posttests, and written laboratory reports. The evaluator of the pretests, posttests, and written laboratory reports will not be aware of whether the learner submitting the assessment was a member of group one or group two.

The data from each experiment will be analyzed and compared between groups one and two. The level of improvement achieved by each group will be determined by taking the difference in the pretest and posttest scores. Evidence of achievement of learning outcomes will be present if the posttest scores have been shifted upward. The mean, median, mode, range, standard deviation, variance, and skewness for the distribution of pretest and posttest differences and the written laboratory report scores will be provided for each group. The mean differences in the pretest and posttest scores and the mean written laboratory report scores will be evaluated between the two groups using a \( t \)-test and presented visually using frequency distributions.

Learner reaction will be measured using a questionnaire requiring written comments. The areas explored by the questionnaire will include the learner’s perspective on their ability to perform the experiments with the instructions and equipment provided in the kit, how much time they spent completing the experiments, their interaction with the course instructor and with other learners, whether they have a preference for the online approach or the traditional laboratory, their level of satisfaction with learning experiences inside and outside of the physical laboratory, as well as any additional comments or suggestions. The results of the questionnaire will be categorized and representative comments selected for inclusion in the research findings.
Anticipated Outcomes

This research proposes to investigate the learning outcomes and learner reactions to independently performed physics laboratory experiments designed using the learner-centered approach to instruction and completed by learners in their homes using a comparison to physics laboratory experiments designed using the learner-centered approach to instruction and completed by learners in a physical laboratory. Evidence in the literature review indicated instruction designed from the learner’s perspective and implemented using cognitive theory results in achievement of learning outcomes that surpass equivalent face-to-face instruction. Evidence from the literature review also indicates instruction designed from the learner’s perspective and implemented with multiple avenues for interaction will receive an overwhelming positive response from learners regarding their learning experience.

Therefore it is anticipated learning outcomes as measured by pretest and posttest differences as well as written laboratory report scores for the learner-centered laboratory experiments completed by learners in their homes using kits will exceed those achieved by the learners completing the same experiments in the physical laboratory. It is further anticipated learner reaction as measured by their comments on a questionnaire will indicate an overwhelming preference for the learner-centered laboratory experiments completed by learners in their homes over the experiments performed by learners in the physical laboratory.

Reducing Experimental Bias

Although every effort will be made to minimize bias there is the potential for researcher bias in this inquiry. Being aware of this limitation will work towards the reduction
of bias. Experimental bias according to Gall, Gall, and Borg (2003) refers to the unintentional transmission of the researcher’s expectations of the study’s outcomes to the participants so as to influence their behavior. Experimental bias can affect the validity of an investigation as accurate measurements will not be made of the outcomes as well as possibly affecting the reliability as findings may be inconsistent with comparable studies. As a means of reducing the potential for experimental bias in this study the researcher will request the participants limit their discussions during the study to issues relating to the physics experiments and not aspects of the research.

Even though the evaluation technique proposed for use in this study is a valuable inclusion with the mixed methodology there is the potential for bias in the scoring of the assessment instruments. Therefore when the pretests, posttests, and written laboratory reports are graded the evaluator will not know whether the learner completed the experiment inside of the physical laboratory or outside of the physical laboratory.
CHAPTER 4. DATA COLLECTION AND ANALYSIS

Summary of Research Design and Methods

This research study is an examination of the learning outcomes achieved by two groups of physics learners who performed two hands-on experiments outside of a physical laboratory simulating an online format and two hands-on experiments in a physical laboratory utilizing the traditional or face-to-face format. The learning outcomes were measured by pretest, posttest, and written laboratory report scores. These quantitative measurements are used as the means of comparison between the two groups of learners who conducted the same physics experiments using the different delivery formats.

Data from each experiment is compared between the two groups using descriptive statistics including the mean, median, mode, range, standard deviation, variance, and skewness for the differences between the pretest, posttest, and written laboratory report scores. Frequency distributions are employed as a means to make visual comparisons between groups for each experiment. The hypotheses regarding learning outcomes are tested statistically by means of the $t$-test.

Learner reaction to both types of experiments was measured using a questionnaire. This qualitative feedback regarding learner preferences and level of satisfaction with their learning experiences outside and inside of the physical laboratory is also examined. The learner reactions are categorized as either affirming the online laboratory format, signifying no difference between the online and face-to-face laboratory formats, or affirming the face-to-face laboratory format. Representative learner responses are presented to clearly articulate the learner’s meaning using their own words.
Description of Sample

The participants in this study are learners who enrolled in the college physics course offered during the spring 2006 semester at LeTourneau University and who completed both the face-to-face and online physics laboratories along with the accompanying assessments and the learner reaction questionnaire. Of the 83 learners who began the study 71 completed the experiments, assessments, and learner reaction questionnaire therefore these 71 learners constitute the sample for this study. The characteristics of the learners in this sample will be presented in a later section of this chapter.

Description of Instruments, Variables, and Measurements

The instruments utilized to measure learning outcomes for the online physics laboratory consisted of similarly constructed pretests, posttests, and written laboratory reports. The pretests and posttests were evaluated using an interval scale from zero to 15 points. The written laboratory reports were evaluated with an interval scale from zero to 20 points. Grading rubrics were employed to ensure consistent scoring of pretests, posttests, and written laboratory reports.

When the pretests, posttests, and written laboratory reports were graded the evaluator did not know whether the learner completed the experiment inside of the physical laboratory or outside of the physical laboratory. This blind grading was accomplished using the following procedure. The learner was identified only on the cover sheet of the experiment instruction packet. The data collected and the analysis performed by the learners for the physics experiments was recorded on the third or fourth page of the pre-prepared form. Prior to grading any of the physics experiments the evaluator shuffled the experiment packets and
then opened them to the first data entry page by folding over the cover sheet and any preliminary pages of the packet. This concealed the identity of the learners as well as their group membership during the grading process. All the experiments were graded before any scores were recorded on the cover sheets thereby ensuring consistent scoring for the experiments performed inside and outside of the physical laboratory.

**Description of Research Procedures**

This research is an investigation of the effectiveness of a series of physics laboratory experiments designed for incorporation into an online college physics course which would satisfy the laboratory requirement of the course. Learners who consented to participate in the study voluntarily provided background information consisting of gender, grade, academic major, prior physics courses, and prior online learning experience using an anonymous paper-and-pencil survey.

In the first phase of data collection learners were assigned randomly generated numbers which were used to create two groups identified as group one and group two. Group one consisted of learners with random numbers less than or equal to the median number in the sample and group two consisted of learners with random numbers greater than the median number in the sample. The learners in group one conducted two physics experiments outside of the physical laboratory and the learners in group two conducted the same two physics experiments inside the physical laboratory. These experiments were entitled the two dimensional motion investigation and the Newton’s Third Law investigation.

During the next phase of data collection the learners in group one conducted another two physics experiments inside the physical laboratory and the learners in group two
conducted the same two physics experiments outside of the physical laboratory. These experiments were entitled the Newton’s Second Law investigation and the determining the coefficient of friction investigation.

In the final phase of data collection the learners completed the learner reaction questionnaire. This questionnaire was available as an anonymous survey through the Blackboard learning management system.

Learner Characteristics

The 71 learners participating in this study can be characterized by the information supplied on the background information survey. These characteristics of the sample will create the setting from which the remaining data is examined. The gender and class demographics of learners are presented in Table 1 for each group and for the combined groups. Following each demographic characteristic its contribution to the sample of 71 learners is given as a percent.

The gender breakdown of 82 % male and 18 % female is typical of many college physics courses and the distribution of male and female learners between groups one and two was essentially equal. Sophomores represented the largest class with 39 % of the learners in the sample followed by seniors, juniors, and freshman with 23 %, 21 %, and 17 % of the sample respectively. The college physics course is typically scheduled during the second year in college however it is not unusual to have a mix of classes. Each of the groups in the study contained a balanced representation from each class.
Table 1

*Gender and Class Demographics of Learners by Group*

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Combined groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>% of Sample</td>
<td>Count</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>29</td>
<td>41%</td>
<td>29</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
<td>10%</td>
<td>6</td>
</tr>
<tr>
<td>Year in college</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>5</td>
<td>7%</td>
<td>7</td>
</tr>
<tr>
<td>Sophomore</td>
<td>16</td>
<td>23%</td>
<td>12</td>
</tr>
<tr>
<td>Junior</td>
<td>9</td>
<td>13%</td>
<td>6</td>
</tr>
<tr>
<td>Senior</td>
<td>6</td>
<td>8%</td>
<td>10</td>
</tr>
</tbody>
</table>

The background information survey made prior physics course and online experience inquiries of the learners. These characteristics of the learners in the sample are displayed for each group and for the combined groups in Table 2.
Table 2

*Prior Physics Courses and Online Experience of Learners by Group*

<table>
<thead>
<tr>
<th>Category</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Combined groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>% of Sample</td>
<td>Count</td>
</tr>
<tr>
<td>Prior college physics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3</td>
<td>4%</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>33</td>
<td>46%</td>
<td>34</td>
</tr>
<tr>
<td>Prior high school physics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>26</td>
<td>37%</td>
<td>29</td>
</tr>
<tr>
<td>No</td>
<td>10</td>
<td>14%</td>
<td>6</td>
</tr>
<tr>
<td>Prior online course</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9</td>
<td>13%</td>
<td>11</td>
</tr>
<tr>
<td>No</td>
<td>27</td>
<td>38%</td>
<td>24</td>
</tr>
</tbody>
</table>

Six percent of learners had previously enrolled in a college physics course making this college physics course the first for 94% of the learners. The majority of learners in the study (77%) had taken a course in high school which included physics. For 23% of the learners this course was their first exposure to physics. The distribution of prior physics knowledge between the groups was similar.
Twenty-eight percent of the learners participating in the study had previously taken an online course and these learners were distributed almost evenly between the two groups. The majority of learners (72%) had no experience with online learning. Learners without online experience were well represented in each of the two groups.

The distribution of academic majors in each of the two groups and for the combined groups is shown in Table 3. Aeronautical science majors are the majority in each group along with a representation of the other majors that is consistent with their distribution in the sample.

Table 3

_Academic Majors of Learners by Group_

<table>
<thead>
<tr>
<th>Academic Major</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Combined groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>% of Sample</td>
<td>Count</td>
</tr>
<tr>
<td>Aeronautical Science</td>
<td>19</td>
<td>27%</td>
<td>16</td>
</tr>
<tr>
<td>Engineering Technology</td>
<td>7</td>
<td>10%</td>
<td>6</td>
</tr>
<tr>
<td>Biology</td>
<td>7</td>
<td>10%</td>
<td>7</td>
</tr>
<tr>
<td>Business</td>
<td>1</td>
<td>1%</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>3%</td>
<td>3</td>
</tr>
</tbody>
</table>
In the study sample there were 35 (49%) aeronautical science majors, 14 (20%) biology majors, 13 (18%) engineering technology majors, four (6%) business majors, and five (7%) other majors including two kinesiology, one teacher education, one English, and one Christian ministries. This distribution of academic majors is typical for this college physics course at LeTourneau University.

Research Question 1

How effectively will learning outcomes as measured by a pretest, written laboratory report, and posttest be realized for an online physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in their home as compared with a physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in a physical laboratory? To determine the effectiveness of each physics experiment the differences between the pretest and posttest scores and the written laboratory report scores will be examined for the two groups conducting each experiment. Because of the different nature of the pretest and posttest assessments as compared with the written laboratory report a separate statistical test is made for each measurement within the analysis of each experiment.

The research hypotheses will be investigated for each of the four experiments performed for this study. The effectiveness of each experiment will be examined in the order in which the experiments were performed by the learners. The experiment order was the two dimensional motion investigation, the Newton’s Third Law investigation, the Newton Second Law investigation, and the determining the coefficient of friction investigation respectively.
Computer software was employed to determine the descriptive statistics and the t-statistic or t-value for each experiment’s analysis.

Research Hypotheses 1

PreTest Versus PostTest Hypothesis

The null hypothesis states there will be no difference between the pretest and posttest scores for the online physics laboratory experiments completed by learners in their homes as compared with the physics laboratory experiments completed by learners in a physical laboratory. The alternative hypothesis states there will be a difference between the pretest and posttest scores for the online physics laboratory experiments completed by learners in their homes as compared with the physics laboratory experiments completed by learners in a physical laboratory.

Laboratory Report Hypothesis

The null hypothesis states there will be no difference between the written laboratory report scores for the online physics laboratory experiments completed by learners in their homes as compared with the physics laboratory experiments completed by learners in a physical laboratory. The alternative hypothesis states there will be a difference between the written laboratory report scores for the online physics laboratory experiments completed by learners in their homes as compared with the physics laboratory experiments completed by learners in a physical laboratory.

Statistical Analysis for Research Hypotheses 1

There were 36 learners in group one who completed two experiments outside of the physical laboratory and two experiments inside of the physical laboratory. There were 35
learners in group two who conducted two experiments inside the physical laboratory and two experiments outside of the physical laboratory. These two groups of learners represent an independent sample as the learners in groups one and two are not related. According to Triola (2005) the mean difference between the pretest and posttest scores and the difference between the mean laboratory report scores can be compared between these two groups using a \( t \)-test because the number in each group is greater than 30. The \( t \)-test criteria for rejecting the null hypothesis occurs when the magnitude of the standardized \( t \)-statistic or \( t \)-value is in the rejection region or has a value greater than the magnitude of \( t \)-critical otherwise the null hypothesis is not rejected.

Two Dimensional Motion Investigation

*Two Dimensional Motion Investigation Data*

Table 4 displays the descriptive statistics for the differences between the pretest, posttest, and written laboratory report scores collected for the two dimensional motion investigation. The data from the two dimensional motion investigation is separated by group and the comparison between groups is presented in the frequency distributions of figures 1 and 2.

The complete data set for the two dimensional motion investigation is located in Appendix L. The two dimensional motion investigation was conducted by learners in group one using an online format while the learners in group two performed the same experiment inside the physical laboratory.
Table 4

*Descriptive Statistics for Two Dimensional Motion Investigation*

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Online)</td>
<td>Group Two (Face-to-Face)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>8.04</td>
<td>6.07</td>
</tr>
<tr>
<td>Median</td>
<td>8.75</td>
<td>6.00</td>
</tr>
<tr>
<td>Mode</td>
<td>9.50</td>
<td>6.50</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.00</td>
<td>-1.50</td>
</tr>
<tr>
<td>Maximum</td>
<td>15.00</td>
<td>12.50</td>
</tr>
<tr>
<td>Range</td>
<td>15.00</td>
<td>14.00</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3.61</td>
<td>3.29</td>
</tr>
<tr>
<td>Variance</td>
<td>13.01</td>
<td>10.83</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.24</td>
<td>-0.06</td>
</tr>
</tbody>
</table>
**Figure 1.** Frequency Distribution of PreTest versus PostTest Differences for the Two Dimensional Motion Investigation

**Figure 2.** Frequency Distribution of Laboratory Report Scores for the Two Dimensional Motion Investigation
Two Dimensional Motion Investigation Statistical Analysis

Table 5 contains results for the $t$-test comparison of means between groups one and two for the pretest versus posttest difference and the laboratory report scores for the two dimensional motion investigation. The direction of the differences for the descriptive statistics and the $t$-test is group one as variable two and group two as variable one.

Table 5

Two Dimensional Motion Investigation $T$-tests

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Online)</td>
<td>Group Two (Face-to-Face)</td>
</tr>
<tr>
<td></td>
<td>Group One (Online)</td>
<td>Group Two (Face-to-Face)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>8.04</td>
<td>6.07</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>$p$-value</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>$t$-value</td>
<td>+2.41</td>
<td>+1.17</td>
</tr>
<tr>
<td>$t$-critical (two-tail)</td>
<td>±1.99</td>
<td>±1.99</td>
</tr>
<tr>
<td>$t$-test decision</td>
<td>reject the null hypothesis</td>
<td>fail to reject the null hypothesis</td>
</tr>
</tbody>
</table>

Based on the $t$-test comparing the mean pretest and posttest differences between groups one and two for the two dimensional motion investigation the null hypothesis is
rejected as the \( t \)-statistic or \( t \)-value is greater than \( t \)-critical. The alternative hypothesis that there is a difference between the mean pretest and posttest differences of groups one and two for the two dimensional motion investigation is not rejected. The direction of this difference indicates a greater improvement between pretest and posttest scores for the online delivery of this physics experiment. There is a five percent probability of rejecting a true null hypothesis.

Based on the \( t \)-test comparing the mean laboratory report score between groups one and two for the two dimensional motion investigation the null hypothesis is not rejected as the \( t \)-statistic or \( t \)-value is less than \( t \)-critical. This result asserts there is statistically no difference in the mean laboratory report scores of groups one and two for the two dimensional motion investigation. No difference in the laboratory report scores signifies learner performance did not depend on where the two dimensional motion investigation was performed. Learners can perform this laboratory investigation outside of the physical laboratory and inside the physical laboratory with equal proficiency. The mean laboratory report score for learners in both groups was approximately 17 points out of a possible 20 points or 85 % on a 100 % scale.

Newton’s Third Law Investigation

\textit{Newton’s Third Law Investigation Data}

Table 6 displays the descriptive statistics for the differences between the pretest, posttest, and written laboratory report scores collected for the Newton’s Third Law investigation. The data is separated by group and the comparison between groups is presented in the frequency distributions of figure 3 and figure 4. The complete data set for the Newton’s Third Law investigation is located in Appendix M. The Newton’s Third Law
investigation was conducted outside of the physical laboratory by the learners in group one while the learners in group two performed the same experiment inside the physical laboratory.

Table 6

*Descriptive Statistics for Newton’s Third Law Investigation*

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Online)</td>
<td>Group Two (Face-to-Face)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>6.69</td>
<td>4.43</td>
</tr>
<tr>
<td>Median</td>
<td>7.00</td>
<td>5.50</td>
</tr>
<tr>
<td>Mode</td>
<td>9.00</td>
<td>5.50</td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.00</td>
<td>-4.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>13.00</td>
<td>13.00</td>
</tr>
<tr>
<td>Range</td>
<td>15.00</td>
<td>17.00</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3.09</td>
<td>4.49</td>
</tr>
<tr>
<td>Variance</td>
<td>9.55</td>
<td>20.16</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.75</td>
<td>-0.081</td>
</tr>
</tbody>
</table>
Figure 3. Frequency Distribution of PreTest versus PostTest Differences for the Newton’s Third Law Investigation

Figure 4. Frequency Distribution of Laboratory Report Scores for the Newton’s Third Law Investigation
**Newton’s Third Law Investigation Statistical Analysis**

Table 7 contains results for the $t$-test comparison of means between groups one and two for the pretest versus posttest difference and the laboratory report scores for the Newton’s Third Law investigation. The direction of the differences for the descriptive statistics and the $t$-test is group one as variable two and group two as variable one.

Table 7

**Newton’s Third Law Investigation T-tests**

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Online)</td>
<td>Group Two (Face-to-Face)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>6.69</td>
<td>4.43</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>$p$-value</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>$t$-value</td>
<td>$+2.48$</td>
<td>$+0.42$</td>
</tr>
<tr>
<td>$t$-critical (two-tail)</td>
<td>$±1.99$</td>
<td>$±1.99$</td>
</tr>
<tr>
<td>$t$-test decision</td>
<td>reject the null hypothesis</td>
<td>fail to reject the null hypothesis</td>
</tr>
</tbody>
</table>

Based on the $t$-test comparing the mean pretest and posttest differences between groups one and two for the Newton’s Third Law investigation the null hypothesis is rejected
as the $t$-statistic or $t$-value is greater than $t$-critical. The alternative hypothesis that there is a difference between the mean pretest and posttest differences of groups one and two for the Newton’s Third Law investigation is not rejected. The direction of this difference indicates a greater improvement between pretest and posttest scores for the online delivery of this physics experiment. There is a five percent probability of rejecting a true null hypothesis.

Based on the $t$-test comparing the mean laboratory report score between groups one and two for the Newton’s Third Law investigation the null hypothesis is not rejected as the $t$-statistic or $t$-value is less than $t$-critical. This result asserts there is statistically no difference in the mean laboratory report scores of groups one and two for the Newton’s Third Law investigation.

No difference in the laboratory report scores signifies learner performance did not depend on where the Newton’s Third Law investigation was performed. Learners can perform this laboratory investigation outside of the physical laboratory and inside the physical laboratory with equal proficiency. The mean laboratory report score for learners in both groups was approximately 17 points out of a possible 20 points or 85 % on a 100 % scale.

Newton’s Second Law Investigation

**Newton’s Second Law Investigation Data**

Table 8 displays the descriptive statistics for the differences between the pretest, posttest, and written laboratory report scores collected for the Newton’s Second Law investigation. The data is separated by group and the comparison between groups is presented in the frequency distributions of figure 5 and figure 6. The complete data set for
the Newton’s Second Law investigation is located in Appendix N. The Newton’s Second Law investigation was conducted inside the physical laboratory by the learners in group one while the learners in group two performed the same experiment outside of the physical laboratory.

Table 8

Descriptive Statistics for Newton’s Second Law Investigation

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Face-to-Face)</td>
<td>Group Two (Online)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>3.26</td>
<td>5.64</td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Mode</td>
<td>3.00</td>
<td>8.00</td>
</tr>
<tr>
<td>Minimum</td>
<td>-7.00</td>
<td>-2.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>11.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Range</td>
<td>18.00</td>
<td>17.00</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3.89</td>
<td>4.17</td>
</tr>
<tr>
<td>Variance</td>
<td>15.16</td>
<td>17.38</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.31</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Figure 5. Frequency Distribution of PreTest versus PostTest Differences for the Newton’s Second Law Investigation

Figure 6. Frequency Distribution of Laboratory Report Scores for the Newton’s Second Law Investigation
Newton’s Second Law Investigation Statistical Analysis

Table 9 contains results for the \( t \)-test comparison of means between groups one and two for the pretest versus posttest difference and the laboratory report scores for the Newton’s Second Law investigation. The direction of the differences for the descriptive statistics and the \( t \)-test is group one as variable two and group two as variable one.

Table 9

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Face-to-Face)</td>
<td>Group Two (Online)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>3.26</td>
<td>5.64</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>( t )-value</td>
<td>-2.48</td>
<td>-0.99</td>
</tr>
<tr>
<td>( t )-critical (two-tail)</td>
<td>( \pm 1.99 )</td>
<td>( \pm 1.99 )</td>
</tr>
<tr>
<td>( t )-test decision</td>
<td>reject the null hypothesis</td>
<td>fail to reject the null hypothesis</td>
</tr>
</tbody>
</table>

Based on the \( t \)-test comparing the mean pretest and posttest differences between groups one and two for the Newton’s Second Law investigation the null hypothesis is
rejected as the $t$-statistic or $t$-value is greater than $t$-critical. The alternative hypothesis that there is a difference between the mean pretest and posttest differences of groups one and two for the Newton’s Second Law investigation is not rejected. The direction of this difference indicates a greater improvement between pretest and posttest scores for the online delivery of this physics experiment. There is a five percent probability of rejecting a true null hypothesis.

Based on the $t$-test comparing the mean laboratory report score between groups one and two for the Newton’s Second Law investigation the null hypothesis is not rejected as the $t$-statistic or $t$-value is less than $t$-critical. This result asserts there is statistically no difference in the mean laboratory report scores of groups one and two for the Newton’s Second Law investigation.

No difference in the laboratory report scores signifies learner performance did not depend on where the Newton’s Second Law investigation was performed. Learners can perform this laboratory investigation outside of the physical laboratory and inside the physical laboratory with equal proficiency. The mean laboratory report score for learners in both groups was approximately 17 points out of a possible 20 points or 85% on a 100% scale.

Determining the Coefficient of Friction Investigation

Determining the Coefficient of Friction Investigation Data

Table 10 displays the descriptive statistics for the differences between the pretest, posttest, and written laboratory report scores collected for the determining the coefficient of friction investigation. The data is separated by group and the comparison between groups is presented in the frequency distributions of figure 7 and figure 8. The complete data set for
the determining the coefficient of friction investigation is located in Appendix O. The determining the coefficient of friction investigation was conducted inside the physical laboratory by the learners in group one while the learners in group two performed the same experiment outside of the physical laboratory.

Table 10

*Descriptive Statistics for Determining the Coefficient of Friction Investigation*

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Differences PreTest vs. PostTest</th>
<th>Laboratory Report Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group One (Face-to-Face)</td>
<td>Group Two (Online)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Mean</td>
<td>4.79</td>
<td>6.91</td>
</tr>
<tr>
<td>Median</td>
<td>5.00</td>
<td>7.50</td>
</tr>
<tr>
<td>Mode</td>
<td>5.00</td>
<td>5.50</td>
</tr>
<tr>
<td>Minimum</td>
<td>-2.00</td>
<td>-5.00</td>
</tr>
<tr>
<td>Maximum</td>
<td>13.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Range</td>
<td>15.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3.98</td>
<td>4.15</td>
</tr>
<tr>
<td>Variance</td>
<td>15.80</td>
<td>17.23</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.20</td>
<td>-0.86</td>
</tr>
</tbody>
</table>
Figure 7. Frequency Distribution PreTest versus PostTest Differences for the Determining the Coefficient of Friction Investigation

Figure 8. Frequency Distribution Laboratory Report Scores for the Determining the Coefficient of Friction Investigation
Determining the Coefficient of Friction Investigation Statistical Analysis

Table 11 contains results for the $t$-test comparison of means between groups one and two for the pretest versus posttest difference and the laboratory report scores for the determining the coefficient of friction investigation. The direction of the differences for the descriptive statistics and the $t$-test is group one as variable two and group two as variable one.

Table 11

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Group One (Face-to-Face)</th>
<th>Group Two (Online)</th>
<th>Group One (Face-to-Face)</th>
<th>Group Two (Online)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of observations</td>
<td>36</td>
<td>35</td>
<td>36</td>
<td>35</td>
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<tr>
<td>Mean</td>
<td>4.79</td>
<td>6.91</td>
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<td>17.21</td>
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<tr>
<td>Degrees of freedom</td>
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<tr>
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<tr>
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<td>$^\pm$1.99</td>
<td></td>
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<tr>
<td>$t$-test decision</td>
<td>reject the null hypothesis</td>
<td>fail to reject the null hypothesis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Based on the $t$-test comparing the mean pretest and posttest differences between groups one and two for the determining the coefficient of friction investigation the null hypothesis is rejected as the $t$-statistic or $t$-value is greater than $t$-critical. The alternative hypothesis that there is a difference between the mean pretest and posttest differences of groups one and two for the determining the coefficient of friction investigation is not rejected. The direction of this difference indicates a greater improvement between pretest and posttest scores for the online delivery of this physics experiment. There is a five percent probability of rejecting a true null hypothesis.

Based on the $t$-test comparing the mean laboratory report score between groups one and two for the determining the coefficient of friction investigation the null hypothesis is not rejected as the $t$-statistic or $t$-value is less than $t$-critical. This result asserts there is statistically no difference in the mean laboratory report scores of groups one and two for the determining the coefficient of friction investigation.

No difference in the laboratory report scores signifies learner performance did not depend on where the determining the coefficient of friction investigation was performed. Learners can perform this laboratory investigation outside of the physical laboratory and inside the physical laboratory with equal proficiency. The mean laboratory report score for learners in both groups was approximately 17 points out of a possible 20 points or 85 % on a 100 % scale.

Research Question 2

What reactions will learners express regarding their experiences as measured by a questionnaire with the online physics laboratory designed using the learner-centered
approach to instruction and completed by the learner in their home as compared with a physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in a physical laboratory? Results from the seven questions on the questionnaire were categorized as either affirming the online laboratory format, signifying no difference between the online and face-to-face laboratory formats, or affirming the face-to-face laboratory format. The cumulative responses in each category will be utilized to test research hypothesis 2.

Research Hypothesis 2

It is hypothesized the convenience and flexibility offered by the physics experiments performed outside of the physical laboratory will result in a majority of learners indicating a positive reaction to these experiments. Learners are expected to express satisfaction with their learning experiences outside of the physical laboratory because the independence offered by performing physics experiments outside of the physical laboratory will increase their level of confidence in their ability to understand physics.

Learner Reaction Data

After completion of the online and face-to-face laboratories the 71 participants in this study completed the learner reaction questionnaire. The questionnaire consisted of seven questions requiring essay-type responses. Learner responses to each question were categorized as either affirming the online laboratory format, signifying no difference between the online and face-to-face laboratory formats, or affirming the face-to-face laboratory format. Findings from the questionnaire are discussed by question and representative learner comments are presented. Learner responses are presented in no particular order and exactly
as they were submitted by learners without spelling, grammar, or punctuation corrections. An
editorial change was employed if learners used proper names a generic term was inserted
enclosed by parentheses. The complete set of responses provided on the learner reaction
questionnaire are available in Appendix P.

*Responses to Question 1 of the Learner Reaction Questionnaire*

In question 1 learners were asked to describe whether or not they were provided with
adequate instructions and the necessary materials to independently perform the experiments
done outside of the laboratory. Learner responses affirmed the online laboratory format with
96 % indicating the instructions where sufficient and 94 % indicating the materials where
adequate to independently perform the experiments outside of the laboratory. The following
learner responses are representative of question 1 responses.

1. The materials provided to accomplish the experiments outside of class were
   sufficient. Most of the materials were items that could be found in any
   household, and thus needed little explaining. The instructions were more than
   sufficient and easily understandable.

2. Yes, I had adequate material and instructions. There were pictures (which helped
   a lot), and I felt pretty much comfortable with it.

3. I believe we were supplied with both the materials and the information to
   complete these experiments, however the fact that the teacher wasn't there gave
   way to more of an open approach to doing the labs and perceiving the
   informations.

4. I was given the right materials and was given in detail instructions on how to do
   all the experiments.

5. I was provided with adequate instructions and the necessary material to complete
   the labs outside of class without any trouble.

6. The lab packets provided were more than adequate. All of the procedures were
   clearly spelled out and the materials were provided.
As indicated by the learners in this study when provided with appropriate instructions and materials they were capable of independently performing physics experiments outside of the physical laboratory. For this study learners were supplied with materials purchased from local retail stores and similar materials would be readily available to learners enrolled in an online physics laboratory.

*Responses to Question 2 of the Learner Reaction Questionnaire*

In question 2 learners were asked to compare the amount of time spent on the experiments conducted outside and inside of the laboratory. The majority of learners (56 %) indicated the amount of time spent conducting experiments in both settings was equivalent with 33 % replying they spent more time on experiments outside of the laboratory and 11 % replying they spent less time on experiments outside of the laboratory. The learner comments which follow are reflective of each category of response.

1. I probably spent the same amount of time on the experiments outside of the lab as I did in the lab, but I was glad to be able to perform the experiments when it was convenient to me.

2. With the experiments outside of the laboratory you can just read at your own pace, and go however fast you want. In the lab however you have to go as fast as everyone in your group so you might not get all the information that you could if you went slower.

3. The experiments I completed on my own were completed quicker than the ones in the lab due to the fact that in lab, I had to work with several other people and we had to wait on each other. I would rather work at my own pace on my own.

4. I spent more time on the experiments out of lab that in the laboratory. This was mainly because my lab partners were rushing to finish the lab early during the in-lab experiments. That detracted from my reading and understanding of the material provided.

5. I spent less time out of lab. I work well on my own pace.
6. I think I used the same amount of time in and out of the lab. I wanted to fully understand what I was doing whether or not I was in the lab or at home.

7. I would say they were about the same. I think it seemed to take a little longer in the lab because I was distracted by those I was doing it with. When they are more opinions it seems to take longer than when you do it on your own. But I did not find a great difference.

Experiments conducted outside and inside of the laboratory requiring equivalent time to complete is categorized as a no difference response which supports neither the online physics laboratories nor the face-to-face physics laboratories. However learner comments seem to indicate the ability to work at a comfortable pace and convenient time was a beneficial aspect of the online physics laboratories.

Responses to Question 3 of the Learner Reaction Questionnaire

Question 3 asked learners to indicate whether face-to-face interaction with the instructor was important to their successful completion of any of the experiments. Sixty-four percent of learners indicated that face-to-face interaction with the instructor was not a factor in their successful completion of any of the experiments, 11% indicated they had no interaction with the instructor, and 25% indicated face-to-face interaction was important.

The comments which follow are representative of the learner responses to question 3.

1. No, face-to-face was nice in case we had an issue, but it was not necessary at all. I found the labs packet to have all that I needed for lab.

2. My interaction with the instructor was of course greater in the laboratory, but I did better and was more complete on my labs done outside the laboratory, at a time of my choosing.

3. It was important and I am glad that we had an instructor there for the experiments done in the lab. It is surely good to be able to ask questions if need be.

4. Face-to-face interaction with the professor was not necessary to complete any of the experiments. The fact that the professor was available in person to answer questions on the last two labs certainly allowed us to work through certain hang-ups
in them much quicker, but I don't think the professor would have been crucial to finishing any of the 4 labs.

5. I think so. I feel like it's important to have the instructor present to be able to help with any questions. However, the instructor did supply home phone number in case there was a question, was I guess is good for people that are good on the phone.

6. I really had no interaction with the instructor. Interaction was not important in any of the experiments.

7. I had a few questions on some of the experiments that made it convenient to be in the lab, but not any questions that I could have probably found out from another student or figured out myself if I looked at the problem long enough.

While interaction with the instructor is an important contributor to learner success in the majority of learning environments a face-to-face interaction may not be required. Many learner responses affirmed the online physics laboratory format and several referenced the availability of instructor interaction using the alternative means of email or telephone. The ability to receive immediate feedback was included as an important consideration in learner comments affirming face-to-face interaction.

Responses to Question 4 of the Learner Reaction Questionnaire

Question 4 examined the learner to learner interaction during the online and face-to-face physics experiments. The interaction with other learners and the importance of that interaction was evaluated. The majority of learners (59 %) provided a response that affirmed they interacted with other learners outside of the physics laboratory and this interaction was important to their learning. The remaining learners (41 %) did not interact with other learners outside of the physics laboratory and did not feel interaction with other learners was important to their learning. The following learner responses represent both of these viewpoints on question 4.
1. I was able to meet with and work with other members outside of class, in a setting that was a little more informal. I feel that this interaction is important; the feedback I received from my peers and the collective analysis work helped immensely.

2. I worked with one other person outside the laboratory. Interaction with other learners is important because you can learn from the other person and you can save time by completing two things at one time.

3. In the out-of-lab experiments, I did not interact with any other learner. In this lab, being with other learners detracted from my learning because they were rushing to finish and leave.

4. I did both the experiments outside of lab completely on my own. I don't think that interaction with the other students is necessary, although for some it may be helpful. I think physics lab is more about understanding the relation of physics to the world than it is to students. If extra help is needed understanding something, then of course, I would ask someone else.

5. The major thing that the "outside of class" labs have going for them is the fact that we can work with floormates and friends not in our lab section. I had a major interaction with other students outside of class, and I feel that it is very important to have people to bounce ideas off of, and to work things out so they can correct mistakes you make and vice versa.

6. It is important if you don't understand the material and you don't really want to ask the instructor, but other than that you really don't need the interaction.

7. On the outside labs, I worked only with one other person and that was only because we thought we could save time by working together instead of finding outside hands to help with some of the tasks.

Interaction with learners outside of the laboratory seemed to provide the opportunity for learners to exchange ideas and improve their understanding. Some learner interaction with other learners outside of the laboratory was perceived as a time saver. Other learners benefited from interaction outside of the laboratory with learners not in their class. These interactions drew upon an expertise not available to learners inside the laboratory. Learners who did not interact cited potential distractions from other learners and a preference for
working at their own pace. The overall response to this question seems to affirm the face-to-face laboratory format.

Responses to Question 5 of the Learner Reaction Questionnaire

For question 5 learners indicated which laboratory format they preferred selecting either experiments performed outside of the laboratory or experiments performed inside the laboratory. Fifty-two percent of the responses affirmed a preference for the online physics experiments, 38% preferred face-to-face physics experiments, and 10% indicated an equal preference for either format or a preference for a combination of formats. The comments which follow are reflective of the learners’ preferences.

1. I prefer labs done inside the lab. I have this opinion b/c I was able to complete the labs with equal understanding for both formats, yet the experiments done in lab were done much quicker. They were done quicker b/c of access to a teacher and an increase number of students to draw insights from.

2. I liked the outside of lab experiments because I could choose the time, instead of having to follow the school schedule and plan around that. I was able to do it in a less formal setting where I was more comfortable to voice my opinions and ideas. I feel like the group I was with shared more information about their understanding of the experiment then they would have if we had been in lab.

3. I prefered the out-of-lab experience 1) because my in-lab partners were not interested in learning from the lab and 2) because my presence in the lab did not afford me any extra benefit, largely because the lab was the exact same format as the out-of-lab experiments.

4. I preferred experiments inside of the laboratory. Having a set time to get them done helps to stave off procrastination and late nights. Also, I enjoy the interaction with the other students as well as the teacher. I think more care may be taken in a lab setting just because it is a lab setting.

5. I prefer the experiments performed outside of the laboratory. I was able to take my time with the experiment and perform them at my own will. Inside the classroom, my group rushes to get done.

6. I perfered the outside labs, because it allowed me to work on them at times that were convienent to me and not at a set time. Meaning that i did my labs in the late
evenings during my down time instead during the middle of the day when i have other classes on my mind.

7. outside! It felt much less restricted, and I could take as much time as I wanted and get good results.

8. I think a mix is nice. You have the convenience of working at your own pace and working in groups

Learner responses affirming the online physics laboratory format cited convenience of time and place, the ability to work at their own pace, or freedom from distractions as justifications for their selection. Learner responses affirming the face-to-face physics laboratory format referred to the importance of learner-instructor interaction, the importance of learner-to-learner interaction, or a tendency to procrastinate as explanations for their preference.

*Responses to Question 6 of the Learner Reaction Questionnaire*

For question 6 learners expressed their level of satisfaction with learning from the laboratory experiments performed outside of the laboratory compared to the experiments performed inside the laboratory. The majority of learner responses (59 %) indicated an equal level of satisfaction with both laboratory formats. These responses indicate there was no difference in the level of satisfaction with learning outcomes between the online physics laboratory and the face-to-face laboratory.

Responses indicating a greater level of satisfaction with either the online physics laboratory format or the face-to-face physics laboratory format were approximately equal at 17 % and 15 % respectively. The remainder of learners either did not specify a level of satisfaction or did not specify a format. The following comments are representative of those provided by learners regarding their level of satisfaction.
1. Well I enjoyed them both but, again, the outside of lab projects were more suitable because of time and scheduling issues. I am happy to have the chance to do the outside lab project experiments.

2. I feel that I learned the same in class as out of class. The lab basically reinforced and proved what was learned in class.

3. I am enjoyed performing the labs outside of class and am satisfied with it and prefer it over the in class labs.

4. I was more satisfied with the experiments done in the lab. I was able to really bounce ideas off the other students, which helped me to learn.

5. I honestly think that both were about equal with the inclass being a little bit more distracting with all of the people talking and trying to get their experiments done.

6. I feel like I learned the same from the labs outside of lab as well as the ones performed in lab. I think that the instructions were good enough that it didn't make a difference in where I was when I did the lab.

7. My satisfaction of learning was the same for both the experiments done both inside and out of lab. By just doing each experiment I was able to see what happens.

8. I was actually proud of myself that I accomplished and understood a physics experiment without having to lean on my instructor for help.

Expressing an equal level of satisfaction with learning for the online physics laboratory and the face-to-face laboratory indicates there was no difference in level of satisfaction between formats. Individual learner comments highlighted the independence afforded with the online laboratories and the interaction which occurs in the face-to-face laboratory. The structuring and descriptive nature of the laboratory instructions where cited as factors which contributed to learning in both environments.

*Responses to Question 7 of the Learner Reaction Questionnaire*
Question 7 provided learners an opportunity to make additional comments or suggestions as well as share any experience not previously expressed. The majority of learners (58%) provided no response or indicated they had no additional comments. From the remaining responses two ideas were expressed by multiple learners. First, 17% of learners indicated they thought the research was a positive step forward and online physics laboratories should be made available to learners. Second, ten percent of learners affirmed their positive experiences with the online physics laboratory format. The following representative responses were chosen from those learners who made comments.

1. I think a combination of both formats is the way to go. Doing experiments outside of lab takes a little bit longer, but it is enjoyable and can be done at the students pace. Ultimately, both formats teach the lessons well.

2. I think that doing the experiment outside of class is a good idea. I enjoyed not having the stress of attending another class while still learning. The experiments were good and demonstrated their ideas and concepts.

3. I think it would be a good idea to complete as many labs outside of the lab as possible in the future. I think that I learned just as much outside of the lab, and the convenience of being able to perform the experiment when I wished was an added bonus.

4. I think it could be really cool to do physics online. I would have taken that option last summer, if offered.

5. I think it is good to offer the labs as take home labs. I can tell that they aren't for everyone. I don't think that you will be able to get rid of the in lab option though.

The content in the majority of comments provided by learners would be considered affirming to the online physics laboratory format. The learner’s experiences were generally positive such as learners enjoying being part of the research and providing comments supportive of offering online physics laboratories.

Analysis of Learner Reaction
The cumulative responses from the questionnaire which affirmed the online laboratory format, signified no difference between the online and face-to-face laboratory formats, and affirmed the face-to-face laboratory format are displayed in the graphic of figure 9. Figure 9 shows significantly more learner responses affirming the online physics laboratory format.

**Figure 9. Analysis of Responses from the Learner Reaction Questionnaire**

In affirming the online laboratory format learners indicated the instructions for the experiments were descriptive and easy to use, the required materials were provided in the kit, and learner to instructor interaction through email or telephone was appropriate. Preference for the online laboratory format was chosen by a majority of learners because it offered them the opportunity to work at more convenient times and at their own pace therefore the
hypothesis which states the convenience and flexibility offered by the physics experiments performed outside of the physical laboratory would result in a majority of learners indicating a positive reaction to these experiments is not rejected. Learner responses on the learner reaction questionnaire affirmed a preference for the online physics laboratory format as responses to multiple questions cited the convenience, flexibility, and the ability to work at their own pace as justifications for a positive reaction to the online physics laboratories.

The only area where learner responses tended toward the face-to-face format was learner to learner interaction. Sharing ideas with and getting different perspectives on physics concepts from other learners was important for a majority of learners. Some learners thought interaction with other learners reduced the amount of time required to complete the experiments even though the majority of learners reported both the online and face-to-face laboratory formats required the same time commitment.

The majority of responses to the question which specifically addressed learner satisfaction found learners had an equal level of satisfaction with learning in the online physics laboratory and the face-to-face laboratory. The majority of responses to this question indicate there was no difference in level of satisfaction between formats. Independence was cited by some learners as justification for their satisfaction with the online laboratories and the explanatory nature of the laboratory instructions was cited as an important contributor in both learning environments.

At the end of each experiment optional explorations into the physics concepts introduced by the investigation were available to the learners. These explorations challenged learners to assess their physics understanding and expand their physics knowledge. Learners
received no additional credit for attempting or completing these explorations but were asked to summarize their experiences with these optional activities. Optional explorations were attempted by two learners performing physics experiments inside the physical laboratory and 32 learners completing physics experiments outside of the physical laboratory. The removal of time constraints and pressure from peers inside the physical laboratory prompted significantly more learners to attempt additional explorations into physics concepts while outside of the physical laboratory.
CHAPTER 5. RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Discussion of Results

Purpose of the Research Study

This research investigated the effectiveness of a series of physics laboratory experiments designed for incorporation into an online college physics course which would satisfy the laboratory requirement of the course. The experiments employed a hands-on approach and were performed by physics learners outside and inside of the physical laboratory using learner-centered instructions and equipment which would be available to physics learners from local retail stores.

The physics experiments performed outside of the physical laboratory simulated an online physics laboratory experience while the physics experiments performed inside the physical laboratory employed a traditional face-to-face instructional approach. The effectiveness of both instructional approaches was measured with pretests, posttests, and written laboratory reports. The results from these assessments were used to determine whether there was a difference in learning outcomes between the learners who worked independently on physics experiments outside of the physical laboratory and learners who performed the same physics experiments inside the physical laboratory.

Learner reaction to both types of laboratory experiences was obtained using a questionnaire. Learner feedback was used to determine learner preferences and level of satisfaction with the learning experiences outside and inside of the physical laboratory. These reactions and the level of satisfaction were clearly articulated using the learner’s own words. For analysis learner responses were categorized as either affirming the online laboratory
format, signifying no difference between the online and face-to-face laboratory formats, or affirming the face-to-face laboratory format.

*Significance of the Research*

Learner-centered self-directed educational opportunities with flexibility for the learner and cost-effectiveness for the institution are promoting the growth of online learning. The undergraduate physics course’s transition to the online environment is lagging behind because there is minimal evidence showing an online laboratory’s effectiveness in producing learning outcomes and positive learner reactions.

The review of research in this area indicated an investigation into this approach to online laboratory delivery had not been performed with physics learners. There was a gap in the knowledge with regard to this type of physics instruction as well as learner evaluations of such a laboratory approach. This research study proposed to fill that gap with an investigation comparing learning outcomes and learner reactions to physics laboratory experiments conducted using both the traditional and online delivery.

This research determined the efficacy of delivering physics laboratory instruction outside of the physical laboratory using pretests, posttests, and written laboratory reports to measure learning outcomes and a questionnaire to evaluate learner reactions. The results from this research study can be utilized to design additional experiments for learners to perform independently outside of the physical laboratory. The objective is to design an entire sequence of experiments that can be performed independently by online learners outside of the laboratory satisfying the laboratory requirement for the two semester college physics course.
Summary of Literature Review

This research proposed an integration of theory and application for a specific instructional situation by investigating the efficacy of a learner-centered theoretical framework incorporated into the instructional design of undergraduate physics experiments for online delivery. Literature reviewed in preparation for this study reflected the learner-centered theoretical framework and its application in online learning, application of behaviorism to physics instruction, instruction in the psychomotor domain, examination of studies comparing online instruction to face-to-face instruction, investigation into existing methods of delivering undergraduate science laboratories online, and possible future trends in online learning.

Learner-centered theory and application.

McCombs and Vakili (2005) indicated the learner-centered online environment must meet the learner’s need for interpersonal relationships; acknowledge individual differences; recognize the diversity of learner needs, abilities, and interests; utilize different learning strategies; and assess the efficacy of technology to meet the needs of a diverse learning community. This research study into online physics laboratories attempted to develop effective online learner-centered instruction as exemplified by this framework.

Cox (2005) found the approach taken for the development of online courses at community colleges was not dramatically different from face-to-face courses. The lecture driven format of college courses was typically transported to the Internet without considering the instructional differences in an online environment. This method of producing online learning is unlikely to improve without changing the thinking in the present environment.
The impetus for a change might be research that instead of indicating online courses are equivalent to face-to-face courses demonstrates a design which makes online instruction superior.

*Application of behaviorism to physics instruction.*

Behaviorism places emphasis on visible, perceptible, and quantifiable behaviors performed in response to environmental stimuli and the administering of negative or positive reinforcement. In a learning environment detectable change in the frequency of an observed behavior or a reduction in the time between the stimulus and response indicates learning is occurring (Gredler, 2004). The learning environment usually controlled by the instructor is the basis for developing and strengthening the learned relationship between instructional prompt and correct learner response (Gredler, 2004).

In an online environment learners must receive objectives, expectations, stimuli, and reinforcement without the assistance of a face to face instructor. The instructional designer must develop a virtual behaviorist environment which employs individualized instruction with the drill and practice process of repetition and feedback to generate the desired responses.

The virtual classroom allows learners to work at their own pace to understand the requirements of the learning objectives and examine new material. The foundational nature of the physics course requires certain knowledge be consistently repeated in subsequent courses. To build the learner’s ability to respond correctly drill and practice with immediate and reinforcing feedback must be available. These practice activities should increase in
difficulty and complexity for completion on the learner’s schedule and be repeatable until the learner achieves proficiency.

*Instruction in the psychomotor domain.*

The psychomotor domain describes a hierarchy for learning physical behaviors primarily through practice and repetition. The level of a learner’s motor skill development is important in the physics laboratory as learners are required to perform specific physical movements when collecting data. The learner’s ability to make physical measurements affects the accuracy of the data and the reliability of the results.

The method proposed by Romiszowski (1999) for the development of physical skills is intended for application in all psychomotor learning situations. According to Romiszowski’s (1999) theory, there are three phases in the development of psychomotor skills. First, the learner acquires knowledge of the purpose, sequence, and means for performing the activity through demonstration. Next, the learner develops basic skills through controlled practice of each step or sequence of steps. Finally, through repetition the learner becomes proficient and is able to automatically perform the required physical movements.

It is anticipated college physics learners are equipped with certain laboratory skills such as the ability to make measurements and construct graphs. Physics laboratory experiments initially utilize these basic activities as the foundation for developing more complex movements required in subsequent experiments. Whether the physics laboratory is online or face-to-face, corrective and encouraging feedback from the instructor is vital to the development of the required psychomotor skills. The physics laboratories designed to be
performed by learners in their homes applied Romiszowski’s (1999) instructional methods for the development of physical skills.

*Comparing online instruction to face-to-face instruction.*

Ouellette (2000) presented a research study examining the characteristics and behaviors of learners in the same technology management course delivered face-to-face and online at the University of Maryland University College. Learners indicated a higher level of satisfaction with and preference for the activities presented in the face-to-face course (Ouellette, 2000). It was noted the elements and materials of the face-to-face course were transferred to the online environment therefore a learner-centered instructional design was not applied to the online course.

Zhao et al. (2005) conducted a study which analyzed a significant body of research to highlight the factors that determine the effectiveness of distance education programs. There were variations in the effectiveness of distance education programs; however it appears that factors impacting the effectiveness of distance education would have a similar affect if applied to traditional programs (Zhao et al., 2005).

Interaction appears to be an important contributor to effective learning outcomes for online courses. Farahani (2003) researched the importance of online interaction from the learner and instructor perspective in online courses at Mid-Atlantic Community College. Learner to instructor, learner to learner, and learner to content interactions were reported to be available at a high level by the learners. Communication with the instructor through email was most prominent and along with feedback on assignments was considered very important
to the learners. Interaction with other learners, group projects, and interaction with content were perceived by learners to be less important (Farahani, 2003).

The instructors rated direct interaction with learners through email or for feedback as less significant in the online teaching experience (Farahani, 2003). Online instructors in this study appeared not to value the majority of the interactivity criteria listed in the survey. Farahani (2003) indicated instructors in this sample may not have been familiar with online instruction practices and consequently did not utilize them in these courses.

Farahani’s (2003) study provides evidence that online interactions might be affected by the perceptions of the instructor, therefore the design of the Koory (2003) study controlled both the instructor and the course content while examining the same course offered online and face-to-face. This was accomplished using an extended experimental comparison of learning outcomes in both courses and the investigation of effective course design and teaching practices (Koory, 2003).

Koory’s (2003) results showed consistently better learning outcomes in the online course compared to the on-campus versions indicated by grade comparisons and learner satisfaction. The satisfaction indicated 100% of online learners would recommend the online version of the course to others.

Literature on online laboratories.

Dowd et al. (2005) reports the results of an investigation into learner perceptions of web based course components with lab activities in the instructional modules. The online lab activities allowed learners to investigate phenomena and learn about the techniques and challenges of scientific inquiry (Dowd et al., 2005). Learners considered the site an
enhancement to their learning, a valuable addition to their learning, and a good addition to the course (Dowd et al., 2005).

Reeves and Kimbrough (2004) sought to remove a barrier to online learning in science courses at the University of North Carolina at Wilmington by making a laboratory science course accessible to distance learners. Reeves and Kimbrough (2004) describe an undergraduate chemistry course for science and non-science majors featuring laboratory experiments conducted by learners in their homes using materials typically available from local stores.

Based on the distribution of final course grades the learners in the distance learning laboratory outperformed their traditional counterparts indicating the well-organized calendar, links to lessons, assignments, laboratory quizzes, and accessibility of the course instructor as contributors to their success (Reeves & Kimbrough, 2004). Reeves and Kimbrough (2004) concluded the distance laboratory experiments were suitable replacements for the traditional laboratory. This study demonstrates undergraduate chemistry laboratory experiments can be performed successfully by learners in their homes with positive results.

Sethi and Antcliffe (2002) describe a set of physics experiments developed at Devry University in Pomona, California which utilize selected Java and Shockwave Applets accessible over the Internet. The project supports a learner-centered approach to education and opens up the possibility for science based courses to be offered online.

This method presents experiments through a visually-based interface which uses graphical representations of physics experiments. Rather than manipulating equipment the learners see and understand the physics principles as the effect of changing one parameter is
reflected in the other parameters (Sethi & Antcliffê, 2002). Learners tested a prototype and a majority of learners provided substantially positive responses (Sethi & Antcliffê, 2002).

Meisner and Hoffman (2001) tested their design for a standalone distance learning course for introductory physics which incorporates open exploration and guided investigations called Learn Anywhere Anytime Physics (LAAPhysics). The LAAPhysics experiments are interactive simulations where students are allowed to manipulate variables, make decisions independently, make mistakes, and determine measurement errors simulating real experiments (Meisner & Hoffman, 2001).

Learners indicated they would choose LAAPhysics over a traditional laboratory course and they were stimulated by the opportunity to work independently (Meisner & Hoffman, 2001). Meisner and Hoffman (2001) indicated testing continues as more learners utilize LAAPhysics for their undergraduate physics laboratory course.

Alhalabi et al. (2004) presents remote laboratories as an alternative to simulations for online physics laboratories. The remote laboratory concept is still under development for electrical engineering and physics. The remote laboratory is a real physical laboratory accessed through an interface using the Internet (Alhalabi et al., 2004). According to Alhalabi et al. (2004), the remote laboratory provides learners with real responses to inputs from physical elements and stimulation of higher order thinking skills by involving the learner’s individual senses with the element of reality. Prototypes of a few experiments have been produced and as of this report no testing of the learning outcomes or learner reactions had been completed.
Faltin et al. (2002) presents a remote laboratory concept providing access to real laboratories with the additional distributed learning support of a tutorial assistant. The Internet assisted Laboratories (I-Labs) is a collaborative effort between the Stanford Center for Innovations in Learning in California and the Learning Lab Lower Saxony in Germany (Faltin et al., 2002).

There is a potential with I-Labs for a network of participating educational institutions sharing remote laboratories or commercial laboratories providing learners with the opportunity to access multiple facilities (Faltin et al., 2002). This technology and networking is under development as well as plans for testing of learning outcomes and learner reactions.

Adams (2003) describes the introductory physics course taught online through the Kentucky Virtual University in Paducah, Kentucky. This course includes lecture and laboratory components completed entirely online. Equipment for the online laboratory experiments was not supplied, rather inexpensive and readily available materials in the learners’ homes or from local stores were utilized (Adams, 2003). Laboratory reports were written for each experiment and submitted through the course room.

Learner success as measured by grade was comparable to the face-to-face counterpart of the course (Adams, 2003). Course evaluations were not conducted for the separate components with lecture and laboratory evaluated together and the majority of learners rated the course materials appropriate and the overall course as excellent (Adams, 2003).

Future trends in online learning.

The future of distance education was postulated by Natriello (2005) with an exploration of the past developments in distance learning, characteristics of current distance
learning programs, and future implications for educational researchers. Natriello (2005) identifies four fundamental changes affecting education which are currently or likely to occur (a) the shift of traditional and established packaging of education, (b) the changing role of faculty, (c) increased capital being made available to invest directly in the technology of education, and (d) a major re-mapping of the education sector as new participants become substantial players in a global educational market (p.1892).

Natriello (2005) suggests learners in the distance learning marketplace will insist on more accountability in a global market of educational services. Educational organizations and institutions will be required to be responsive to the needs of learners in order to remain competitive. This research study proposed a method of delivering online physics laboratories which would be responsive to the needs of learners.

Research Methodology

Data collected for this study consisted of background information, changes in the understanding of physics concepts, and learner reactions. The quantitative methodology was best suited for the analysis of changes in the understanding of physics concepts, however it did not allow for the full exploration of learner reactions. Therefore this study employed a mixed quantitative and qualitative methodological approach for data analysis.

Attributes of the evaluation methodology were incorporated into the research instruments used to evaluate the design of the online physics laboratories and an evaluation methodology was utilized to determine learning outcomes for both types of physics laboratories. The mixed quantitative and qualitative methodological approach complemented the evaluation design of this research study.
Research design.

This research study examined the learning outcomes achieved by two groups of physics learners who performed two hands-on experiments outside of a physical laboratory simulating an online format and two hands-on experiments in a physical laboratory utilizing the traditional or face-to-face format. The learning outcomes were measured by pretest, posttest, and written laboratory report scores. These quantitative measurements were used as the means of comparison between the two groups of learners who conducted the same physics experiments using the different delivery formats.

Data from each experiment was compared between the two groups using descriptive statistics for the differences between the pretest, posttest, and written laboratory report scores. Frequency distributions were employed as a means of making visual comparisons between the groups conducting each experiment. The hypotheses regarding learning outcomes were tested statistically by means of the t-test.

Learner reaction to both types of experiments was measured using a questionnaire. The learner reactions were categorized as either affirming the online laboratory format, signifying no difference between the online and face-to-face laboratory formats, or affirming the face-to-face laboratory format. Representative learner responses were presented to clearly articulate the learner’s meaning using their own words.

Description of sample.

The sample for this study consisted of 71 learners enrolled in a college physics course. The participants in this study completed both the face-to-face and online physics laboratories along with the accompanying assessments and the learner reaction questionnaire.
This is a self-selected sample which places constraints on the generalization of the results. The findings from this research should be generalized only to comparable sets of physics learners enrolled in a comparable physics course. The learner characteristics of a comparable set of physics learners should have a high degree of positive correlation with the characteristics of the learners in this research sample and the characteristics of a comparable physics course should have a high degree of positive correlation with the characteristics of the physics course utilized for this research otherwise the likelihood of comparable results is decreased.

Description of instruments, variables, and measurements.

The instruments utilized to measure learning outcomes for the online physics laboratory consisted of similarly constructed pretests, posttests, and written laboratory reports. The pretests and posttests were evaluated using an interval scale from zero to 15 points. The written laboratory reports were evaluated with an interval scale from zero to 20 points.

Grading rubrics were employed to ensure consistent scoring of pretests, posttests, and written laboratory reports. The evaluator of the pretests, posttests, and written laboratory reports was unaware of where the learner completing these assessments performed the experiment.

Summary of research procedures.

This research investigated the effectiveness of a series of physics laboratory experiments designed for incorporation into an online college physics course which would satisfy the laboratory requirement of the course. Learners who consented to participate in the
study voluntarily provided background information consisting of gender, grade, academic major, prior physics courses, and prior online learning experience using an anonymous paper and pencil survey.

In the first phase of data collection learners were assigned randomly generated numbers which were used to create two groups identified as group one and group two. The learners in group one conducted two physics experiments outside of the physical laboratory and the learners in group two conducted the same two physics experiments inside the physical laboratory.

During the next phase of data collection the learners in group one conducted another two physics experiments inside the physical laboratory and the learners in group two conducted the same two physics experiments outside of the physical laboratory. In the final phase of data collection the learners completed the learner reaction questionnaire.

**Summary of Findings for Research Question and Hypotheses 1**

Research question 1 asked how effectively will learning outcomes as measured by a pretest, written laboratory report, and posttest be realized for an online physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in their home as compared with a physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in a physical laboratory? The null hypothesis for research question 1 states there will be no difference between the pretest and posttest scores and the written laboratory report scores for the online physics laboratory experiments completed by learners in their homes as compared with the physics laboratory experiments completed by learners in a physical
laboratory. The alternative hypothesis for research question 1 states there will be a difference between the pretest and posttest scores and the written laboratory report scores for the online physics laboratory experiments completed by learners in their homes as compared with the physics laboratory experiments completed by learners in a physical laboratory.

**Findings for Research Hypotheses 1**

Based on the $t$-test comparing the mean pretest and posttest differences between groups one and two for each of the four physics laboratory investigations the null hypothesis was rejected. The alternative hypothesis that there was a difference between the mean pretest and posttest differences of groups one and two for each of the four physics laboratory investigations was not rejected. The direction of this difference indicated a greater improvement between pretest and posttest scores for the online delivery of the four physics experiments. There is a five percent probability of rejecting a true null hypothesis.

Based on the $t$-test comparing the mean laboratory report score between groups one and two for each of the four physics laboratory investigations, the null hypothesis was not rejected. This result asserts there was statistically no difference in the mean laboratory report scores of groups one and two for each of the four physics laboratory investigations.

No difference in the laboratory report scores signifies learner performance did not depend on where the physics laboratory investigations were performed. Learners can perform these laboratory investigations outside of the physical laboratory and inside the physical laboratory with equal proficiency. The $t$-tests comparing the mean pretest and posttest
differences and the mean laboratory report score between groups one and two were both two-tail tests with a p-value of 0.05.

Summary of Findings for Research Question and Hypothesis 2

Research question 2 asked what reactions will learners express regarding their experiences as measured by a questionnaire with the online physics laboratory designed using the learner-centered approach to instruction and completed by the learner in their home as compared with a physics laboratory experiment designed using the learner-centered approach to instruction and completed by the learner in a physical laboratory? For research question 2 it was hypothesized the convenience and flexibility offered by the physics experiments performed outside of the physical laboratory would result in a majority of learners indicating a positive reaction to these experiments. Learners were expected to express satisfaction with their learning experiences outside of the physical laboratory because the independence offered by performing physics experiments outside of the physical laboratory would increase their level of confidence in their ability to understand physics.

Analysis of Learner Reaction

The cumulative responses from the learner reaction questionnaire were categorized as affirming the online laboratory format, signifying no difference between the online and face-to-face laboratory formats, or affirming the face-to-face laboratory format. The cumulative result of learner responses showed learners affirming the online physics laboratory format in six of the nine categories. Therefore the hypothesis which stated the convenience and flexibility offered by the physics experiments performed outside of the
physical laboratory would result in a majority of learners indicating a positive reaction to these experiments was not rejected.

The learner reaction questionnaire affirmed a preference for the online physics laboratory format as responses to multiple questions cited the convenience, flexibility, and the ability to work at their own pace as justifications for a positive reaction to the online physics laboratories. Responses to the question specifically addressing learner satisfaction found learners had an equal level of satisfaction with learning in the online physics laboratory and the face-to-face laboratory. The responses to this question indicated there was no difference in level of satisfaction between the formats. Independence was cited by some learners as justification for their satisfaction with the online laboratory; learner to learner interaction was cited by some learners as justification for their satisfaction with the face-to-face laboratory, and the explanatory nature of the laboratory instructions were cited as important contributors to learner satisfaction in both learning environments.

Conclusions

Online learning is growing in scope and acceptance across the academic curriculum along with an awareness of the quality of learning being delivered by these courses. Learner-centered self-directed educational opportunities with flexibility for the learner and cost-effectiveness for the institution have contributed to this growth in online learning. Quality instruction in an online environment is different from instruction in the traditional face-to-face classroom, meaning there is a requirement for online courses to be designed to meet the learner’s needs through the integration of best learning practices with technology. Online
courses designed from a learner-centered philosophy empower learners to become active participants in the achievement of academic and career goals.

When research is conducted to compare the learning outcomes of instruction delivered in the face-to-face environment with those achieved by learners in an online environment the online course must be designed for the presentation medium. The transfer of traditional classrooms to the Internet creates a disconnect between what is known about learning processes and actual online practices. The physics experiments performed by learners for this research study were designed for independent study and delivery using an online medium.

In the design of online courses consideration should be given to managing learner attention, reducing cognitive load, and providing multiple avenues for interaction. Learner to instructor, learner to learner, learner to content, and learner to interface interactions are important contributors to effective learning outcomes in online courses. When the design of the instruction in an online course is based on an online pedagogy the result is more effective learning outcomes and higher learner satisfaction as was evidenced in this study.

The online learning environment offers the promise that learner-centered instruction will be designed and implemented removing the learner from the traditions of face-to-face instruction and placing them in a virtual classroom where learning is self-directed and self-paced. However, the lack of online courses in science and particularly in physics limits learners desiring the flexibility and independence of learning opportunities offered online.
Learners seeking degrees which require an undergraduate physics course with a lecture and laboratory component cannot complete their degrees online because online physics courses are very limited.

Proposed online physics laboratories such as simulations and remote laboratories can offer interactive engagement based on a constructivist learning philosophy; however while each of these distance laboratory experiences has benefits, there are apparent inadequacies. Neither system provides learners with the opportunity to physically put their hands on equipment. The lack of online physics course offerings with both lecture and laboratory components may be due to the lack of research into effective design of an online course which provides hands-on laboratory experiences.

This research study attempted to fill that gap by investigating the effectiveness of a series of four hands-on physics laboratory experiments designed for incorporation into an online college physics course which would satisfy the laboratory requirement of the course. The effectiveness of four learner-centered online physics experiments designed to be performed by learners individually in their homes with equipment provided in a kit was evaluated.

This study found a greater improvement between pretest and posttest scores for the online delivery of the four physics experiments compared to the same four experiments conducted inside of the physical laboratory. When the learners conducted physics experiments outside of the physical laboratory, time constraints and pressure from peers was removed allowing for self-directed and self-paced investigations promoting learning. Optional explorations which challenged learners to assess their physics understanding and
expand their physics knowledge were attempted by significantly more learners performing physics experiments outside of the physical laboratory. The greater improvement in learning outcomes for the simulated online laboratory experiments may, in part, be attributed to learner inquiries beyond the required investigation.

The comparison of the mean laboratory report score between groups performing the four hands-on physics laboratory investigations inside and outside of the physical laboratory found there was statistically no difference in the mean laboratory report scores of the two groups. This no difference in the laboratory report scores signifies learner performance did not depend on where the physics laboratory investigations were performed.

Learners could perform these laboratory investigations outside of the physical laboratory and inside the physical laboratory with equal proficiency. This result may be due to the design of the four physics investigations. The four physics experiments utilized in this study were designed to be completed by learners independently outside of the physical laboratory. The no difference findings for laboratory report scores is an indication this design objective was achieved.

The results from this research study can be utilized to design additional experiments for learners to perform independently outside of the physical laboratory. The objective being the design of an entire sequence of experiments that could be performed independently by online learners outside of the laboratory satisfying the laboratory requirement for the two semester college physics course.

The undergraduate physics course’s transition to the online environment may also be lagging behind because there is minimal evidence showing an online laboratory’s
effectiveness in producing positive learner reactions. This research study examined learner reactions to the physics experiments designed to be performed by learners individually in their homes with equipment from a kit.

Learner reactions to the online physics laboratory format were predominately positive. When learners conducted experiments outside of the physical laboratory, time constraints and pressure from peers was removed allowing for self-directed and self-paced investigations which promoted learning.

The majority of learners in this study provided affirming responses to the online physics laboratory format by indicating the instructions in the physics investigations were descriptive and easy to use, the materials required to perform the investigations were appropriate and available in the kit, and face-to-face interaction with the instructor was not required as long as other options were available. The majority of learners preferred working at their own pace outside of the laboratory and enjoyed the convenience and flexibility offered by the at home experiments.

Learners expressed equal satisfaction with their learning experiences outside and inside of the physical laboratory. The majority of learners felt they experienced an equal level of learning in both laboratory settings. Their responses signify learner satisfaction did not depend on where the physics laboratory investigations were performed.

Learner satisfaction is critical in a competitive education marketplace. Learners will continue to demand quality learning experiences which address their needs and allow for the achievement of their academic and career goals. Learner-centered self-directed online opportunities offer educational institutions a cost-effective means of meeting this demand.
Online learning opportunities need to be available across the curriculum including physics and science courses. In the future educational institutions will be required to offer both the lecture and laboratory components of physics and science courses online in order to be responsive to learners.

The four online physics experiments evaluated in this study were found to be effective in achieving learning outcomes and proficient in design. The learners in this study embraced the online learning opportunity, expressed a preference for self-directed self-paced physics investigations, and significantly more online learners attempted additional explorations into physics concepts. The results of this research have shown the two dimensional motion investigation, the Newton’s Third Law investigation, the Newton’s Second Law investigation, and the determining the coefficient of friction investigation can be the initial contribution to the creation of an online physics laboratory course.

Recommendations

General Recommendations from the Research

Evaluation and revision of instruction are essential functions in the instructional design process. Based on the reaction of learners and their experiences with the physics experiments performed for this study, these revisions are recommended.

The statistical analysis showed a greater improvement between pretest and posttest scores for the online delivery of the four physics experiments. The optional explorations at the end of each experiment designed to challenge learners to assess their physics understanding and expand their physics knowledge were attempted by significantly more learners performing physics experiments outside of the physical laboratory. There may be a
relationship between the statistical findings and learners attempting additional explorations into the physics concepts. Therefore, it is recommended that some of the going further explorations provided with the physics experiments be required rather than remain optional.

Learners indicated in responses on the learner reaction questionnaire that the instructions for the experiments were descriptive and easy to use. The ability to understand and follow the experiment instructions was aided by the inclusion of photographs showing the investigation’s set-up. For visual learners these photographs are important for comprehending the experiment’s data collection process. The physics investigations utilized in this study could be improved with the addition of photographs or illustrations detailing the data collection process for the experiments and the going further investigations.

Learners indicated in responses on the learner reaction questionnaire the materials required to perform the investigations were provided in the kit. Learners participating in this study were enrolled in a traditional physics laboratory course which required the payment of a laboratory fee. In lieu of a laboratory fee, online physics learners would be required to purchase materials for their experiments from local retail stores. For online learners the equipment list must include detailed descriptions with photographs to ensure the items required to perform the investigations are obtained.

*Limitations of the Study*

There are limitations for this study arising from uncontrolled variables and the self-selected sample. The non-random selection procedure may have contributed to a sample non-representative of the physics learner population. The distribution of academic majors
for which college physics is a requirement may not have been represented in the sample
due to the number and type of programs offered at the host university.

There was moderate gender diversity in the prospective sample for this research
study. College physics courses are typically composed of significantly more males than
females. This study did not make an analysis of learning outcome differences with respect to
gender due to the lack of a statistically significant female sample.

The learner population at the host university has minimal racial and ethnic diversity.
This limitation in the sample means an analysis of learning outcome differences with respect
to race or ethnicity was not viable.

Learners with pre-existing self-regulatory learning skills and preference for self-
directed learning are more likely to succeed in the simulated online physics laboratory. This
research study did not analyze learning outcome differences between self-directed learners
and learners preferring classroom instruction. However as part of the learner reaction
questionnaire learners indicated whether face-to-face interaction with the instructor and other
learners was important to their successfully completing any of the experiments.

*Recommendation for Further Research*

This research study compared the learning outcomes and learner reactions to physics
experiments completed by learners in their homes to the same physics experiments
performed inside of a physical laboratory. These experiments were designed using the
learner-centered approach to instruction; and there is evidence in the research findings that
learning outcomes achieved by learners outside of the physical laboratory surpassed
equivalent face-to-face instruction. Evidence from learner reactions comparing both types of
laboratory formats indicated learner preference for the online laboratory format. Therefore
the anticipated outcomes of the research study have been achieved for this sample of
learners.

The composition of the sample and scope of the analysis are potential limitations for
the findings of this study. Accordingly, further research varying the sample and expanding
the analysis are recommended.

The theoretical population for this research study consists of college or university
learners taking an introductory physics course. The research sample consisted of learners at
LeTourneau University enrolled in the college physics course during the spring 2006
semester who completed both the learner-centered traditional and online physics laboratories
along with the accompanying assessments and evaluations. The demographics of this group
of learners can be generalized to the theoretical population; however the full range of
expected academic majors may not have been thoroughly represented in the sample. This is a
result of the number and type of programs offered at LeTourneau University. While the
academic majors represented in the sample are typical for LeTourneau University, this
distribution may not be common at the majority of colleges and universities. Therefore, it is
recommended this research study be conducted at another institution with varied academic
programs prior to generalizing the outcomes of this study to the theoretical population.

The sample utilized for this study lacked a statistically significant female sample as
the college physics learners were predominately male. An analysis of learning outcome
differences with respect to gender was not performed. It is recommended this study be
conducted where a statistically significant female sample is available to explore potential learning outcome differences which are a result of gender.

The sample utilized for this study lacked racial and ethnic diversity and an analysis of learning outcome differences with respect to race or ethnicity was not viable. It is recommended this study be conducted where a racially and ethnically diverse sample is available to explore potential learning outcome differences which are a result of race or ethnicity.

This research study did not analyze learning outcome differences between self-directed learners and learners preferring classroom instruction. However, as part of the learner reaction questionnaire learners indicated whether face-to-face interaction with the instructor and other learners was important to their successfully completing any of the experiments. The majority of learners affirmed a preference for the online physics laboratory format citing convenience, flexibility, and the ability to work at their own pace as justifications for their positive reaction to the online physics laboratories. Additional research could be conducted to study the learning outcomes of self-directed learners as compared to those who prefer face-to-face instruction.

The two-semester introductory college physics course typically requires ten to 12 experiments per semester to satisfy the laboratory requirement. It is recommended the additional experiments needed for the laboratory course be designed using the pattern presented in the experiments of this study. These additional experiments would need to be tested and evaluated by learners for effective learning outcomes and positive learner reaction through a research process similar to the design employed for this study.
REFERENCES


APPENDIX A

CONSENT FORM

To General Physics I Laboratory Learners,

You have an opportunity during this semester’s General Physics I Laboratory course to participate in a research study. This form provides you with information about the study and explains how you can contribute. Your participation will be greatly appreciated and is completely voluntary. Choosing not to participate or choosing to withdraw from participation during the research study will not adversely affect your grade in this course. Please review the information and if you decide to participate please sign this form and return it to the course instructor. After signing this form you will be supplied with a copy. If you have any questions or concerns about this research study contact:

Researcher: Gail Ruby, Adjunct Physics Instructor, LeTourneau University, Longview, TX; email: GailRuby@letu.edu   Telephone (903) 643-7423

Researcher’s Supervisor: Dr. Amar Almasude, Florence, South Carolina email: Amar.Almasude@Faculty.Capella.edu   Telephone (843) 661-1668

Institution: Capella University, 225 South 6th Street, 9th Floor, Minneapolis, Minnesota 55402

Proposal to Research Physics at LeTourneau University Learner Consent to Participate in the Research Study Form

Research Study

Your participation in this research study will occur during your General Physics I Laboratory course. This participation will involve the completion of four physics experiments and an evaluation relating your experiences with these experiments.

As a participant in this research study you will perform two physics experiments in your home using equipment provided in a kit and two physics experiments in the physical laboratory using equipment provided in a kit. You will be supplied with the materials required for the experiments and will incur no expenses as a result of participating in this study. These experiments will follow the same safety protocol used in the traditional laboratory and there is no greater risk than ordinarily encountered in the performance of traditional physics experiments.

There will be a pretest and posttest for each experiment as well as a written laboratory report. The physics laboratory experiments performed for this study will cover
concepts and meet the objectives of traditional physics experiments therefore you will receive grades for the written laboratory reports which will contribute to your final course grade. The scores on the pretest and posttest assessments will not affect your course grade.

Confidentiality
Each experiment you perform will have a cover sheet entitled grade tracking form and your name will only appear on this form. After the grade is recorded on this form it will be removed from the experiment and returned to you. Your name will not be associated with the research data or included in any research reports. Your anonymity and privacy will be preserved as no individual will be identified on any research documents.

Consent
The contribution of every participant in this study is significant. In order to contribute you must provide your consent by signing this form.

I ______________________________ (insert your name – please print) consent to participate in the physics research study as described in this document and have signed this form as evidence of this consent.

_________________________________   ____________________________
Signature       Date
APPENDIX B
BACKGROUND INFORMATION SURVEY

Thank-you for your consent to participate in this research study investigating the delivery of physics laboratories online.

Instructions: Please provide the following background information by placing a check mark in the appropriate box and your response in the space provided.

Please note this background information is being requested to assist in the statistical analysis process and your responses will be kept anonymous. Supplying this information is not a requirement for participating in the study and is provided voluntarily. You should provide only the information you feel comfortable disclosing.

1. Please indicate your gender:  □ male  □ female

2. Please indicate your year in college:
   □ freshman  □ sophomore  □ junior  □ senior

3. Please indicate your academic major: ________________________________

4. Prior to this course had you previously enrolled in a physics course at a college or university?
   □ no  □ yes (indicate yes whether or not you completed the course)

5. Did you take a course in high school that included physics?
   □ yes  □ no

6. Have you ever taken a course online either at the college or high school level?
   □ no  □ yes
APPENDIX C

TWO DIMENSIONAL MOTION INVESTIGATION

GRADE TRACKING FORM

The information you supply on and with the Two Dimensional Motion Investigation will be anonymous.

This form is supplied for grade tracking purposes only. This form will be removed from the investigation immediately upon the assignment of a grade and returned to you.

Your Name Will Only Appear On This Form

Write you name on this form only. Do not include your name or any other identifying information anywhere else on or within this investigation. Thank-you.

Name: __________________________________________________

General Physics I Laboratory PHYS1111    Section:____________________

Grade*: ____________________

*Scores for the written lab report are on a 20 point scale

Submission Instructions

Submit the written lab report and post-lab assessment for this investigation by inserting it into the General Physics Lab box in the bookcase outside of the physics lab, Glaske S107.

Instructor Contact Information

If, at any time, during this investigation you encounter questions or problems please contact the course instructor at:

email: (insert address)    Telephone: (insert number)
Pre-Experiment Assessment for the
Two Dimensional Motion Investigation

Instructions: Complete this assessment prior to reading the lab instructions and before you have attempted the experiment. Note there are 5 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. A rifle, at a height, h, above the ground, fires a bullet parallel to the ground. At the same instant and from the same height a second bullet is dropped from rest. Neglecting air resistance which bullet has the greatest velocity just before hitting the ground?

   a) the bullet fired from the gun has the greatest velocity just before hitting the ground
   b) the bullet that was dropped has the greatest velocity just before hitting the ground
   c) both bullets have the same velocity just before hitting the ground
   d) there is not enough information to determine which bullet has the greatest velocity just before hitting the ground

2. The quarterback of a football team is stationary and throws a pass with an initial horizontal velocity to a receiver. What happens to the horizontal velocity of the football during the time it is in the air. (Neglect air resistance)

   a) the horizontal velocity increases
   b) the horizontal velocity decreases
   c) the horizontal velocity remains the same
   d) more information is needed to determine what happens to the horizontal velocity

3. The quarterback of a football team is stationary and throws a pass with an initial horizontal velocity to a receiver. What happens to the vertical velocity of the football during the time it is in the air. (Neglect air resistance)

   a) the vertical velocity increases
   b) the vertical velocity decreases
   c) the vertical velocity remains the same
   d) there is no vertical velocity because the football was thrown with only horizontal velocity
4. The quarterback of a football team is stationary and throws a pass with an initial horizontal velocity to a receiver. What happens to the total velocity of the football during the time it is in the air. (Neglect air resistance)

   a) the total velocity increases  
   b) the total velocity decreases  
   c) the total velocity remains the same  
   d) more information is needed to determine what happens to the total velocity

II. Problem: Show all your work, be sure to include units, and watch significant figures.

5. A package falls out of an airplane that is flying in a straight line with a constant horizontal speed at a height of 915 m above the ground. If air resistance is negligible, the airplane travels 3060 m before the package hits the ground.

   a. What was the horizontal speed of the airplane? (Use acceleration of gravity, \( g = 9.8 \, \text{m/s}^2 \)) (5 points)

   b. Sketch the trajectory (path) of the package from the airplane to the ground.  
      (2 points)
Two Dimensional Motion Investigation

OVERVIEW

The world consists of three-dimensional space with time as the fourth dimension. One-dimensional motion with a constant acceleration is typically used as an introduction to kinematics; however, there are a limited number of systems that can be described using one-dimensional motion with a constant acceleration. Nevertheless, one-dimensional analysis is important for studying multiple dimensions as multiple dimensions can be broken down into one-dimensional components.

Therefore, two-dimensional motion can be broken down into horizontal and vertical components. These components can then be combined, using vector addition to provide the two-dimensional description of the motion. A special case of two-dimensional motion called projectile motion describes an object launched into the air with an initial velocity, v0, at some angle, θ. The resulting motion has no horizontal acceleration (ahor. = 0 meaning vhor. = constant) and a vertical acceleration due to gravity (avert. = |g|). The following are important things to remember about projectile motion:

a. the horizontal component of the motion is not affected by gravity
b. the object’s vertical motion is independent of its horizontal motion
c. the object’s trajectory (path) will be confined to the horizontal-vertical plane.

In order to simulate projectile motion, this investigation will use a ball rolling across a smooth inclined surface. The ball’s two-dimensional motion will be used to represent projectile motion when the projectile is launched at an angle of zero degrees. The incline, at an angle φ, will provide a constant acceleration in the vertical direction, avert. = |g|sinφ. The velocity in the horizontal direction will be constant. The equations that describe this motion are:

<table>
<thead>
<tr>
<th>Horizontal, x, motion</th>
<th>Vertical, y, motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta x = v_{0x}t )</td>
<td>(</td>
</tr>
<tr>
<td>( a =</td>
<td>g</td>
</tr>
</tbody>
</table>

Note: For this experiment assume any resistance, such as air or friction, is negligible.
OBJECTIVES

♦ After completing this investigation the learner will be able to sketch the trajectory (path) of an object with a constant velocity in the horizontal direction and an acceleration in the vertical direction.
♦ After completing this investigation the learner will be able to calculate the horizontal velocity of an object which has a constant horizontal velocity and acceleration in the vertical direction using vertical and horizontal distance measurements.
♦ After completing this investigation the learner will be able to describe the influence on total velocity of a motion which consists of constant horizontal velocity and acceleration in the vertical direction.

MATERIALS

Smooth, Level Surface such as a Table or Desk Top (free of obstructions)*
Water* Books or Blocks to Uniformly Incline the Surface*
Marker, Pen, or Pencil* Scientific Calculator*
Masking Tape Ruler
Tennis Ball Tissue Paper

*These items are not provided in your experiment kit.

SPIRITUAL PREPARATION

Acts 17:26-27 (New International Version)
26From one man he made every nation of men, that they should inhabit the whole earth; and he determined the times set for them and the exact places where they should live. 27God did this so that men would seek him and perhaps reach out for him and find him, though he is not far from each one of us.

Your heavenly Father has placed you at LeTourneau University at this time as part of His plan for your life and He is not far from you at this moment. You have probably experienced how God is a source of strength in difficult situations but God also desires to be involved in every aspect of your life. Before completing this experiment reflect on Acts 17:26-27 and include God in your learning.

REQUIREMENTS

This experiment handout will serve as your written lab report after you have completed the investigation. Enter data, answer questions, and provide all information on this form.
In order to receive full credit for this investigation you must:

♦ Perform all the steps of the Data Collection and record values for h, L, and the angle of your incline in step 2.
Complete all the steps of the Analysis, which involves calculating quantities to be entered in the data table, sketching the shape of the ball’s path, and answering questions regarding the ball’s velocity.

Complete the Conclusion by providing answers to both questions.

DATA COLLECTION

Important Note: Please read through the entire procedure before you setup to perform the experiment. Be sure you have adequate space, clear of obstructions, to perform the experiment and you understand the measurements you will be making as well as have available all the required materials.

_Safety First:_ Be cognizant of safe practices. Do not create an obstruction for others and do not throw the ball in the vicinity of others. Thank-you

1. Select the vertical and horizontal directions on your smooth surface. If your surface is rectangular select the longest distance as the vertical direction. Your surface should be approximately 1.0 m by 1.5 m; clean and free of any obstructions as shown in figure 1.

   Spread the tissue paper over the surface to cover as much surface area as possible. (Secure the tissue paper with masking tape)

   (IMPORTANT Safety Note: Be sure your surface is free from obstructions and the performance of this investigation will not interfere with others. Please inform others that might be present where you will be conducting the experiment and ask them to observe caution.)

   Figure 1: Horizontal and Vertical Directions

2. Incline your surface by placing books or blocks of equal width under one end of the table or desk. The angle of the incline should be between 3 and 5 degrees. Determine the angle by measuring the length, L, between the table legs and the height, h, of the books or blocks placed under the table as shown in Figure 2:

   \[
   \text{Angle of Incline: } \phi = \tan^{-1}\left(\frac{h}{L}\right) = \text{______________________}
   \]

   Include your values for h and L:

   h: ___________________   L: ___________________

   Figure 2: Determining the angle of the incline
3. Practice rolling the ball across the surface (in the horizontal direction) giving the ball only horizontal velocity. The time for the ball to travel across and down the incline should be between two and three seconds.

4. Wet the ball with water, and roll the ball horizontally across the surface as you practiced in step 3. The water on the ball will trace out the path of the ball. (If a problem occurs and you do not get a good run, try again on a different section of the paper or if needed, turn the paper over for additional trials. The paper will dry quickly.)

4. On the tissue paper carefully mark the starting point, ending point, and trace the path of the ball. (Caution: Wet tissue paper will tear very easily.)

5. Restore the surface to its original position by removing the books or blocks you placed under the table or desk.

6. Using the ruler, measure a vertical distance of 20 cm, beginning at your starting point and measuring straight down the surface in the direction of the incline. At the end of this vertical line, make another measurement across the surface (horizontally) until this second line intersects the ball’s path. Record this second measurement in the data table as the horizontal distance, x, for point 1.

7. Using the ruler, measure a vertical distance of 40 cm, beginning at your starting point and measuring straight down the surface in the direction of the incline. At the end of this vertical line, make another measurement across the surface (horizontally) until this second line intersects the ball’s path. Record this second measurement in the data table as the horizontal distance, x, for point 2.

8. Repeat step 7 for vertical distances of 60 cm, 80 cm, and 100 cm. recording the horizontal distances for points 3, 4, and 5.

9. **Clean Up: Be sure that you have removed the books or blocks from under the table legs and have restored the investigation area to its original state.** Thank-you.

### DATA TABLE

<table>
<thead>
<tr>
<th>Point (After Starting Point)</th>
<th>x, Horizontal Distances [cm]</th>
<th>y, Vertical Distances [cm]</th>
<th>Time, t* [s]</th>
<th>Horizontal Velocity* [cm/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ANALYSIS

1. Calculate the time required for the ball to travel to each data point using equation 1. (Substitute into the equation each y value and your angle as recorded in step 2 of the data collection.) Record these values in the data table in the time column.

\[ Time, \ t = \frac{2y}{\sqrt{980 \sin \phi}} \]  
Equation 1

2. Calculate the horizontal velocity at each data point and record it in the data table. Use equation 2:

\[ v_{\text{horizontal}} = \frac{x}{t} \]  
Equation 2

3. Sketch the path of your ball in the diagram below:

Starting Point  \rightarrow  Initial Roll of the Ball in the Horizontal Direction

Vertical DirectionDown The Incline

<table>
<thead>
<tr>
<th>4</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>100</td>
</tr>
</tbody>
</table>
a. Based on this diagram and the values you calculated in the data table, explain what happened to the velocity of the ball in the vertical direction and what happened to the velocity of the ball in the horizontal direction as it rolled across and down the surface.

b. The total velocity at any point along the ball’s path is the vector sum of the horizontal velocity and the vertical velocity at that point. How do the horizontal and vertical components of the velocity influence the ball’s total velocity? In answering this question consider whether the horizontal component, vertical component, and the total velocity increase, decrease, or remain constant as the ball travels across and down the incline.

CONCLUSION

1. Explain what you observed about two dimensional motion by performing this experiment. (Reflect on the path of the ball, the values calculated in the data table, and the important aspects of projectile motion stated in the overview.)

2. After completing this experiment, do you feel you have a good understanding of two dimensional motion which has a constant velocity in one direction and is accelerating in the other direction? (Indicate yes or no. If no, please express your remaining concerns.)
CONFIRM REQUIREMENTS

Before turning in your lab report, please check to make sure you have completed all the requirements, as indicated on page 2. Turn in your lab report as instructed.

EXPERIMENT KIT

Please return all items to the experiment kit, this includes the ball and tissue paper. Please let the tennis ball dry before placing it in the plastic bag. Thank-you.

GOING FURTHER

(These investigations are not a requirement for this experiment but allow you to investigate further, if desired. Please note which investigations you attempted.)

1. What would be the effect of rolling the ball with a larger horizontal velocity? Smaller horizontal velocity?

2. What would be the effect of increasing the angle of the incline? Decreasing the angle?

3. Consider other ways to determine the horizontal velocity of the ball. Can you accomplish this with the data collected or do you need additional data? If so what additional data is needed?

4. Are there other types of two dimensional motion? If so, describe them and how you might investigate them.

5. Indicate your thoughts or ideas for investigating Two Dimensional Motion:

6. Summarize your experiences with the “going further” investigations:
Post-Experiment Assessment for the
Two Dimensional Motion Investigation

Instructions: Complete this assessment after reading the lab instructions, conducting the experiment, and completing the lab report. Note there are 5 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. A rifle, at a height, h, above the ground, fires a bullet parallel to the ground. At the same instant and from the same height a second bullet is dropped from rest. Neglecting air resistance, which bullet hits the ground first?
   a) the bullet fired from the gun hits the ground first
   b) the bullet that was dropped hits the ground first
   c) both bullets hit the ground at the same time
   d) there is not enough information given to determine which bullet hits the ground first

2. A ball is rolled horizontally across an inclined surface and then follows a parabolic path across and down the incline. Which statement best describes the ball’s horizontal velocity? (Neglect friction and air resistance)
   a) the horizontal velocity remains constant
   b) the horizontal velocity increases
   c) the horizontal velocity decreases
   d) more information is needed to determine what happens to the horizontal velocity

3. A ball is rolled horizontally across an inclined surface and then follows a parabolic path across and down the incline. Which statement best describes the ball’s vertical velocity? (Neglect friction and air resistance)
   a) the vertical velocity remains constant
   b) the vertical velocity increases
   c) the vertical velocity decreases
   d) there is no vertical velocity because the ball was rolled with only horizontal velocity
4. A ball is rolled horizontally across an inclined surface and then follows a parabolic path across and down the incline. Which statement best describes the ball’s total velocity? (Neglect friction and air resistance)

   a) the total velocity remains constant  
   b) the total velocity increases  
   c) the total velocity decreases  
   d) the total velocity initially increases and then decreases

II. Problem: Show all your work, be sure to include units, and watch significant figures.

5. A ball is rolled horizontally off the edge of a table. The height of the table is 2.5 m and the ball hits the floor a horizontal distance of 3.1 m from the edge of the table.

   a. What was the initial horizontal velocity of the ball? (Use acceleration of gravity, g = 9.8 m/s²; neglect friction and air resistance) (5 points)

   b. Sketch the trajectory (path) of the ball from the time it rolls off the edge of the table until it hits the floor. (2 points)
APPENDIX D

GRADING RUBRICS FOR THE TWO DIMENSIONAL MOTION INVESTIGATION

The grading rubrics presented herein were used to evaluate the pretest, posttest, and written laboratory report for the two dimensional motion investigation. The pretest and posttest were evaluated using an interval scale of zero to 15 points. The written laboratory report was evaluated with an interval scale of zero to 20 points.

Table D1 contains the grading rubric used to evaluate the pretest assessment for the two dimensional motion investigation. Table D2 is the rubric for grading the written laboratory reports submitted by learners for the two dimensional motion investigation. Table D3 contains the grading rubric used to evaluate the posttest assessment for the two dimensional motion investigation.
Table D1

*Grading Rubric for Two Dimensional Motion PreTest Assessment*

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part I</td>
<td>Full (2 points each)</td>
<td>indicating the correct letters: 1. A, 2. C, 3. A, 4. A</td>
</tr>
<tr>
<td>Multiple</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td>Choice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part II</td>
<td>Full (5 points)</td>
<td></td>
</tr>
<tr>
<td>Problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 5</td>
<td>Full (5 points)</td>
<td>[ t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2(915m)}{9.8 \text{ m/s}^2}} = 13.6 \text{s} ]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[ v = \frac{x}{t} = \frac{3060 \text{m}}{13.6 \text{s}} = 224 \text{m/s} ]</td>
</tr>
<tr>
<td>Part a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial (2 points)</td>
<td>correct calculation and unit for time but not calculating or incorrectly calculating velocity</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>correct calculation and unit for the velocity but not calculating or incorrectly calculating the time</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect calculations, indicating an answer without calculations or units</td>
</tr>
<tr>
<td>Part b)</td>
<td>Full (2 points)</td>
<td>sketching a parabolic path</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response or indicating an incorrect path</td>
</tr>
</tbody>
</table>
Table D2

*Grading Rubric for Two Dimensional Motion Written Laboratory Report*

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection</td>
<td>Full (2 points)</td>
<td>numerical values for h and L, and an angle 3° - 5°</td>
</tr>
<tr>
<td>Step 2</td>
<td>Partial (1 point)</td>
<td>numerical values for h and L without an angle or an angle &lt; 3° or &gt; 5°</td>
</tr>
<tr>
<td>Angle of the Incline</td>
<td>Partial (1 point)</td>
<td>no values for h and L, and an angle 3° - 5°</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses</td>
</tr>
<tr>
<td>Data Table</td>
<td>Full (3 points)</td>
<td>values for each of the 5 data points increasing</td>
</tr>
<tr>
<td>Horizontal</td>
<td></td>
<td>between 10 and 150 cm, 3 significant figures</td>
</tr>
<tr>
<td>Distances</td>
<td>Partial (1 point)</td>
<td>values out of range or not increasing in length</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response or illegible response</td>
</tr>
<tr>
<td>Data Table</td>
<td>Full (3 points)</td>
<td>correctly calculating time for each data point, range</td>
</tr>
<tr>
<td>Time Calculation</td>
<td></td>
<td>0 - 3 seconds, increasing from point 1 to 5</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>with 3 significant figures</td>
</tr>
<tr>
<td></td>
<td>None (0 point)</td>
<td>incorrect calculation of time, no response, or illegible responses</td>
</tr>
</tbody>
</table>
Table D2 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Table</td>
<td>Full (3 points)</td>
<td>correctly calculating velocity for each data point, range 0 – 150 cm/s, decreasing or remaining constant from points 1 to 5 with 3 significant figures</td>
</tr>
<tr>
<td>Horizontal</td>
<td>Partial (2 points)</td>
<td>correctly calculating velocity for each data point but out of range due to incorrect time values, must decrease or remain constant from points 1 to 5 with 3 significant figures</td>
</tr>
<tr>
<td>Velocities</td>
<td>Partial (1 point)</td>
<td>correctly calculated velocity values which increase from points 1 to 5</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or illegible responses</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (2 points)</td>
<td>sketch a parabolic path</td>
</tr>
<tr>
<td>Step 3</td>
<td>Partial (1 point)</td>
<td>sketch a linear path</td>
</tr>
<tr>
<td>Sketch the Ball’s Path</td>
<td>None (0 points)</td>
<td>no response or any other type of path</td>
</tr>
<tr>
<td>Item</td>
<td>Credit</td>
<td>Responses</td>
</tr>
<tr>
<td>----------</td>
<td>--------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (2 points)</td>
<td>vertical velocity increases and the horizontal velocity decreases or remains the same</td>
</tr>
<tr>
<td>Step 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question a)</td>
<td>Partial (1 point)</td>
<td>vertical velocity decreases or remains the same and the horizontal velocity decreases or remains the same</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>vertical velocity increases and the horizontal velocity decreases</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (2 points)</td>
<td>total velocity increases as horizontal velocity decreases because vertical velocity increases at a greater rate</td>
</tr>
<tr>
<td>Step 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question b)</td>
<td>Partial (1 point)</td>
<td>total velocity increases but not discussing contributions from horizontal and vertical velocities</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>discussing contributions from horizontal and vertical velocities but not discussing total velocity</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
</tbody>
</table>
Table D2 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conclusion</td>
<td>Full (2 points)</td>
<td>reflective response</td>
</tr>
<tr>
<td>Question 1</td>
<td>Partial (1 point)</td>
<td>response with limited logical progression</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Full (1 point)</td>
<td>providing a response of yes or no, if no an</td>
</tr>
<tr>
<td>Question 2</td>
<td></td>
<td>explanation must be given</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>failing to respond or indicating a no response</td>
</tr>
<tr>
<td></td>
<td></td>
<td>without an explanation</td>
</tr>
<tr>
<td>Significant</td>
<td>Deduct $\frac{1}{4}$ point for each occurrence</td>
<td>incorrect number of significant figures, failing to provide correct units, or providing incorrect units for numerical values</td>
</tr>
<tr>
<td>Figures and Units</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table D3

*Grading Rubric for the Two Dimensional Motion PostTest Assessment*

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td>Choice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part II</td>
<td>Full (5 points)</td>
<td></td>
</tr>
<tr>
<td>Problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial (2 points)</td>
<td>correct calculation and unit for time but not calculating or incorrectly calculating velocity</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>correct calculation and unit for the velocity but not calculating or incorrectly calculating the time.</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect calculations, indicating an answer without calculations or units</td>
</tr>
<tr>
<td>Part b)</td>
<td>Full (2 points)</td>
<td>sketching a parabolic path</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response or indicating an incorrect path</td>
</tr>
</tbody>
</table>

\[
t = \sqrt{\frac{2y}{g}} = \sqrt{\frac{2(2.5m)}{9.8\text{m/s}^2}} = 0.71\text{s}
\]

\[
v = \frac{x}{t} = \frac{3.1m}{0.71\text{s}} = 4.4\text{m/s}
\]
APPENDIX E
NEWTON’S THIRD LAW INVESTIGATION

GRADE TRACKING FORM

The information you supply on and with the Newton’s Third Law Investigation will be anonymous.

This form is supplied for grade tracking purposes only. This form will be removed from the investigation immediately upon the assignment of a grade and returned to you.

Your Name Will Only Appear On This Form

Write your name on this form only. Do not include your name or any other identifying information anywhere else on or within this investigation. Thank-you.

Name: __________________________________________________

General Physics I Laboratory PHYS1111    Section:____________________

Grade*: ____________________

*Scores for the written lab report are on a 20 point scale

Submission Instructions

Submit the written lab report and post-lab assessment for this investigation by inserting it into the General Physics Lab box in the bookcase outside of the physics lab, Glaske S107.

Instructor Contact Information

If, at any time, during this investigation you encounter questions or problems please contact the course instructor at:

email: (insert address) Telephone: (insert number)
Instructions: Complete this assessment prior to reading the lab instructions and before you have attempted the experiment. Note there are 6 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. The force pairs of Newton’s Third Law consist of forces:
   a) that are opposite but not always equal.
   b) that are equal and opposite but act on different objects.
   c) that cancel each other out.
   d) that act on the same object.

2. A parent pushes a small child on a swing such that the child moves away rapidly while the parent remains at rest. How does the magnitude of the force the child exerts on the parent compare to the magnitude of the force the parent exerts on the child? (Air resistance is negligible)
   a) The force the parent exerts is larger.
   b) The force the child exerts is larger.
   c) The forces have equal magnitudes.
   d) There is not enough information given to compare the forces.

3. A rocket’s forward motion results from gases being propelled backwards. The action force is exerted by
   a) the rocket
   b) the gases
   c) both the rocket and the gases
   d) gravity

4. A rocket’s forward motion results from gases being propelled backwards. The reaction force is exerted by
   a) the rocket
   b) the gases
   c) both the rocket and the gases
   d) gravity
II Questions: Refer to the graph in figure 1 when answering the following questions. (3.5 points each)

5. Using the curve on the plot in figure 1, estimate the distance for a Volume, V, of 4000 cm$^3$. Show how you determined this value on the graph or with calculations. (Be sure to include units.)

estimated distance (when V is 4000 cm$^3$) = __________________________

6. Using the curve on the plot in figure 1, estimate the Volume for a distance, d, of 200 cm. Show how you determined this value on the graph or with calculations. (Be sure to include units.)

estimated volume (when d is 200 cm) = __________________________
Newton’s Third Law Investigation

OVERVIEW

Newton’s Third Law of Motion is commonly stated: for every action there is an equal and opposite reaction; this means if object A exerts a force, \( F \), on object B, then object B exerts an equal and opposite force, \( -F \), on object A. Newton’s Third Law can also be expressed in an equation, \( F_{AB} = -F_{BA} \) which is read: the force on object A exerted by object B, \( F_{AB} \), is equal in magnitude and opposite in direction to the force on object B exerted by object A, \( F_{BA} \).

It is important to note the action and reaction forces act on different objects and do not cancel each other out. Firing a gun produces an action force which propels the bullet forward and a reaction or backwards force called the recoil. Similarly, a rocket’s forward motion results from gases being propelled backwards. You must be careful stepping out of a small boat unto a dock because of Newton’s Third Law. If the boat is not tied to the dock and you do not have a handhold on the dock, as you step out, the boat will move away from the dock leaving you straddling the increasing gap between the boat and the dock. According to Newton's Third Law: as your legs propel your body towards the dock, they also apply an equal and opposite force to the boat pushing it away from the dock. In this experiment you will investigate Newton’s Third Law of Motion using the controlled propulsion of a balloon.

OBJECTIVES

♦ After completing this investigation the learner will be able to identify the action and reaction forces for the controlled propulsion of a balloon.
♦ After completing this investigation the learner will be able to graphically illustrate the relationship between the amount of air in a balloon and the distance it is propelled along a string.
♦ After completing this investigation the learner will be able to predict the distance a balloon filled with different amounts of air will travel using controlled propulsion.
♦ After completing this investigation the learner will be able to predict the amount of air needed in a balloon to propel it a given distance using controlled propulsion.

MATERIALS

4 Balloons      Drinking Straw     String
Ruler    Masking Tape    Scissors*
Long Space (~30 ft) such as a Hallway, free of obstructions*    Calculator*
Sturdy Objects such as Chairs for attaching the string*    Marker(s)*

*These items are not provided in your experiment kit.
SPIRITUAL PREPARATION

Galatians 6:7 (NKJV)
7 Do not be deceived, God is not mocked; for whatever a man sows, that he will also reap.

Galatians 6:7 is an easily understood passage. The problem is not with its understanding, but our willingness to deal with our nature which tends to deceive us. We will not fool God as God knows our hearts. The principle, we will reap what we sow is fundamental. If we spend our wealth, time, and talents on other things and give God the crumbs, we are not going to reap a bounteous spiritual harvest. If we sow for God, then we will reap eternal reward.

There is a cause-and-effect correlation to the choices we make in life. Analogous to Newton’s action-reaction principle. Reflect on the sowing and reaping principle as you prepare for this investigation. Ask Jesus to help you see the important things you need to invest in and for wisdom to deal with self-deception.

REQUIREMENTS

This experiment handout will serve as your written lab report after you have completed the investigation. Enter data, answer questions, and provide all information on this form. In order to receive full credit for this investigation you must:

♦ Perform all the steps of the Data Collection and record distance values in the data table.
♦ Complete all the steps of the Analysis, which involves calculation of quantities to be entered in the data table, the creation of a graph, fitting a curve to the data points on the graph, and answering the questions in steps 5 and 6.
♦ A copy of your graph must be attached to your lab report!
♦ Complete the Conclusion by providing answers to all three questions.

PRELIMINARY SETUP INFORMATION

Important: Be sure you have a large enough area clear of obstructions and all the materials needed to complete this experiment before proceeding. Please read through the entire procedure before you setup to perform the experiment in order to understand the measurements you will be making. Weather permitting, you might consider doing this investigation outside but please be courteous of others and their property. Always follow safe experimental practices. Do not create an obstruction for others and do not propel the balloon toward yourself or others. Thank-you
DATA COLLECTION

1. Cut pieces of string that are: 65 cm (~25.6 inches), 55 cm (~21.7 inches), 45 cm (~17.7 inches), and 35 cm (~13.8 inches) long from one end of the string provided in the experiment kit. Set these pieces of string aside as they will be used later to measure the circumference of the balloon.

2. Slide the drinking straw onto the remaining piece of string which should be approximately 9.0 m (~30 feet) long.

3. Stretch the string across a large room or hallway and between two sturdy objects so it is level. Attach each end securely to the sturdy objects by tying the string around the objects and/or using masking tape.

4. Place two short strips of masking tape over the straw (while it is on the string) so that the sticky side of the tape is facing down.

5. Blow up the balloon to a circumference of 65 cm. The circumference should be measured at the largest part of the balloon.

(You may devise your own technique for blowing up the balloon and measuring its circumference. A possible suggestion is to form a loop around the balloon with the 65 cm long string – holding the ends together with the thumb and finger of one hand, then blow up the balloon – holding it with the other hand, until it fills the loop.)

Hold the neck of the balloon tightly so no air escapes; it is no longer necessary to hold the 65 cm loop of string around the balloon.

6. Attach the filled balloon to the straw with the pieces of masking tape, so that the balloon is underneath the string, as shown in figure 1. The neck of the balloon should be parallel to the string and close to one of the sturdy objects holding the string.

Figure 1: How to Attach the Balloon to the String
7. To test the length of your string, be sure the path is clear, release your hold on the neck of the balloon letting the air propel the balloon along the string. If the balloon does not stop before reaching the end of the string you will need to lengthen the string. If you lengthen the string repeat this test to ensure the balloon stops before reaching the end of the string.

*Important Note:* The balloon must be securely attached to ensure it travels in a straight line. **It must not spin or rotate around on the string.**

8. Make a mark on the string at one end of the straw, to indicate a starting point. The balloon needs to start at the same location for each trial. (A marker or masking tape can be used as a means of marking points on the string.)

9. Blow up the balloon to a circumference of 65 cm (use the 65 cm long piece of string cut in step 1 to be sure the circumference is correct – refer to step 5), securely attach the balloon to the straw with masking tape as illustrated in figure 1, holding the neck of the balloon tightly so no air escapes.

10. Place the straw at the starting point and release your hold on the neck of the balloon letting the air propel the balloon along the string. Mark where the balloon stops by placing a mark at the same end of the straw you marked in step 8.

*Important Note:* the balloon needs to follow a straight line to ensure accurate results. **If the balloon rotated around the string, repeat the trial.**

11. Select a second balloon and repeat steps 9 and 10 for a balloon circumference of 55 cm. Use the 55 cm. long piece of string cut in step 1.

12. Select another balloon and repeat steps 9 and 10 for a balloon circumference of 45 cm. Use the 45 cm. long piece of string cut in step 1.

13. Using the last balloon, repeat steps 9 and 10 for a balloon circumference of 35 cm. Use the 35 cm. long piece of string cut in step 1.

14. Measure the distances the balloon traveled along the string. Measure from the starting point to the ending point for each balloon circumference. Record the values in the appropriate column of the data table. (You can make these measurements while the string is still attached or take down the string and use a flat, level surface. If you take the string down be careful not to stretch it tighter then it was for the experiment. The string will lengthen when stretched.)

15. **Clean Up:** Be sure that you have taken down the string and restored the investigation area to its original state. *Thank-you.*
DATA TABLE

<table>
<thead>
<tr>
<th>Circumference [cm]</th>
<th>Radius*, r [cm]</th>
<th>Volume of Air*, V [cm³]</th>
<th>Distance the Balloon Traveled, d [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* These quantities will be determined in the analysis.

ANALYSIS

1. Calculate the radius, r, for each amount of air in the balloon using equation 1

   \[ r = \frac{Circumference}{2\pi} \]  \hspace{1cm} \text{Equation 1}

2. Calculate the volume of air in the balloon for each circumference, using the volume of a sphere (equation 2) as an approximation:

   \[ Volume = \frac{4\pi r^3}{3} \]  \hspace{1cm} \text{Equation 2}

3. Make a graph of volume of air, V, versus distance traveled, d. This can be done on graph paper or with computer software such as Microsoft Excel. \textbf{This graph must be submitted with your lab report.} (Note: V is on the vertical axis and d is on the horizontal axis. The point (0, 0) \textit{must} be included on your graph.)

4. The force is proportional to V/d, therefore, this graph illustrates the action force. Fit a curve to the points on your graph. (Note: The graph is not a straight line and you should not “connect the dots”.) You can use software with fitting capability or sketch a shape which follows the pattern of the data points.

5. Using the curve you fitted to your data points, estimate the distance a balloon would travel if its circumference, C, was 15 cm?

   estimated distance (when C is 15 cm) = __________________________
6. Using the curve you fitted to your data points, estimate the volume of air needed for the balloon to travel a distance of 980 cm.

\[
\text{volume of air needed for balloon to travel 980 cm} = \text{______________________}
\]

CONCLUSION

1. Explain how the propulsion of the balloon demonstrates Newton's Third Law and what you learned about Newton’s Third Law from doing this investigation. Consider how the direction of the air escaping from the balloon is related to the direction the balloon travels.

2. Identify the action and reaction forces as the balloon is propelled on the string by stating Newton’s Third Law of Motion using these forces.

3. After completing this experiment, do you feel you have a good understanding of Newton’s Third Law? (Indicate yes or no. If no, please express your remaining concerns.)

CONFIRM REQUIREMENTS

Before turning in your lab report, please check to make sure you have completed all the requirements, as indicated on page 2, including attaching your graph. Turn in your lab report as instructed.

EXPERIMENT KIT

Please return all items to the experiment kit, except the used balloons. Thank-you.
GOING FURTHER

(These investigations are not a requirement of this experiment but will allow you to investigate further, if desired. Please note which investigations you attempted.)

1. According to Newton’s Second Law of Motion (F=ma), two balls with roughly the same size but different masses such as a beach ball and a basketball would require different amounts of force to kick them the same distance. Newton’s Third Law of Motion tells you to expect the basketball to exert a larger force on your foot than the beach ball. Kick the balls and find out. Do you ‘feel’ a force being exerted on your foot by the ball?

2. Place a wooden block or other object that floats in a bucket or container of water. Push the block or object down into the water and release it. What happens? Why? What do you notice if you push the block or object down with a greater amount of force? What happens to the depth of the water? How can you explain this in terms of forces and Newton’s Third Law of Motion?

3. If a balloon filled with air is not guided by the straw and string, as in this experiment, it will move uncontrolled when released into the air. Is there any way to control the balloon’s flight?

4. Using spring scales, investigate the forces exerted when a string or rubber band is stretched.

5. Indicate your thoughts or ideas for investigating Newton’s Third Law:

6. Summarize your experiences with the “going further” investigations:
Post-Experiment Assessment for the Newton’s Third Law Investigation

Instructions: Complete this assessment after reading the lab instructions, conducting the experiment, and completing the lab report. Note there are 6 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. A small car is pushing a larger disabled truck so that their speed gradually increases. Which exerts the larger force on the other?

   a) The truck exerts a larger force on the car.
   b) The car exerts a larger force on the truck.
   c) The force exerted by the car is equal and opposite to the force exerted by the truck.
   d) There is not enough information to compare the forces.

2. Which of the following relationships describe Newton’s Third Law of Motion?

   a) \( F_{AB} = - F_{BA} \)
   b) \( F_{AB} = F_{BA} \)
   c) \( -F_{AB} = - F_{BA} \)
   d) \( -F_{AB} = F_{BA} \)
   e) both a and d
   f) both b and c

3. A balloon is propelled forward as a result of air being propelled backwards. The action force is exerted by

   a) the balloon
   b) the air
   c) both the balloon and the air
   d) gravity

4. A balloon is propelled forward as a result of air being propelled backwards. The reaction force is exerted by

   a) the balloon
   b) the air
   c) both the balloon and the air
   d) gravity
II Questions: Refer to the graph in figure 1 when answering the following questions. 
(3.5 points each)

5. Using the curve on the plot in figure 1, estimate the distance for a Volume, V, of
1000 cm$^3$. Show how you determined this value on the graph or with calculations. 
(Be sure to include units.)

estimated distance (when V is 1000 cm$^3$) = __________________________

6. Using the curve on the plot in figure 1, estimate the Volume for a distance, d, of
450 cm. Show how you determined this value on the graph or with calculations. 
(Be sure to include units.)

estimated volume (when d is 450 cm) = __________________________
APPENDIX F

GRADING RUBRICS FOR THE NEWTON’S THIRD LAW INVESTIGATION

The grading rubrics presented herein were used to evaluate the pretest, posttest, and written laboratory report for the Newton’s Third Law investigation. The pretest and posttest were evaluated using an interval scale of zero to 15 points. The written laboratory report was evaluated with an interval scale of zero to 20 points.

Table F1 contains the grading rubric used to evaluate the pretest assessment for the Newton’s Third Law investigation. Table F2 is the rubric for grading the written laboratory reports submitted by learners for the Newton’s Third Law investigation. Table F3 contains the grading rubric used to evaluate the posttest assessment for the Newton’s Third Law investigation.
## Grading Rubric for Newton’s Third Law PreTest Assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part I</strong></td>
<td>Full (2 points each)</td>
<td>indicating the correct letters: 1. B, 2. C, 3. B, 4. A</td>
</tr>
<tr>
<td>Multiple Choice</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td><strong>Part II</strong></td>
<td>Full (3.5 points)</td>
<td>value between 460 - 480 cm with 2 significant figures and showing how this value was determined</td>
</tr>
<tr>
<td>Question 5</td>
<td>Partial (1 point)</td>
<td>value between 460 - 480 cm with 2 significant figures without showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, or indicating an answer without units</td>
</tr>
<tr>
<td>Question 6</td>
<td>Full (3.5 points)</td>
<td>value between 300 – 460 cm³ with 2 significant figures and showing how this value was determined</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>value between 300 – 460 cm³ with 2 significant figures without showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, or indicating an answer without units</td>
</tr>
</tbody>
</table>
### Table F2

*Grading Rubric for Newton’s Third Law Laboratory Report*

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Table</td>
<td>Full (2 points)</td>
<td>from top of column down: 10.3, 8.75, 7.16, 5.57</td>
</tr>
<tr>
<td>Radius</td>
<td>Deduct ½ point</td>
<td>for each incorrect or missing value</td>
</tr>
<tr>
<td>Data Table</td>
<td>Full (2 points)</td>
<td>from top of column down: 4640, 2810, 1540, 724</td>
</tr>
<tr>
<td>Volume</td>
<td>Deduct ½ point</td>
<td>for each incorrect or missing value</td>
</tr>
<tr>
<td>Data Table</td>
<td>Full (3 points)</td>
<td>decreasing non-repeating values, 3 significant figures</td>
</tr>
<tr>
<td>Distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balloon</td>
<td>Partial (1 point)</td>
<td>increasing or repeating values</td>
</tr>
<tr>
<td>Traveled</td>
<td>Deduct ½ point</td>
<td>for each missing value</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (2 points)</td>
<td>a numeric value &lt; 100 cm</td>
</tr>
<tr>
<td>Question 5</td>
<td>None (0 points)</td>
<td>no response, incorrect value, incorrect unit or indicating an answer without units</td>
</tr>
</tbody>
</table>
### Table F2 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Analysis</strong></td>
<td>Full (2 points)</td>
<td>a numeric value $&gt; 5000 \text{ cm}^3$</td>
</tr>
<tr>
<td><strong>Question 6</strong></td>
<td>None (0 points)</td>
<td>no response, incorrect value, incorrect unit or indicating an answer without units</td>
</tr>
<tr>
<td><strong>Analysis</strong></td>
<td>Full (4 points)</td>
<td>volume versus distance graph, title, major divisions on each axis, each axis label includes quantity and units, data points identified, parabolic fit line to data points</td>
</tr>
<tr>
<td><strong>Graph</strong></td>
<td>Partial (3 points)</td>
<td>volume versus distance graph, each axis label includes quantity and/or units, data points identified, parabolic fit line to data points</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>volume versus distance or distance versus volume graph, each axis label includes quantity and/or units, other than a parabolic type of fit to data points</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>missing graph, graph without labels, or graph without fit line</td>
</tr>
<tr>
<td>Item</td>
<td>Credit</td>
<td>Response</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Full (2 points)</td>
<td>reflective response</td>
</tr>
<tr>
<td>Question 1</td>
<td>Partial (1 point)</td>
<td>response with limited logical progression</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Full (2 points)</td>
<td>state Newton’s Third Law using the air pushing on the balloon as the action force and the balloon pushing on the air as the reaction force</td>
</tr>
<tr>
<td>Question 2</td>
<td>Partial (1 point)</td>
<td>stating Newton’s Third Law using incorrect action-reaction forces or stating action-reaction forces without stating Newton’s Third law</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Full (1 point)</td>
<td>indicate yes or no with an explanation</td>
</tr>
<tr>
<td>Question 3</td>
<td>None (0 points)</td>
<td>failing to respond or indicating a no response without an explanation</td>
</tr>
</tbody>
</table>

Significant Figures: Deduct $\frac{1}{4}$ point per item for an incorrect number of significant figures
### Grading Rubric for Newton's Third Law PostTest Assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part I</td>
<td>Full (2 points each)</td>
<td>indicating the correct letters: 1. C, 2. E, 3. B, 4. A</td>
</tr>
<tr>
<td>Multiple Choice</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td>Part II</td>
<td>Full (3.5 points)</td>
<td>value between 180 - 200 cm with 2 significant figures and showing how this value was determined</td>
</tr>
<tr>
<td>Question 5</td>
<td>Partial (1 point)</td>
<td>value between 180 - 200 cm with 2 significant figures without showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, or indicating an answer without units</td>
</tr>
<tr>
<td>Question 6</td>
<td>Full (3.5 points)</td>
<td>value between 8000 – 8600 cm³ with 2 significant figures and showing how this value was determined</td>
</tr>
<tr>
<td></td>
<td>Partial (1 point)</td>
<td>value between 8000 – 8600 cm³ with 2 significant figures without showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, or indicating an answer without units</td>
</tr>
</tbody>
</table>
APPENDIX G

NEWTON’S SECOND LAW INVESTIGATION

GRADE TRACKING FORM

The information you supply on and with the Newton’s Second Law Investigation will be anonymous.

This form is supplied for grade tracking purposes only. This form will be removed from the investigation immediately upon the assignment of a grade and returned to you.

Your Name Will Only Appear On This Form

Write your name on this form only. Do not include your name or any other identifying information anywhere else on or within this investigation. Thank-you.

Name: __________________________________________________

General Physics I Laboratory

Course Number PHYS1111 Section:__________________

Grade*: __________________

*Scores for the written lab report are on a 20 point scale

Submission Instructions

Submit the written lab report and post-lab assessment for this investigation by inserting it into the General Physics Lab box in the bookcase outside of the physics lab, Glaske S107.

Instructor Contact Information

If, at any time, during this investigation you encounter questions or problems please contact the course instructor at:

email: (insert address) Telephone: (insert number)
Pre-Experiment Assessment for the Newton’s Second Law Investigation

Instructions: Complete this assessment prior to reading the lab instructions and before you have attempted the experiment. Note there are 6 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. According to Newton’s Second Law of Motion a nonzero, net force, F, applied to an object is:
   a) directly proportional to the object’s mass and inversely proportional to the object’s acceleration.
   b) directly proportional to the object’s mass and directly proportional to the object’s acceleration.
   c) inversely proportional to the object’s mass and inversely proportional to the object’s acceleration.
   d) inversely proportional to the object’s mass and directly proportional to the object’s acceleration.

2. According to Newton’s Second Law of Motion when a nonzero, net force, F, is applied to an object of mass, m, it causes the object to accelerate with an acceleration, a. If the force is increased to 3F and the object’s mass remains the same, what is the object’s acceleration?
   a) a
   b) a/3
   c) 3a
   d) a + 3

3. According to Newton’s Second Law of Motion when a nonzero, net force, F, is applied to an object of mass, m, it causes the object to accelerate with an acceleration, a. If the force is doubled to 2F and the object’s acceleration remains the same, what is the object’s mass?
   a) m
   b) m/2
   c) 2m
   d) m + 2
II Questions: Refer to the graph in figure 1 when answering questions 4 - 6. (3 pts. each)

Figure 1: Graph of Force [dynes] versus Mass [grams]

4. Examine the information in figure 1. Does the graph in figure 1 illustrate a constant acceleration?

If yes, what is the numerical value of the acceleration (be sure to include units):

\[ a = \] _________________________

If no, explain what you think the graph illustrates.

5. Using figure 1, determine the force needed to accelerate a 26 g object. Show how you determined the force either on the figure or with calculations. (Be sure to include units.)

\[ \text{Force (to accelerate 26 g object)} = \] _________________________

6. Using figure 1, determine the mass of the accelerating object when a 10 dyne force is applied. Show how you determined the mass either on the figure or with calculations. (Be sure to include units.)

\[ \text{Mass (of accelerating object when F is 10 dynes)} = \] _________________________
Newton’s Second Law Investigation

OVERVIEW

Newton's Second Law of Motion describes the behavior of objects experiencing unbalanced forces as evidenced by the object’s acceleration. This acceleration or change in velocity occurs in the direction of the unbalanced or net force and is directly proportional to the net force. Meaning if you apply twice as much force, the object’s acceleration will double. The object’s acceleration is also inversely proportional to the object’s mass; therefore, when the object’s mass is doubled the acceleration is reduced by one-half.

Newton Second Law of Motion can be stated as:

When a nonzero net force, \( F_{\text{net}} \), acts on an object of mass, \( m \), the acceleration, \( a \), that results is directly proportional to the net force and inversely proportional to the mass. The direction of the acceleration is the same as the direction of the net force.

Newton’s Second Law can also be expressed in equation form as:

\[
F_{\text{net}} = ma \quad \text{or} \quad a = \frac{F_{\text{net}}}{m}
\]

(Note: net force and acceleration are vector quantities with magnitude and direction, while mass is a scalar with magnitude only.)

The unit of force is defined by the above equation as the product of the unit of mass times the unit of acceleration. In the SI system the unit of force is the Newton, N, and in the cgs system the unit of force is the dyne, as illustrated below:

\[
1 \text{ Newton} = \frac{1 \text{ kg m}}{s^2} \quad \text{and} \quad 1 \text{ dyne} = \frac{1 \text{ g cm}}{s^2}
\]

In this investigation, Newton’s Second Law of Motion will be used to determine the acceleration of a car in cm/s\(^2\) by varying the mass measured in grams, g, and the net force, measured in dynes.

OBJECTIVES

♦ After completing this investigation the learner will be able to determine the force required to accelerate an object as its mass is varied.
♦ After completing this investigation the learner will be able to construct a graph of force versus mass.
After completing this investigation the learner will be able to determine the acceleration of an object from the graph of force versus mass.

MATERIALS

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td>2</td>
</tr>
<tr>
<td>2 Hooks</td>
<td></td>
</tr>
<tr>
<td>Short piece of string</td>
<td></td>
</tr>
<tr>
<td>Pulley with clamp</td>
<td>4</td>
</tr>
<tr>
<td>4 Paper clips</td>
<td></td>
</tr>
<tr>
<td>3 Quarters</td>
<td></td>
</tr>
<tr>
<td>3 Dimes</td>
<td></td>
</tr>
<tr>
<td>3 small stackable cans of cat food</td>
<td>3</td>
</tr>
<tr>
<td>3 Dimes</td>
<td></td>
</tr>
<tr>
<td>Graph Paper (or computer graphing program*)</td>
<td>3</td>
</tr>
<tr>
<td>3 Pennies</td>
<td></td>
</tr>
<tr>
<td>Calculator*</td>
<td></td>
</tr>
</tbody>
</table>

*These items are not supplied in the experiment kit.

MASS INFORMATION

- Mass of the Car = 39.9 g
- Mass of one paper clip = 0.40 g
- Mass of one quarter = 5.6 g
- Mass of one dime = 2.25 g
- Mass of one penny = 2.5 g
- Mass of one can of cat food = 94.7 g

The mass of the string and hooks are negligible.

REQUIREMENTS

This experiment handout will serve as your written lab report after you have completed the investigation. Enter data, answer questions, and provide all information on this form. In order to receive full credit for this investigation you must:

- Perform all the steps of the Data Collection and fill in the Data Table.
- Complete all the steps of the Analysis, which requires answering questions 1, 4, and 5; constructing a graph, and determining a linear fit line.
- **Be sure a copy of your graph with fit line is attached to this lab report.**
- Complete the Conclusion by providing answers to both questions.

DATA COLLECTION

1. Attach the pulley to the edge of a table with the clamp and attach one hook to each end of the piece of string.
2. Attach one hook to the car and extend the other hook over the pulley allowing it to hang over the edge of the table, as illustrated in figure 1.

![Figure 1: Experimental Set-up](image)

Make sure the car and string are aligned with the center of the pulley forming a straight line.

3. Determine how much mass is needed to move the car by adding paper clips (one at a time) to the hook hanging over the table. You want the car to just start moving and proceed to the edge of the table. (Note: You can tap the car to get it started but do not push it.)

4. Remove the paper clips from the hook and determine the mass needed to move the car by summing the masses of the paper clips. Record this value in the “Applied Mass” column of the data table.

5. Calculate the force by multiplying the applied mass by gravity, \( g = 980 \text{ cm/s}^2 \).

6. Add one can of cat food to the car. Determine how much mass is needed to move the car and can by inserting a quarter, dime or penny into a paper clip and hanging it on the hook suspended over the edge of the table. You want the car to just start moving and proceed to the edge of the table at the same rate as in step 3.

   If the car moves too rapidly, use less mass.
   If it does not move, add more mass.

7. Remove the paper clip(s) and coin(s) from the hook and determine the mass needed to move the car and can by summing the masses of the paper clip(s) and coin(s). Record this value in the “Applied Mass” column of the data table.

8. Calculate the force by multiplying the applied mass by gravity, \( g = 980 \text{ cm/s}^2 \).

9. Repeat steps 6, 7, and 8 for the car and two cans of cat food.

10. Repeat steps 6, 7, and 8 for the car and three cans of cat food. This will complete your data table.
11. **Clean Up:** Be sure that you have restored the experiment area to its original state and have returned all items to the experiment kit. *Thank-you.*

**DATA TABLE**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mass $^{(1)}$ [g]</th>
<th>Applied Mass [g]</th>
<th>Force $^{(2)}$ [dynes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Condition</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Car</td>
<td>39.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + One Can</td>
<td>134.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + Two Cans</td>
<td>229.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car + Three Cans</td>
<td>324.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) The mass data in this column is placed on the horizontal axis of your graph.

(2) The force data in this column is placed on the vertical axis of your graph.

**ANALYSIS**

1. In this investigation you observed an acceleration which was caused by an unbalanced or net force.

   a. What was the relationship between the direction of the acceleration and the direction of the unbalanced force?

   b. What effect did adding mass to the car have on the unbalanced force required to move the car?

   c. What effect did adding mass to the car have on the acceleration when the unbalanced force required to move the car was applied?
2. Construct a graph of Force versus Mass using the data from your data table. You can use graph paper or a computer graphing program. (Note: Be sure that Force is on the vertical axis, mass is on the horizontal axis, and you have included the (0, 0) initial condition.)

3. Fit a linear line in the form of $y = mx + b$ to the data, where $m$ is the slope of the line and $b$ is the y intercept. (Note: The y intercept, $b$, should be zero.) **This line must be displayed on your graph. Be sure to attach a copy of your graph, with fit line, to this report.**

4. The slope of your linear fit line is the acceleration of the car. Record this value below and be sure to include units:

   acceleration = _____________________________

5. Using your linear fit information, determine the force and applied mass needed to accelerate the car with 4 cans of cat food. (Use the acceleration stated in step 4 and be sure to include units.)

   Force (to accelerate car with 4 cans) = _____________________________

   applied mass (to accelerate car with 4 cans) = _____________________________

   Could you apply this much mass with the items supplied in the experiment kit? (If so, explain how.)

CONCLUSION

1. Describe what relationship between force, mass, and acceleration you think is illustrated by your data and your graph.
2. After completing this experiment, do you feel you have a good understanding of Newton’s Second Law of Motion? (Indicate yes or no. If no, please express your remaining concerns.)

CONFIRM REQUIREMENTS

Before turning in your lab report, please check to make sure you have completed all the requirements, as indicated on page 2. Turn in your lab report as instructed.

EXPERIMENT KIT

Please return all items to the experiment kit. Thank-you.

GOING FURTHER (OPTIONAL)

(These investigations are not a requirement for this experiment but allow you to investigate further, if desired. Please note which investigations you attempted.)

1. For this experiment you determined acceleration by varying both force and mass. Are there other ways to examine the relationship between force, mass, and acceleration? If so describe or illustrate how you might set up an experiment and collect data.

2. The force needed to accelerate the car was supplied by gravity. How might a Newton’s Second Law experiment be conducted on a horizontal surface without employing gravity?

3. If you were supplied with a timing device, you could measure acceleration directly. How might this be accomplished using distance versus time data? How might this be accomplished using velocity versus time data?

4. Your thoughts or ideas for investigating Newton’s Second Law of Motion:

5. Summarize your experiences with these “going further” investigations:
Post-Experiment Assessment for the Newton’s Second Law Investigation

Instructions: Complete this assessment after reading the lab instructions, conducting the experiment, and completing the lab report. Note there are 6 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. According to Newton’s Second Law of Motion an object’s acceleration is:
   a) directly proportional to the object’s mass and inversely proportional to the applied force.
   b) directly proportional to the object’s mass and directly proportional to the applied force.
   c) inversely proportional to the object’s mass and inversely proportional to the applied force.
   d) inversely proportional to the object’s mass and directly proportional to the applied force.

2. According to Newton’s Second Law of Motion when a nonzero, net force, F, is applied to an object of mass, m, it causes the object to accelerate with an acceleration, a. If the force is increased to 3F and the object’s mass is increased to 3m, what is the object’s acceleration?
   a) a
   b) a/3
   c) 3a
   d) a + 3

3. According to Newton’s Second Law of Motion when a nonzero, net force, F, is applied to an object of mass, m, it causes the object to accelerate with an acceleration, a. If the force is increased to 4F and the object’s acceleration remains the same, what is the object’s mass?
   a) m
   b) m/4
   c) 4m
   d) m + 4
II Questions: Refer to the graph in figure 1 when answering questions 4 - 6. (3 pts. each)

Figure 1: Graph of Force [dynes] versus Mass [grams]

4. Examine the information in figure 1. Does the graph in figure 1 illustrate a constant acceleration?

If yes, what is the numerical value of the acceleration (be sure to include units):

\[ a = \text{__________________________} \]

If no, explain what you think the graph illustrates.

5. Using figure 1, determine the force needed to accelerate a 180 g object. Show how you determined the force either on the figure or with calculations. (Be sure to include units.)

\[ \text{Force (to accelerate 180 g object) = } \text{__________________________} \]

6. Using figure 1, determine the mass of the accelerating object when a 25 dyne force is applied. Show how you determined the mass either on the figure or with calculations. (Be sure to include units.)

\[ \text{Mass (of accelerating object when F is 25 dynes) = } \text{__________________________} \]
APPENDIX H

GRADING RUBRICS FOR THE NEWTON’S SECOND LAW INVESTIGATION

The grading rubrics presented herein were used to evaluate the pretest, posttest, and written laboratory report for the Newton’s Second Law investigation. The pretest and posttest were evaluated using an interval scale of zero to 15 points. The written laboratory report was evaluated with an interval scale of zero to 20 points.

Table H1 contains the grading rubric used to evaluate the pretest assessment for the Newton’s Second Law investigation. Table h2 is the rubric for grading the written laboratory reports submitted by learners for the Newton’s Second Law investigation. Table H3 contains the grading rubric used to evaluate the posttest assessment for the Newton’s Second Law investigation.
### Table H1

*Grading Rubric for Newton’s Second Law PreTest Assessment*

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part I</td>
<td>Full (2 points each)</td>
<td>indicating the correct letters: 1. B, 2. C, 3. C</td>
</tr>
<tr>
<td>Multiple</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td>Question 4</td>
<td>Full (3 points)</td>
<td>2.2 cm/s²</td>
</tr>
<tr>
<td>Question 5</td>
<td>None (0 points)</td>
<td>not responding, indicating a no response, incorrect value, or indicating an answer without units</td>
</tr>
<tr>
<td>Question 6</td>
<td>Full (3 points)</td>
<td>4 - 5 grams showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, indicating an answer without units, or failing to show how value was determined</td>
</tr>
<tr>
<td>Item</td>
<td>Credit</td>
<td>Responses</td>
</tr>
<tr>
<td>------------</td>
<td>----------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Data Table</td>
<td>Full (3 points)</td>
<td>values for each of the 4 data points increasing between 1.0 and 21 grams, 2 - 3 significant figures</td>
</tr>
<tr>
<td>Applied</td>
<td>Deduct ¾ point</td>
<td>for out of range values or missing values</td>
</tr>
<tr>
<td>Mass</td>
<td>Full (2 points)</td>
<td>values calculated by multiplying applied force by 980 cm/s²</td>
</tr>
<tr>
<td>Force</td>
<td>Deduct ½ point</td>
<td>for each incorrectly calculated value or missing values</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (1 point)</td>
<td>force and acceleration are in the same direction</td>
</tr>
<tr>
<td>Question 1</td>
<td>None (0 points)</td>
<td>no response or any other response</td>
</tr>
<tr>
<td>Part a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (1 point)</td>
<td>adding mass required an increase in the unbalanced force</td>
</tr>
<tr>
<td>Question 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part b)</td>
<td>None (0 points)</td>
<td>no response or any other response</td>
</tr>
</tbody>
</table>
Table H2 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis Question 1</td>
<td>Full (1 point)</td>
<td>adding mass to the car did not affect the acceleration</td>
</tr>
<tr>
<td>Part c)</td>
<td>None (0 points)</td>
<td>no response or any other response</td>
</tr>
<tr>
<td>Analysis Question 2</td>
<td>Full (4 points)</td>
<td>force versus mass graph, title, major divisions</td>
</tr>
<tr>
<td>Graph</td>
<td></td>
<td>on each axis, each axis label includes quantity and units, data points</td>
</tr>
<tr>
<td></td>
<td></td>
<td>identified, linear fit line to data points, linear fit equation</td>
</tr>
<tr>
<td>Partial (3 points)</td>
<td></td>
<td>force versus mass graph, each axis label includes quantity and/or units, data points identified, linear fit line to data points</td>
</tr>
<tr>
<td>Partial (1 point)</td>
<td></td>
<td>force versus mass or mass versus force graph, each axis label includes quantity and/or units, other than a linear fit line to data points</td>
</tr>
<tr>
<td>None (0 points)</td>
<td></td>
<td>missing graph, graph without labels, or graph without fit line</td>
</tr>
<tr>
<td>Item</td>
<td>Credit</td>
<td>Responses</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (2 points)</td>
<td>20 – 40 cm/s²</td>
</tr>
<tr>
<td>Question 4</td>
<td>None (0 points)</td>
<td>no response, incorrect value, incorrect unit or indicating an answer without units</td>
</tr>
<tr>
<td>Question 5</td>
<td>Full (1 point)</td>
<td>10,000 – 14,000 dynes</td>
</tr>
<tr>
<td>Part a)</td>
<td>None (0 points)</td>
<td>no response, incorrect value, incorrect unit, or indicating an answer without units</td>
</tr>
<tr>
<td>Question 5</td>
<td>Full (1 point)</td>
<td>10-15 grams</td>
</tr>
<tr>
<td>Part b)</td>
<td>None (0 points)</td>
<td>no response, incorrect value, incorrect unit, or indicating an answer without units</td>
</tr>
<tr>
<td>Question 5</td>
<td>Full (1 point)</td>
<td>yes, including an itemization of which coins to use</td>
</tr>
<tr>
<td>Part b)</td>
<td>None (0 points)</td>
<td>not responding, giving a no response, or failing to itemize coins</td>
</tr>
</tbody>
</table>
Table H2 (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conclusion</td>
<td>Full (2 points)</td>
<td>reflective response</td>
</tr>
<tr>
<td>Question 1</td>
<td>Partial (1 point)</td>
<td>response with limited logical progression</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Full (1 point)</td>
<td>indicate yes or no with an explanation</td>
</tr>
<tr>
<td>Question 2</td>
<td>None (0 points)</td>
<td>failing to respond or indicating a no response</td>
</tr>
<tr>
<td></td>
<td></td>
<td>without an explanation</td>
</tr>
<tr>
<td>Significant Figures</td>
<td>Deduct ¼ point</td>
<td>per item for an incorrect number of significant figures</td>
</tr>
</tbody>
</table>
Table H3

*Grading Rubric for Newton’s Second Law PostTest Assessment*

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part I</td>
<td>Full (2 points each)</td>
<td>indicating the correct letters: 1. D, 2. A, 3. C</td>
</tr>
<tr>
<td>Multiple</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.42 cm/s²</td>
</tr>
<tr>
<td>Part II</td>
<td>Full (3 points)</td>
<td></td>
</tr>
<tr>
<td>Question 4</td>
<td>None (0 points)</td>
<td>not responding, indicating a no response, incorrect value, or indicating an answer without units</td>
</tr>
<tr>
<td>Question 5</td>
<td>Full (3 points)</td>
<td>68 – 72 dynes showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, indicating an answer without units, or failing to show how value was determined</td>
</tr>
<tr>
<td>Question 6</td>
<td>Full (3 points)</td>
<td>58 - 62 grams showing how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, indicating an answer without units, or failing to show how value was determined</td>
</tr>
</tbody>
</table>
APPENDIX I

DETERMINING THE COEFFICIENT OF FRICTION INVESTIGATION

GRADE TRACKING FORM

The information you supply on and with the Coefficient of Friction Investigation will be anonymous.

This form is supplied for grade tracking purposes only. This form will be removed from the investigation immediately upon the assignment of a grade and returned to you.

Your Name Will Only Appear On This Form

Write your name on this form only. Do not include your name or any other identifying information anywhere else on or within this investigation. Thank-you.

Name: __________________________________________________

General Physics I Laboratory

Course Number PHYS1111 Section: ______________________

Grade*: _____________________

*Scores for the written lab report are on a 20 point scale

Submission Instructions

Submit the written lab report and post-lab assessment for this investigation by inserting it into the General Physics Lab box in the bookcase outside of the physics lab, Glaske S107.

Instructor Contact Information

If, at any time, during this investigation you encounter questions or problems please contact the course instructor at:

email: (insert address) Telephone: (insert number)
Pre-Experiment Assessment for the Coefficient of Friction Investigation

Instructions: Complete this assessment **prior** to reading the lab instructions and **before** you have attempted the experiment. Note there are 6 questions; be sure to answer all of them.

1. **Multiple choice:** Circle the letter of the best answer, 2 points each.

1. A general rule for the friction force between solid surfaces in contact states:

   a) the friction force is independent of the surface area of contact.
   b) the friction force is proportional to the normal component of the force pressing the surfaces together.
   c) the friction force is independent of the sliding speed.
   d) all of the above

2. When an object is in contact with a horizontal surface, the normal force is

   a) greater than its weight.
   b) less than its weight.
   c) equal to its weight.
   d) not related to its weight.

3. The coefficient of friction for an object moving uniformly down an incline of angle $\theta$, is equal to the

   a) $\tan \theta$.
   b) $\sin \theta$.
   c) $\cos \theta$.
   d) component of its weight pulling it down the incline.

4. Two independent measurements where made for the coefficient of static friction between surfaces. The reported values were 0.178 and 0.208. What is the percent difference between these values?

   a) 16.9%
   b) 14.4%
   c) 15.5%
   d) 3.0%
II Questions: Refer to the graph in figure 1 when answering questions 5 - 6. (3.5 pts. each)

5. For two surfaces in contact, the friction force was measured for various amounts of normal force. The experimental data is shown in figure 1. Using this information, determine the coefficient of friction between these surfaces.

\[
\text{Coefficient of friction} = \text{______________________________}
\]

Show your calculations or explain how you determined your value.

6. Using figure 1, determine the amount of the friction force when the normal force is 240 N. Show how you determined the friction force either on the figure or with calculations. (Be sure to include units.)

\[
\text{Friction force (when N is 240 N)} = \text{______________________________}
\]
Determining the Coefficient of Friction

OVERVIEW

Friction refers to the resistance of motion occurring between surfaces in contact. The friction force between solids is often characterized by these general rules:

1. The friction force is independent of the surface area of contact.
2. The friction force is proportional to the normal component of the force pressing the surfaces together.
3. The friction force is independent of the sliding speed.

The coefficient of friction, $\mu$, is the ratio of the friction force, $F_f$, and the normal force, $N$, pressing the surfaces together. This relationship is expressed by equations 1 and 2,

$$F_f = \mu N \quad \text{Equation 1}$$

$$\mu = \frac{F_f}{N} \quad \text{Equation 2}$$

When an object is in contact with a horizontal surface, the normal force is equal to the weight, $mg$, of the object.

If the object is in contact with a surface inclined at an angle $\theta$, the Normal force is equal to the component of the weight pressing on the surface, $mg\cos\theta$. When gravity and friction are the only forces present it can be shown, using Newton’s Second Law, that on an incline of angle $\theta$, the friction force, $F_f$, is equal to the component of the weight parallel to the incline, $mgsin\theta$. The coefficient of friction for an object on an incline of angle $\theta$, is then determined by the relationship shown in equation 3.

$$\mu = \frac{F_f}{mg} = \frac{mgsin\theta}{mg \cos \theta} = \tan \theta \quad \text{Equation 3}$$

The amount of force required to move a stationary object is usually greater than the force required to keep it moving at constant velocity. Therefore, two coefficients of friction are typically given for surface pairs, the coefficient of static friction, $\mu_s$, and the coefficient of kinetic friction, $\mu_k$. The coefficient of static friction, $\mu_s$, is usually larger than the coefficient of kinetic friction, $\mu_k$. For this experiment you will determine the coefficient of static friction, $\mu_s$, for two surfaces in contact using two independent measurements, one on a horizontal surface and one on an inclined surface.
OBJECTIVES
♦ After completing this investigation the learner will be able to determine the coefficient of static friction, $\mu_s$, between two horizontal surfaces using a graph of Friction force (represented by the hanging mass) versus Normal force (represented by the block mass).
♦ After completing this investigation the learner will be able to determine the coefficient of static friction, $\mu_s$, between two inclined surfaces using the angle of the incline.
♦ After completing this investigation the learner will be able to compare two independent measurements using a percent difference.

MATERIALS
Wooden Block with Hook  Cardboard  Ruler
Pulley with Clamp  2 Hooks  String
3 equal masses (small cans of Cat Food)  Paper Clips  Quarters
Nickels  Dimes  Pennies
Plastic container to use as a mass holder  Masking Tape

MASS INFORMATION
Mass of Wooden Block with Hook = 219.4 g  Mass of one paper clip = 0.40 g
Mass of empty plastic container = 7.8 g  Mass of one quarter = 5.6 g
Mass of one dime = 2.25 g  Mass of one Nickel = 5.0 g
Mass of one can of cat food = 94.7 g  Mass of one penny = 2.5 g
The mass of the hooks and string are negligible.

REQUIREMENTS
This experiment handout will serve as your written lab report for this investigation. Enter data, answer questions, and provide all information on this form. In order to receive full credit for this investigation you must:
♦ Perform the steps of the Data Collection and fill in the Data Tables for Part A and Part B.
♦ Complete all the steps of the Analysis, which requires providing values for questions 3 and 9, creating a graph using Part A data, determining a linear fit line for Part A data, finding the coefficient of static friction using your graph, finding an average coefficient of static friction for Part B data, and calculating percent difference.
♦ **Be sure a copy of your graph with fit line is attached to this lab report.**
♦ Complete the Conclusion by providing answers to both questions.

DATA COLLECTION
PART A: Horizontal Orientation

1. Setup your experiment on a horizontal surface as shown in figure 1.
a. Place the piece of cardboard on a table and place the wooden block on the cardboard. Orientate the cardboard and the wood so that the largest and smoothest side of the wood block is in contact with the cardboard. The longest side of the cardboard should be parallel with the longest side of the wooden block.

b. Attach the pulley to the edge of the table with the clamp. Attach a hook to each end of the piece of string.

c. Attach one hook to the wooden block and extend the other end of the string over the pulley allowing it to hang over the edge of the table.

Figure 1: Experimental Setup for Part A

2. Secure the empty plastic container to the hook hanging over the edge of the table by inserting the hook into the small hole near the top of the container.

3. Add mass to the plastic container (one item at a time) in the form of quarters, dimes, nickels, pennies, and/or paper clips until the wooden block just starts to move. (You can lightly tap the block but do not push the block.) This movement may not be uniform as the block might start and then stop due to changes in the surface of the cardboard. When the appropriate amount of mass is in the container, the block will move uniformly but very slowly over a smooth section of the cardboard.

4. Remove the coin(s) and/or paper clip(s) from the container and determine the amount of mass that was required to get the block to start moving. Sum the masses in the container, be sure to add the mass of the empty container. (See mass information provided on page 2). Record this value in the data table for Part A under Hanging Mass, $m_H$.

5. Place one can of cat food on top of the wooden block.

6. Find the amount of mass needed to get the block and can moving. The movement should be over the same section of cardboard and similar to the movement observed in step 3. Start with the amount of mass you determined previously and add mass to the plastic container (one item at a time) in the form of quarters, dimes, nickels, pennies, and/or paper clips until the wooden block just starts to move. (You can lightly tap the block but do not push the block.)

7. Remove the coin(s) and/or paper clip(s) from the container and determine the amount of mass that was required to get the block and can to start moving. Sum the masses in the
container, be sure to add the mass of the empty container. (See mass information provided on page 2). Record this value in the data table for Part A under Hanging Mass, \( m_H \).

8. Repeat Steps 5, 6, and 7 for the block plus two cans of cat food.

9. Repeat Steps 5, 6, and 7 for the block plus three cans of cat food.

PART B: Inclined Orientation

10. Setup your experiment on a horizontal surface without the pulley, hooks, and string. Place the same piece of cardboard on the surface then lay the wooden block on the cardboard. Orientate the cardboard and the wooden block as you did for Part A.

11. Slowly lift one end of the cardboard until the block just starts to move, as illustrated in figure 2.

Figure 2: Experimental Set-up for Part B

12. Reduce the angle of the incline slightly and lightly tap the block but do not push the block. You should observe movement similar to the movement observed in Part A, over the same section of cardboard. (Repeat for small variations in the angle until the correct movement has been observed.)

13. For the correct incline measure the vertical distance, \( y \), and horizontal distance, \( x \), as shown in figure 3. Record these values in the data table for Part B.

Figure 3: Illustration showing Incline Measurements

14. Add one can of cat food to the wooden block and repeat steps 11, 12, and 13. (Note: You may want to use a little tape to secure the can to the block to keep it from sliding off.)

15. Repeat steps 11, 12, and 13 for the block plus two cans of cat food.
16. Repeat steps 11, 12, and 13 for the block plus three cans of cat food.

17. **Clean Up:** Be sure that you have restored the experiment area to its original state and have returned all items to the experiment kit.  *Thank-you.*

**DATA TABLES**

**PART A**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Block Mass, $m_B$ [g]</th>
<th>Hanging Mass, $m_H$ [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Condition</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Block</td>
<td>219.4</td>
<td></td>
</tr>
<tr>
<td>Block + One Can</td>
<td>314.1</td>
<td></td>
</tr>
<tr>
<td>Block + Two Cans</td>
<td>408.8</td>
<td></td>
</tr>
<tr>
<td>Block + Three Cans</td>
<td>503.5</td>
<td></td>
</tr>
</tbody>
</table>

**PART B**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Vertical Distance, $y$ [cm]</th>
<th>Horizontal Distance, $x$ [cm]</th>
<th>Coefficient of Friction$^{(1)}$, $\mu_s \tan \theta = y/x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block + One Can</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block + Two Cans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Block + Three Cans</td>
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<td></td>
<td></td>
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<tr>
<td><strong>Average Coefficient of Friction$^{(1)}$, $\mu_s$</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) These values will be calculated in the analysis for part B.
ANALYSIS for PART A

1. Make a graph of Hanging Mass versus Block Mass using the data from Part A. You can use graph paper or computer software such as Microsoft Excel. (Note: Hanging Mass should be on the vertical axis and Block Mass on the horizontal axis.) Be sure to include the point (0,0) on your graph.

   The values used for this graph represent the Friction force (hanging mass) and the Normal force (block mass).

2. Draw the best straight line through the data points on your graph or use the computer program to create a linear fit.

3. Determine the slope of your best fit line or from the linear fit. This value is the coefficient of static friction as shown in equation 2 and should be a value less than one. Record your value for the coefficient of static friction below. (Note: This quantity has no units.)

   Part A Coefficient of Static friction, $\mu_{s_{PartA}} = \ldots$

4. A copy of your graph with the best fit line or linear fit must be attached to your lab report.

ANALYSIS for PART B

5. Determine the coefficient of static friction, $\mu_s$ for each trial in Part B by finding the $\tan \theta = y/x$. Record these values in the data table for Part B.

6. Your values should be less than one and similar in magnitude to the value found for $\mu_s$ in Part A. Consider re-checking or deleting any values that are significantly different.

7. Find the average of your coefficient of Static friction, $\mu_s$, values in Part B. (Use values that are consistent, do not include values that vary significantly from your coefficient determined in Part A.) Record this value in the data table for Part B.

ANALYSIS combining PART A and PART B

8. Calculate the percent difference in the values you determined for the coefficient of static friction in Part A and Part B using equation 4.

   \[
   \text{Percent Difference} = \frac{\left| \mu_{s_{PartA}} - \mu_{s_{PartB}} \right|}{\left( \frac{\mu_{s_{PartA}} + \mu_{s_{PartB}}}{2} \right)} \times 100 \quad \text{Equation 4}
   \]
9. Record your percent difference value below.

    Percent Difference = __________________________

CONCLUSION

1. Which equations and/or general rules described in the overview do you feel were verified by this experiment? Please provide your understanding of how they were verified.

2. After completing this experiment, do you feel you have a good understanding of static friction and friction forces? (Indicate yes or no. If no, please express your remaining concerns.)

CONFIRM REQUIREMENTS

Before turning in your lab report, please check to make sure you have completed all the requirements, as indicated on page 2. Turn in your lab report as instructed.

EXPERIMENT KIT

Please return all items to the experiment kit. Thank-you.

GOING FURTHER (OPTIONAL)

(These investigations are not a requirement for this experiment but allow you to investigate further, if desired. Please note which investigations you attempted.)

1. Investigate kinetic friction by setting up a similar experiment where you determine the mass required to move the block at constant velocity.

2. Repeat this experiment for the smallest side of the wooden block to verify the friction force is independent of the surface area of contact.
3. Consider how you might show the friction force is independent of the sliding speed.

4. Try finding the coefficient of static friction for different surface pairs.

5. Your thoughts or ideas for investigating friction forces:

6. Summarize your experiences with these “going further” investigations:
Post-Experiment Assessment for the Coefficient of Friction Investigation

Instructions: Complete this assessment after reading the lab instructions, conducting the experiment, and completing the lab report. Note there are 6 questions; be sure to answer all of them.

I. Multiple choice: Circle the letter of the best answer, 2 points each.

1. A general rule for the friction force between solid surfaces in contact states:
   a) the friction force is dependent on the surface area of contact.
   b) the friction force is proportional to the normal component of the force pressing the surfaces together.
   c) the friction force is dependent on the sliding speed.
   d) all of the above

2. When an object is in contact with a surface inclined at an angle \( \theta \), the normal force is
   a) \( mg \cos \theta \).
   b) \( mg \sin \theta \).
   c) \( mg \tan \theta \).
   d) not related to its weight.

3. The coefficient of friction for an object moving uniformly across a horizontal surface is equal to
   a) \( \mu = \frac{F_f}{N} \)
   b) \( \mu = \frac{N}{F_f} \)
   c) \( \mu = \frac{F_f}{N} \)
   d) \( \mu = \tan \theta \)

4. Two independent measurements where made for the coefficient of static friction between surfaces. The reported values were 0.192 and 0.167. What is the percent difference between these values?
   a) 13.0%
   b) 13.9%
   c) 15.0%
   d) 2.5%
II Questions: Refer to the graph in figure 1 when answering questions 5 - 6. (3.5 pts. each)

Figure 1: Graph of Friction force, F [Newtons] versus Normal force, N [Newtons]

5. For two surfaces in contact, the friction force was measured for various amounts of normal force. The experimental data is shown in figure 1. Using this information, determine the coefficient of friction between these surfaces.

\[
\text{Coefficient of friction} = \text{__________________________}
\]

Show your calculations or explain how you determined your value.

6. Using figure 1, determine the amount of the friction force when the normal force is 480 N. Show how you determined the friction force either on the figure or with calculations. (Be sure to include units.)

\[
\text{Friction force (when N is 480 N)} = \text{__________________________}
\]
APPENDIX J

GRADING RUBRICS FOR DETERMINING THE COEFFICIENT OF FRICTION INVESTIGATION

The grading rubrics presented herein were used to evaluate the pretest, posttest, and written laboratory report for the determining the coefficient of friction investigation. The pretest and posttest were evaluated using an interval scale of zero to 15 points. The written laboratory report was evaluated with an interval scale of zero to 20 points.

Table J1 contains the grading rubric used to evaluate the pretest assessment for the determining the coefficient of friction investigation. Table J2 is the rubric for grading the written laboratory reports submitted by learners for the determining the coefficient of friction investigation. Table J3 contains the grading rubric used to evaluate the posttest assessment for the determining the coefficient of friction investigation.
Table J1

Grading Rubric for Determining the Coefficient of Friction PreTest Assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part I</td>
<td>Full (2 points each)</td>
<td>indicating the correct letters: 1. D, 2. C, 3. A, 4. C</td>
</tr>
<tr>
<td>Multiple Choice</td>
<td>None (0 points)</td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td>Part II</td>
<td>Full (3.5 points)</td>
<td>0.17 (no unit) with an indication that this is the slope of the fit line or show a slope calculation</td>
</tr>
<tr>
<td>Question 5</td>
<td>None (0 points)</td>
<td>no response, incorrect value, indicating an answer with units, not providing an explanation or showing a calculation</td>
</tr>
<tr>
<td>Question 6</td>
<td>Full (3.5 points)</td>
<td>value between 38 – 44 Newtons with 2 significant figures and illustrating on graph or showing with calculations how value was determined</td>
</tr>
<tr>
<td></td>
<td>None (0 points)</td>
<td>no response, incorrect value, indicating an answer without units, or failing to show how the value was determined</td>
</tr>
</tbody>
</table>
**Grading Rubric for Determining the Coefficient of Friction Laboratory Report**

<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Table</td>
<td>Full (2 points)</td>
<td>values for each of the 4 data points increasing</td>
</tr>
<tr>
<td>Hanging Mass</td>
<td>Deduct ½ point</td>
<td>for each incorrect or missing value</td>
</tr>
<tr>
<td></td>
<td></td>
<td>between 1.0 and 150 grams, 3 significant figures</td>
</tr>
</tbody>
</table>

| Data Table            | Full (2 points) | values for each of the 4 data points, decreasing or remaining approximately the same |
|                       | Deduct ½ point  | for each incorrect or missing value                                       |

| Data Table            | Full (2 points) | values for each of the 4 data points, decreasing or remaining approximately the same |
|                       | Deduct ½ point  | for each incorrect or missing value                                       |

<p>| Data Table            | Full (3 points) | vertical distance divided by horizontal distance for each of the 4 data points |
|                       | Deduct ¾ point  | missing values or incorrectly calculated values                           |</p>
<table>
<thead>
<tr>
<th>Item</th>
<th>Credit</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Table</td>
<td>Full (1 point)</td>
<td>correctly determining the average of the 4 coefficient of friction values, answer has no units</td>
</tr>
<tr>
<td>Average</td>
<td>None (0 points)</td>
<td>no response, incorrectly calculated value, or indicating an answer with units</td>
</tr>
<tr>
<td>Coefficient of Friction</td>
<td>Partial (3 points)</td>
<td>hanging mass versus block mass graph, each axis label includes quantity and/or units, data points identified, linear fit line to data points</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (4 points)</td>
<td>hanging mass versus block mass graph, title, major divisions on each axis, each axis label includes quantity and units, data points identified, linear fit line to data points, and fit equation</td>
</tr>
<tr>
<td>Analysis Graph</td>
<td>Partial (3 points)</td>
<td>hanging mass versus block mass graph, each axis label includes quantity and/or units, data points identified, linear fit line to data points</td>
</tr>
<tr>
<td>Analysis</td>
<td>Partial (1 point)</td>
<td>hanging mass versus block mass or block mass versus hanging mass graph, each axis label includes quantity and/or units, other than a linear fit to data points</td>
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<tr>
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<td>None (0 points)</td>
<td>missing graph, graph without labels, or graph without fit line</td>
</tr>
<tr>
<td>Item</td>
<td>Credit</td>
<td>Responses</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Analysis</td>
<td>Full (1 point)</td>
<td>Record slope of linear fit line with no units</td>
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<td>Question 3</td>
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<td>no response, incorrect response, or indicating an answer with units</td>
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<tr>
<td>Analysis</td>
<td>Full (2 points)</td>
<td>report percent difference value, must be &lt; 10%</td>
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<td>Question 9</td>
<td>None (0 points)</td>
<td>no response, incorrectly calculated value, or a value &gt; 10 %</td>
</tr>
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<td>Conclusion</td>
<td>Full (2 points)</td>
<td>reflective response</td>
</tr>
<tr>
<td>Question 1</td>
<td>Partial (1 point)</td>
<td>response with limited logical progression</td>
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<tr>
<td></td>
<td>None (0 points)</td>
<td>no responses or any other responses</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Full (1 point)</td>
<td>indicate yes or no with an explanation</td>
</tr>
<tr>
<td>Question 2</td>
<td>None (0 points)</td>
<td>failing to respond or indicating a no response without an explanation</td>
</tr>
<tr>
<td>Significant</td>
<td>Deduct ¼ point</td>
<td>per item for an incorrect number of significant figures</td>
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</table>
### Grading Rubric for Determining the Coefficient of Friction PostTest Assessment

<table>
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<tr>
<th>Item</th>
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</thead>
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<tr>
<td><strong>Multiple</strong></td>
<td><strong>None (0 points)</strong></td>
<td>not selecting a letter, selecting more than one letter, or not clearly indicating the correct letter</td>
</tr>
<tr>
<td><strong>Choice</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Part II</strong></td>
<td><strong>Full (3.5 points)</strong></td>
<td>0.21 (no unit) with an indication that this is the slope of the fit line or show a slope calculation</td>
</tr>
<tr>
<td><strong>Question 5</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>None (0 points)</strong></td>
<td></td>
<td>no response, incorrect value, indicating an answer with units, not providing an explanation or showing a calculation</td>
</tr>
<tr>
<td><strong>Question 6</strong></td>
<td><strong>Full (3.5 points)</strong></td>
<td>value between 90 - 100 Newtons with 2 significant figures and illustrating on graph or showing with calculations how value was determined</td>
</tr>
<tr>
<td><strong>None (0 points)</strong></td>
<td></td>
<td>no response, incorrect value, indicating an answer without units, or failing to show how the value was determined</td>
</tr>
</tbody>
</table>
APPENDIX K

LEARNER REACTION QUESTIONNAIRE

(After the two groups have completed experiments using both formats this survey will be administered anonymously using the Blackboard learning management system.)

Instructions: Please answer the following questions by supplying your comments in the spaces provided. This information will be submitted anonymously therefore please feel free to express your opinion. Your input is important to this process and all responses whether positive, negative, or neutral will be helpful. These questions refer to the two experiments you performed independently outside of the laboratory using kits and the two experiments you performed in the laboratory using kits. Please focus answers on your experiences with these experiments.

1. Describe whether or not you were provided with adequate instructions and the necessary materials to independently perform the experiments done outside of the laboratory?

2. Compare the amount of time you spent on the experiments outside of the laboratory to the experiments conducted in the laboratory.

3. Compare your interaction with the laboratory instructor on the experiments performed inside and outside of the laboratory. Was face-to-face interaction with the instructor important to your successfully completing any of the experiments?

4. For the experiments you performed outside of the physical laboratory, how much interaction did you have with other learners in the class? For physics experiments, do you feel interaction with other learners is important?

5. Indicate which laboratory format you preferred, experiments performed outside of the laboratory or experiments performed inside the laboratory, and why?

6. Describe your level of satisfaction with the learning you acquired from the laboratory experiments performed outside of the laboratory compared to the experiments performed inside the laboratory.

7. Please provide any additional comments, suggestions, or experiences you would like to share.

Thank-you for taking the time to complete this questionnaire. Your time and opinions are appreciated.
APPENDIX L

DATA SET FOR TWO DIMENSIONAL MOTION INVESTIGATION

The two dimensional motion investigation was performed by the learners in group one outside of the physical laboratory simulating an online physics laboratory. Table L1 contains the two dimensional motion investigation pretest, posttest, difference, and laboratory report scores achieved by learners in group one. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
# Two Dimensional Motion Data for Group One (Online Delivery Format)

<table>
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<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
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</table>
Learners in group two conducted the two dimensional motion investigation inside the physical laboratory as a traditional or face-to-face laboratory. Table L2 contains pretest, posttest, difference, and laboratory report scores achieved by learners in group two on the two dimensional motion investigation assessments. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
<table>
<thead>
<tr>
<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
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</table>
Data from the two dimensional motion investigation was utilized to construct frequency distributions for the pretest and posttest differences as well as the written laboratory report scores. Table L3 displays the frequency distribution data for the difference between the pretest and posttest scores for the two dimensional motion investigation. Table L4 presents the frequency distribution data for the laboratory report scores for the two dimensional motion investigation. For tables L3 and L4 the data is separated by group.

### Table L3

**Two Dimensional Motion Frequency Distribution Data for PreTest vs. PostTest Differences**

<table>
<thead>
<tr>
<th>Difference in Scores (PostTest Minus PreTest)</th>
<th>Group One (Online)</th>
<th>Group Two (Face-to-Face)</th>
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### Table L4

**Two Dimensional Motion Frequency Distribution Data for Laboratory Report Scores**

<table>
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<th>Laboratory Report Scores</th>
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<th>Group Two (Face-to-Face)</th>
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</table>
APPENDIX M

DATA SET FOR THE NEWTON’S THIRD LAW INVESTIGATION

The Newton’s Third Law investigation was performed by the learners in group one outside of the physical laboratory simulating an online physics laboratory. Table M1 contains the Newton’s Third Law investigation pretest, posttest, difference, and laboratory report scores achieved by learners in group one. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
**Table M1**

*Newton’s Third Law Data for Group One (Online Delivery Format)*

<table>
<thead>
<tr>
<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
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Learners in group two conducted the Newton’s Third Law investigation inside the physical laboratory as a traditional or face-to-face laboratory. Table M2 contains pretest, posttest, difference, and laboratory report scores achieved by learners in group two on the Newton’s Third Law investigation assessments. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
<table>
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<th>Diff.</th>
<th>Report</th>
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<th>PostTest</th>
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<th>Report</th>
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</tr>
</tbody>
</table>
Data from the Newton’s Third Law investigation was utilized to construct frequency distributions for the pretest and posttest differences as well as the written laboratory report scores. Table M3 displays the frequency distribution data for the difference between the pretest and posttest scores and table M4 presents the frequency distribution data for the laboratory report scores for the Newton’s Third Law investigation. For tables M3 and M4 the data is separated by group.

Table M3

<table>
<thead>
<tr>
<th>Difference in Scores (PostTest Minus PreTest)</th>
<th>Group One (Online)</th>
<th>Group Two (Face-to-Face)</th>
</tr>
</thead>
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</table>
Table M4

*Newton’s Third Law Frequency Distribution Data for Laboratory Report Scores*

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<th>Group Two (Face-to-Face)</th>
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APPENDIX N

DATA SET FOR THE NEWTON’S SECOND LAW INVESTIGATION

The Newton’s Second Law investigation was performed by the learners in group one inside the physical laboratory as a traditional or face-to-face laboratory. Table N1 contains the Newton’s Second Law investigation pretest, posttest, difference, and laboratory report scores achieved by learners in group one. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
# Table N1

*Newton’s Second Law Data for Group One (Face-to-Face Delivery Format)*

<table>
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<tr>
<th>Learner #</th>
<th>PreTest</th>
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<th>Report</th>
<th>Learner #</th>
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<th>PostTest</th>
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<th>Report</th>
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Learners in group two conducted the Newton’s Second Law investigation outside of the physical laboratory simulating an online physics laboratory. Table N2 contains pretest, posttest, difference, and laboratory report scores achieved by learners in group two on the Newton’s Second Law investigation assessments. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
Table N2

*Newton’s Second Law Data for Group Two (Online Delivery Format)*

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</table>
Data from the Newton’s Second Law investigation was utilized to construct frequency distributions for the pretest and posttest differences as well as the written laboratory report scores. Table N3 displays the frequency distribution data for the difference between the pretest and posttest scores for the Newton’s Second Law investigation. Table N4 presents the frequency distribution data for the laboratory report scores for the Newton’s Second Law investigation. For tables N3 and N4 the data is separated by group.

Table N3

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<th>Group One (Face-to-Face)</th>
<th>Group Two (Online)</th>
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</table>
Table N4

*Newton’s Second Law Frequency Distribution Data for Laboratory Report Scores*

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<th>Group Two (Online)</th>
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APPENDIX O

DATA SET FOR DETERMINING THE COEFFICIENT OF FRICTION INVESTIGATION

The determining the coefficient of friction investigation was performed by the learners in group one inside the physical laboratory as a traditional or face-to-face laboratory. Table O1 contains the determining the coefficient of friction investigation pretest, posttest, difference, and laboratory report scores achieved by learners in group one. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
Table O1

*Determining the Coefficient of Friction Data for Group One (Face-to-Face Delivery Format)*

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<th>Report</th>
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<td>-1.50</td>
<td>10.00</td>
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</tbody>
</table>
Learners in group two conducted the determining the coefficient of friction investigation outside of the physical laboratory simulating an online physics laboratory. Table O2 contains pretest, posttest, difference, and laboratory report scores achieved by learners in group two on the determining the coefficient of friction investigation assessments. The heading for the difference column is abbreviated (Diff.) and the laboratory report score column has the heading report. Learners are identified by number and the difference is determined by subtracting the posttest score from the pretest score.
### Table O2

**Determining the Coefficient of Friction Data for Group Two (Online Delivery Format)**

<table>
<thead>
<tr>
<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
<th>Learner #</th>
<th>PreTest</th>
<th>PostTest</th>
<th>Diff.</th>
<th>Report</th>
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<td>-5.00</td>
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<td>18.50</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Data from the determining the coefficient of friction investigation was utilized to construct frequency distributions for the pretest and posttest differences as well as the written laboratory report scores. Table O3 displays the frequency distribution data for the difference between the pretest and posttest scores and table O4 presents the frequency distribution data for the laboratory report scores for the determining the coefficient of friction investigation. For tables O3 and O4 the data is separated by group.

**Table O3**

*Determining the Coefficient of Friction Frequency Distribution Data for PreTest vs. PostTest Differences*

<table>
<thead>
<tr>
<th>Difference in Scores (PostTest Minus PreTest)</th>
<th>Group One (Face-to-Face)</th>
<th>Group Two (Online)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5--3</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>-2--1</td>
<td>4</td>
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<td>14-15</td>
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<td>1</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>35</strong></td>
</tr>
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</table>

**Table O4**
### Determining the Coefficient of Friction Frequency Distribution Data for Laboratory Report Scores

<table>
<thead>
<tr>
<th>Laboratory Report Scores</th>
<th>Group One (Face-to-Face)</th>
<th>Group Two (Online)</th>
</tr>
</thead>
<tbody>
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<td>10</td>
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<td>1</td>
</tr>
<tr>
<td>14</td>
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<td>20</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>36</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>35</td>
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</tbody>
</table>
APPENDIX P

LEARNER RESPONSES ON THE LEARNER REACTION QUESTIONNAIRE

Learner responses on the learner reaction questionnaire are presented herein in no particular order and exactly as they were submitted by learners without corrections. One editorial change was employed if learners used proper names a generic term was inserted enclosed by parentheses. The learner responses are grouped by question and the questions are presented in the order they appeared on the learner reaction questionnaire. After the final learner response of the current question the subsequent question begins on a new page to facilitate the transition between questions.

Question 1

Describe whether or not you were provided with adequate instructions and the necessary materials to independently perform the experiments done outside of the laboratory?

Learner Responses to Question 1.

1. We were given the adequate instructions and necessary materials to perform the experiments.

2. The instruction were adequate and the material that given to us was adequate.

3. Yes, materials were provided and instructions were understood enough to complete labs. Sometimes I had to read the instructions through a couple of times, but figured it out in the end.

4. All of the experiments ad highly detailed information about each lab. It was easy to follow the directions and do the necessary work to get the results needed. All of the material was provided. No need for purchasing random stuff, it was all together.

5. Yes. I was provided with all the instructions and necessary materials to perform the experiments outside of the laboratory.
6. I was given the right materials and was given in detail instructions on how to do all the experiments.

7. Instructions were clear with well gathered materials.

8. The instructions seemed almost too detailed at times. The materials were adequate.

9. The instructions and materials provided for the experiments done outside of the lab were enough to independently perform the experiments.

10. I was provided with everything that I needed to perform the experiments outside of the lab. The instruction sheets provided accurate explanations and explained the lab procedure clearly.

11. I was provided adequate instructions and all necessary materials for the experiments outside the lab. They could be set up and done fairly easily.

12. I was provided with adequate instructions and materials to independently perform the experiments outside of the laboratory. I did not have any questions as to the steps that I needed to take in order to accomplish the experiments. I think that the experiment with the balloons needed to have several more balloons in order to account for some of them popping.

13. Yes, I feel that I was provided with adequate instruction and the necessary materials. I was definitely capable to accomplish the experiments done outside of the laboratory.

14. Yes. The experiments were easy to follow, no harder than it would have been in a lab setting.

15. Yes, I was provided with adequate instructions and the necessary materials to independently perform the experiments.

16. Yes, everything was provided to complete the labs in full.

17. I feel that I was provided with more than enough information/materials to perform the experiments done outside of the laboratory!

18. Yes the instructions were adequate and I liked the fact that the labs could be completed on my own time.

19. Yes, I was.

20. Yes. For the most part, the lab instructions along with the packets were adequate for what was required. However, for the balloon lab, it was difficult to get accurate
readings because the balloon kept spinning or turning around the string rather than traveling in a straight line.

21. yes we were provided with everything needed.

22. The material were more than adequate, and provided the best way to conduct the experiments.

23. Yes, I all the instructions possible to understand the labs and also there were plenty of materials to complete the labs.

24. I was provided with enough materials, but the balloons kept getting ripped apart by the tape.

25. During the independent experiments outside of the classroom, adequate instructions were given for the experiment and all necessary materials were given in order for the lab to be completed. For both labs outside of the classroom, a yardstick was helpful in doing most of the measurements.

26. I think that the experiments were well planned out and everything we needed was given to us. I mean it was not always easy to find the space but I think it was well planned out and we were well equipped.

27. The instructions and materials were adequate.

28. I was provided with adequate materials, but I must say the instructions were not quite clear. I performed the lab according to what I understood of the instructions, and I ended up doing it wrong, so I was deducted points (specifically on lab 1.)

29. The instructions were good. The experiments were very clear.

30. Both the instructions and materials were adequate.

31. The instructions were fine to complete the experiments. The smaller materials needed for each experiment were all there, as well. However, finding the space to perform these experiments (such as the second one with the balloons), or, for example, finding a large enough table to do the first experiment on with the tennis ball, proved to be a little tricky in a dorm. Other than that, instructions and materials were not a problem.

32. The materials and instructions provided were very adequate for the experiments outside of the lab.

33. The materials provided to accomplish the experiments outside of class were sufficient. Most of the materials were items that could be found in any household,
and thus needed little explaining. The instructions were more than sufficient and easily understandable.

34. I was supplied with more than I needed to do the experiments outside of class.

35. Yes, I had adequate material and instructions. There were pictures (which helped a lot), and I felt pretty much comfortable with it.

36. Some of the instructions were a little confusing at first, but I was able to figure everything out eventually. It would have been nice to have some extra balloons for the second experiment.

37. I believe that we were adequately provided with instructions and directions. Perhaps too much so. The inclusion of the formulas did make the labs simpler, but they also made it just a "Plug-and-chug" assignment, and not really one requiring any thought.

38. There were definitely enough instructions and we always had enough material.

39. Yes. For the most part it was very clear. The only question I came across was how to prop up the table, whether two legs were to be propped, or just one. Other than that it was easy to follow.

40. For the most part, yes. The only problem I can remember as far as equipment was finding a table big enough for experiment #1. Not too many of us have a table 1m x 1.5 m that we can just move, tip, and roll wet tennis balls on.

41. I believe we were supplied with both the materials and the information to complete these experiments, however the fact that the teacher wasn't there gave way to more of an open approach to doing the labs and perceiving the informations.

42. The instructions were very well defined. The purpose of the experiment along with any necessary information and processes were very helpful. I had no problem completing the labs on my own or in class. The materials contained in the lab kits was also fine. The equipment that the student was expected to have was reasonable.

43. I think adequate instruction was provided. The returning of the materials was kind of pointless.

44. Yes there was adequate instructions and materials for the experiments. The instructions could explain a little more clear what the objective was, but other than that it was good.

45. Yes all the materials were provided and the instructions were perfectly clear.
46. I was provided with adequate instructions and the necessary materials to independently perform the experiments done outside of the laboratory.

47. Yes, the instructions were easy to follow and I had all the necessary materials to complete the experiments.

48. Yes I was

49. The instructions were very helpful and thorough. There was more than enough material to complete the lab.

50. Yes, all of the instructions, and materials given for the experiments were adequate for completing the experiments.

51. The instructions were well specified, and all the materials needed were adequately provided.

52. I was provided with adequate instructions and the necessary materials.

53. Yes, I had all that I needed--because I do not know much about Physics I still had to ask questions after the experiment was finished but I had everything to actually perform the experiment.

54. Yes I was provided with everything needed. I did run across some problems with the expectations of accuracy on the first one. I tried multiple attempts to get it correct by the book, just to find out that the experiment allowed for error. It was just sort of frustrating not having a professor present to help me out.

55. The lab packets provided were more than adequate. All of the procedures were clearly spelled out and the materials were provided.

56. Yes, I felt that I had enough instructions and materials to successfully complete each of the experiments outside of class. In each lab, I felt that we had more than enough information to complete the experiment, and was never confused about what to do.

57. Yes, I think we were provided with all the instructions and materials that we needed for our outside experiments. The instructions for the experiment was very self explanatory.

58. I felt that the instructions were thorough enough to follow and complete the experiment on my own. The materials provided were also satisfactory.

59. I was given clear instructions and given the necessary materials to perform the experiments.
60. The instructions and materials provided were almost enough for the out-of-lab experiments. Discrepancies between the terms and units used by the class professor and lab professor make working on an out-of-lab experiment sightly difficult without introduction to the terms.

61. I had good instructions and the right material.

62. I feel that the materials in the lab packet where adequate to perform the labs outside of class. The instructions were clear for the most part. There was a few times that my group had to read the instruction a few times to understand the instructions.

63. Instructions and materials were adequate to perform out of the laboratory. The instructions were easy to understand and the picture or diagrams really helped.

64. Yes, I was.

65. Yes very adequate.

66. Were provided with necessary materials and adequate instructions.

67. We were provided with adequate instructions and materials outside of class to do the experiments at our leisure.

68. I found that the explanations in the kits were quite comprehensive. There was very little other information required if any in most cases, though working with others on these experiments helped considerably.

69. Adequate instructions and the necessary materials were supplied

70. We had enough materials supplied for the lab experiment performed outside of class.

71. I was provided with adequate instructions and the necessary material to complete the labs outside of class without any trouble.
Question 2

Compare the amount of time you spent on the experiments outside of the laboratory to the experiments conducted in the laboratory.

Learner Responses to Question 2.

1. From my experience, it took longer to do the labs in lab because I had no selection of whom i did it with. I found it easier to get a group of people together that I knew/wanted to work with and perform the experiment. All told the labs at home took less of my time.

2. I spent about half the time in the lab as I did at home. I think this is b/c there are multiple people in the lab group and a teacher is accessible.

3. They were about the same. I really liked being able to do them on my own time instead of coming to an evening class.

4. It took about the same amount of time.

5. I spent less time out of lab. I work well on my own pace.

6. I probably spent the same amount of time on the experiments outside of the lab as I did in the lab, but I was glad to be able to preform the experiments when it was convenient to me.

7. I spent about 30-40 more minutes outside the lab due to doing the experiements solo instead of splitting up responsibilities.

8. The amount of time I spent on the experiments was about the same in and out of the laboratory.

9. The time it took to do the labs outside of class took more space but were pretty much the same amount of time and difficulty.

10. The time was the same. They both required reading the material to prepare, and doing the experiment was the same.

11. I found that I spent less time on the experiments in the laboratory than I did outside of it. Especially in the case of the balloon experiment; it was difficult to find a big enough space and set up efficiently outside the lab. However, I generally worked with fewer people outside the lab than in the lab.
12. The time was about that same. Maybe a little longer in the laboratory because of the amount of people in my group.

13. About the Same.

14. The time was about the same.

15. I think a little more time was spent on the experiments outside the lab. I think this was because the time spent setting up the things to do the experiment took longer.

16. The experiments that we did outside of class were easier than the ones we did in class. I spent more time on the labs conducted in the classroom than on the take-home labs.

17. Probably about the same amount of time. While it was nice being able to do it on the weekends and just turn it in, actual time involved was still about equal.

18. I spent about the same amount of time on each.

19. I think I actually spent about 10-15 minutes longer out of lab. Probably part of the reason is that I had to do everything on my own. I suppose that's mostly my own choice for working alone.

20. I spent about twice the time on an outside of the lab experiment due to the group effort involved on an experiment in the lab.

21. They are about the same.

22. The times were about the same for the in class and out of class assignments. If there was a difference it seemed that the in class experiments did take a small amount more time than the out of class experiments.

23. With the experiments outside of the laboratory you can just read at your own pace, and go however fast you want. In the lab however you have to go as fast as everyone in your group so you might not get all the information that you could if you went slower.

24. The time was comparable. The biggest things that I prefer about doing the labs in class, is that you don't have to spend time hunting for a suitable place, then setting up your workstation. Also, when you do it during your lab time, and finish early, you feel like you've accomplished something.

25. I spent about the same amount of time doing the experiments outside of the lab as I spent doing them actually in the lab.
26. The amount of time spent was approximately the same. Setting up for the experiment was a little of a hassle, since finding a long table, or finding the space to do the experiment required more creativity.

27. It seemed to take the same amount of time in and out of class if I worked with a group. I think it would take quite a bit longer outside of class if I had to work alone.

28. I spent maybe a few minutes less outside of the lab than I did when in the labs.

29. The time I spent on experiments outside the laboratory was about the same amount of time I spent on the experiments in the laboratory.

30. The experiments outside the lab took slightly longer than in the lab.

31. I spent less time in the laboratory, because contemplating things took less time when you had four minds available via lab partners.

32. More time outside lab however, it was convenient to my time to do the lab when I wanted to.

33. They were comparable, but having the freedom to do them at any convenient time was definitely a major plus.

34. The time spent on the experiments outside of class was a bit more than when the lab was conducted in a classroom.

35. Similar amounts of time spent on each. Both times I worked in a group, and the two of us managed to finish in the same time that it took in lab.

36. I spent slightly more time outside the lab than in the lab.

37. I would say that they were very similar in time spent.

38. The experiments done outside the lab took slightly more time than the experiments done inside the lab.

39. The amount of time spent on both experiments inside and outside of the laboratory were about the same. Both labs outside of the lab took around an hour or so. Inside the classroom, they took about an hour and a half.

40. well outside of lab I always put it off and totally forgot about it untill I didn't have much time left. In the lab, I can get stuff done much quicker and I have people to help me with the experiment.
41. I spent the same amount of time on experiments outside of the laboratory that I would have with the experiments in the laboratory.

42. It was about the same, maybe even quicker when doing it at home. The big problem was finding a table or a long hallway

43. Experiments took less time in the lab because I could focus better and I had the assistance of an instructor.

44. I would say that it took approximately the same amount of time to do the out of class experiments as it did to do the in class ones.

45. The experiments in the laboratory took about the same time as the experiments in the dorm, and the dorm was more homy, but the lab had the instructor there in case we had any questions.

46. All of them took about the same time.

47. About the same amount of time for both.

48. The experiments I completed on my own were completed quicker than the ones in the lab due to the fact that in lab, I had to work with several other people and we had to wait on each other. I would rather work at my own pace on my own.

49. I definitely took less time outside of the laboratory because I was working on my own, so I didn't have to wait for anyone.

50. They were almost the same actually. The time it usually takes us in the lab is about 35-45 minutes and the same is true for the lab projects.

51. I spent about the same time outside of class performing the experiments as I did performing the experiments in class.

52. The both took the same time, it was just how quickly you wanted it to get it done.

53. The amount of time that I spent on the experiments outside of the laboratory to the experiments inside of the laboratory is just about the same. It took me on average between one hour and an hour and a half to complete the experiments.

54. It was approximately the same amount of time

55. I would say they were about the same. I think it seemed to take a little longer in the lab because I was distracted by those I was doing it with. When they are more opinions it seems to take longer than when you do it on your own. But I did not find a great difference.
56. I spent a little more time on the labs performed outside of the lab. This was because I worked with one other person. When I performed the lab in lab, I worked with 3 other people. This allowed the lab to be completed in a short period of time.

57. I spent more time on the labs that were outside of class. Part of this time difference could have been due to the factor that I did the labs outside of the laboratory on my own and the labs in the laboratory with three other people.

58. When doing the labs on my own, it took longer to set up and tear down the experiment and to take measurements.

59. I spent a little bit more time outside of class. It took me longer because I didn't have a group like I do in class.

60. I spent more time on the experiment outside of the lab due to the fact that I had to read over the instructions more than having the teacher help me in class.

61. It was about equal, but I believe I spent less time in the lab getting the experiment done than outside the lab because I was easily distracted and didn't stay as on task as I did when I was in the lab.

62. Both the experiments in and out of the laboratory took around the same amount of time.

63. I spent about the same amount of time in both settings.

64. I spent more time on the experiments out of lab that in the laboratory. This was mainly because my lab partners were rushing to finish the lab early during the in-lab experiments. That detracted from my reading and understanding of the material provided.

65. On average, the experiments outside of lab took me 30-45 minutes to complete the lab. However, in lab, it usually took me a little over an hour to complete the lab.

66. The time taken to do the experiments was about the same in and out of the lab

67. They took slightly a longer time outside of the laboratory. This however was because the experiments could be worked on collectively in a small group inside the class.

68. I think that the time spent in the lab was normally less than the time I spent outside of the lab. The ones I did outside of the lab normally took about 1:15 and the ones inside the lab took between 45 min to an hour.

69. The experiments took a little longer to conduct when they were done in the lab. It is still possible to complete the experiments in both settings fairly quickly.
70. The time I spent in or out of lab was the same. I did like the flexibility of performing the experiments out of lab, because it allowed you to perform the lab when you had time.

71. I think I used the same amount of time in and out of the lab. I wanted to fully understand what I was doing whether or not I was in the lab or at home.
Question 3

Compare your interaction with the laboratory instructor on the experiments performed inside and outside of the laboratory. Was face-to-face interaction with the instructor important to your successfully completing any of the experiments?

Learner Responses to Question 3.

1. No, face-to-face was nice in case we had an issue, but it was not necessary at all. I found the labs packet to have all that I needed for lab.

2. I do appreciate the help inside the classroom so if I had a question I would not have to guess what the answer was.

3. Face-to-face interaction was not required but it did help many times.

4. No, I didn't need an instructor. The labs were well explained.

5. No, face to face interaction was not necessary.

6. Well, I thought that this particular aspect of this study was odd. I asked the instructor maybe two questions on experiments in the lab. I did not see any significant difference in professor input between the two experimental settings, but then we were using the rather comprehensive lab sheets both times.

7. It was not really a burden to have. Face to face could be good for certain people but I felt that it was fine.

8. The instructions were very detailed, so I did not need much help on it very much.

9. It was important and I am glad that we had an instructor there for the experiments done in the lab. It is surely good to be able to ask questions if need be.

10. I didn't think it made a difference whether I performed the experiment in class or out of class. Having the instructor there didn't make a difference because the lab's were self explanatory.

11. No, face to face interaction with my instructor was not important in any of these experiments.

12. No, it was not too important because my group usually knew what to do.
13. Not really the hand-outs were self explanatory and the instructor if asked any questions just gave an okay to verify if we were doing the experiments correctly.

14. I didn't interact with the instructor outside of class, and in class the instructor was helpful to speed things along.

15. My interaction with the instructor was of course greater in the laboratory, but I did better and was more complete on my labs done outside the laboratory, at a time of my choosing.

16. I did not interact with the instructor either inside or outside of the laboratory. I had no questions that needed answering. My lab group worked well to make sure everyone knew what was going on.

17. I did not interact with the lab instructor during the out-of-lab experiments. Overall, that did not detract from my ability to preform the lab. During the lab, the instructor did not attempt to interact very much. In most of the labs I've had, face-to-face interaction with the instructor was important. In this lab, there wasn't much interaction at all, and what there was didn't help my success.

18. The instructor's help was not needed for the most part on the experiments that were done. Where help was needed, the instructor easily corrected us.

19. A face to face interaction with my instructor really helped me with the things I didn't understand.

20. Interaction with the instructor when doing the labs in the laboratory was helpful because I had some questions on some of the labs. When I did the labs outside of the laboratory, I had to try and figure out the questions I had on my own which took a lot more time and I would usually end up getting them wrong anyways.

21. Face-to-face instruction was not an important factor in completing the labs. I learned just as much outside of lab as I did inside the lab.

22. No face to face interaction was required.

23. I do think face-to-face interaction with the instructor is important in order to successfully complete the experiments. The reason I say so is because when I did the experiments outside of the lab and I had questions as to what the results meant or trended towards I didn't have anybody to ask. It would have been very easy to misinterpret some of the results especially if I completed the experiment wrong. At least in the lab groups can ask questions to help explain results.

24. I didn't interact with the lab instructor when I was performing the labs out of lab, but in the laboratory I did ask questions and interact.
25. Face-to Face interaction was pretty important because I could get an answer immediately after I asked it.

26. I preferred having the instructor in the lab to help with questions. There were times when doing the labs outside of the laboratory that it was hard to figure out what to do. Having the instructor there to answer questions was nice.

27. Not required but (my instructor) did answer some questions very quickly for us that might have taken a while longer for us to figure out by ourselves.

28. Face-to-face interaction was not necessary in our successful completion of the experiments - both inside and outside of the lab. The directions we were given were straightforward and easy to follow.

29. I feel that I was able to complete the labs out of the classroom successfully. However, certain questions arose that I could not ask on the spot. Instead, I had to wait and ask the lab instructor the next day.

30. I did not interact with the instructor inside or outside of the laboratory.

31. I had to ask my instructor questions on all of the experiments to make sure I understood the concept but I did not have to ask questions about how to do the experiment.

32. The first experiment outside of class I had to get some help from the instructor before turning it in. The other experiments I was able to understand and complete without assistance.

33. No.

34. Neither the experiments in lab or lab required any help or interaction with the instructor.

35. no instructor help was not needed.

36. For some of the later experiments it was a help that we could go straight to the instructor. Mostly we could figure out in our group what was going on and didn't really need any further help.

37. Not really. Some of the information that the instructors gave could have been included in the lab packet and then done by the student.

38. No, the experiments were straightforward and you didn't need the additional help with the instructor really. If you wanted to make sure of an answer I guess the instructor would be important for that.
39. I didn't really interact a whole lot with the instructor in either case.

40. Um... with the experiments that we did in lab, it was good to have face-to-face interaction, simply because the labs themselves were harder, and we wanted to double-check to see if our answers were in the right range. But of the labs we did on our own, we had no assistance whatsoever, and we did great.

41. I found that working in group of two or three outside the laboratory was about as helpful as having a teacher available during in-class experiments. I did not need to communicate with the professor during independent experiments.

42. While not vital, I did like seeing a professor there, taking a personal interest in our experiments, making jokes with us, and just showing that they cared. While it never happened to us this semester, I've had times in the past where the instructor pointed out a subtle mistake that we were making, and wouldn't have noticed until the grade came back and we failed. I think having the professor there is a severe boon to anyone trying to do the experiment.

43. No.

44. I didn't interact with the instructor outside of the actual lab itself. In the lab the instructor was able to introduce the lab and answer a question or two regarding the interpretation of what a question was asking but that was it.

45. Face-to-face interaction with the professor was not necessary to complete any of the experiments. The fact that the professor was available *in person* to answer questions on the last two labs certainly allowed us to work through certain hang-ups in them much quicker, but I don't think the professor would have been crucial to finishing any of the 4 labs.

46. Having the instructor answer a few questions regarding the theory of the experiment was nice in the lab, but the instructor made it clear that if we had questions about the outside labs, we could ask.

47. No, the instructions were sufficient to complete the lab. The help from an instructor was not necessary.

48. Face to face interaction helped a little bit, but for the most part I could have completed the labs without the instructor.

49. I liked the face to face interaction between me and the instructor.

50. It was not vital, although in a way it was psychologically comforting to have the instructor around in case any questions arose. The experiments were of a level
that was simple enough to not have to have and instructor, but still taught the subject well.

51. I think so. I feel like it's important to have the instructor present to be able to help with any questions. However, the instructor did supply home phone number in case there was a question, was I guess is good for people that are good on the phone.

52. nope.

53. Face-to-face instruction was helpful in cases of indecision when setting up the lab or deciding what certain parts of the written assignment were correct; however, they were not needed in both at-home assignments which I did not see the instructor at all and got good grades on them.

54. I had no interaction with the lab instructor outside the lab. I had very low interaction inside the lab.

55. The face-to-face interaction was not necessary on any of the experiments. I didn't consult the instructor on any experiment.

56. It was beneficial to work in class with because the instructor was there to help and answer questions. But if I ever had a question (my instructor) was available during normal lab periods to answer them.

57. Face to face interaction was helpful. When I needed it, not having instructor contact really slowed me down.

58. I feel the experiments were fairly self explanatory.

59. Yes, face-to-face interaction was Important to me, because it helped me to understand what the lab is asking for.

60. The laboratory instructor was more than helpful. During one of my experiments in the lab, my lab. partners and I were confused and the instructor explained and helped us to understand the concepts better. For as the experiments done outside of class, an instructor wasn't needed because the material was very informative and easy to understand.

61. I really had no interaction with the instructor. Interaction was not important in any of the experiments.

62. Yes, it was very nice to have someone there in person to explain some stuff to me.

63. There was virtually no interaction with the teacher on the experiments.
64. When doing the labs in lab, I didn't actually need to ask the instructor anything. The materials and instructions were satisfactory and so there was no point in asking the instructor.

65. outside the lab the instructor was not needed. And we were offered my instructors email just in case we needed assistance.

66. When in class, I only asked (my instructor) one question during both experiments. The handouts provided most of the answers I needed and what I needed help with could have been asked easily through email.

67. No, it didn't seem to really matter one way or the other the explanations were strait forward enough that we were able to get them complete without the instructors help on either of the two different formats. Though I am sure there would probably be times when the face to face interaction would be nice.

68. I did not interact with the instructor outside of the classroom. This might have made my ressults differ on one of my experiments

69. Sort of, in the third lab,(the instructor’s) help was really needed when explaining the graphs-how to use the program and interpret it. Besides that, and the question involving propping legs, i would say interaction was not completely necessary.

70. No, not really. I didn't need much face to face interaction either inside or outside the classroom.

71. I had a few questions on some of the experiments that made it convenience to be in the lab, but not any questions that I could have probably found out from another student or figured out myself if I looked at the problem long enough.
Question 4

For the experiments you performed outside of the physical laboratory how much interaction did you have with other learners in the class? For physics experiments do you feel interaction with other learners is important?

Learner Responses to Question 4.

1. Like I said earlier, I prefer having the labs at home because I could select the friends whom I wanted to do it with. I feel it was important to have my friends helping me with the task.

2. I did "Newton's Third Law Investigation" with a group of about five other friends. The others I did by myself. Either way worked for me. If there is something I have to learn that is confusing to me, I would rather do it on my own and use the group to ask any questions I may have. I already had a pretty good grasp on Physics, though, so doing it with a group is fun. I think on an engineering campus, people have other people to ask any of their questions and having the students do the lab on their own in an environment with a lot of other engineers around is the perfect learning environment. However, there are those few people who come from off campus and whatnot that don't have people to ask questions, but even then they have the instructor they can call.

3. None, I do feel that having more people help me to understand the lab.

4. I did the labs with one other student. I feel the more people I can do the lab with the easier the lab is to accomplish. I think I learn about the same, however, either way.

5. I was able to meet with and work with other members outside of class, in a setting that was a little more informal. I feel that this interaction is important; the feedback I received from my peers and the collective analysis work helped immensely.

6. None--I usually work alone on any project

7. For the labs outside the class I interacted with one other class member throughout the entire experiment. I also would interact with others about certain questions and results, but not to the degree that I would have in the physical lab. I think there needs to be a balance of interaction because it is good to discover things for yourself instead of always relying on others. However, it is also beneficial to have some insight and guidance from others when things are not clear.

8. All the experiments I did were in a group of 2 or 3 other people
9. I did the experiments with a small group of students, having the extra hands made the experiments work smoother and the extra brains made figuring it out a little easier. I think the interaction was positive, we helped each other out and interacted more than we would have inside the laboratory.

10. outside the lab i worked alone. In lab I worked in a group. I learned about the same

11. For one of the experiments I had interaction with only one other person. For the second experiment I had interaction with two classmates. I do feel that the interaction with other learners is important. Interaction leads to questioning, and questioning leads to good discussion as to why things are done. I think without interaction there is an easier chance for error. Other people can help correct errors in performing the experiments and also thoughts obtained after the experiment.

12. I worked with one other person outside the laboratory. Interaction with other learners is important because you can learn from the other person and you can save time by completing two things at one time.

13. Outside of the laboratory I would perform each lab with at least one other student. Working with another student allowed me to share the work load and complete the experiment faster. It also allowed me to ask questions and get answers when I was confused.

14. I think that interaction if very important. I usually did the lab with at least 3 other people. You learn for other people and help other people learn as you share your knowledge.

15. Outside of the laboratory, I did not have hardly any interaction with other class members. The only time I had interaction was for one lab I asked another class member two questions about what we were supposed to do. I think that interaction with other learners is not essential for conducting physics experiments, but it is helpful.

16. I basically performed them with one other individual. I attain more interaction within the classroom experiments than that of outside the classroom.

17. I didn't interact with other students

18. Outside of lab, I worked with two other people from my dorm floor. During the in lab experiments, working with other people greatly added to my knowledge and understanding of the material discussed. Without each others inputs, it would have been much harder to do the in lab experiments.
19. In the out-of-lab experiments, I did not interact with any other learner. In this lab, being with other learners detracted from my learning because they were rushing to finish and leave.

20. Normally, I find interaction with a lab partner is useful. It helps me to talk to someone else so that we can correct each other's mistakes or misconceptions.

21. Having a lab group, we interacted a great deal in reading the experiment out-loud and a few people putting the experiment together. I feel that interaction with other learners is important because the people who understand it the best can help teach the other people who don't understand it as well.

22. Interaction outside the laboratory was minimal. It also didn't seem very important.

23. I had quite a bit of interaction because I worked in a group of 4 people. It helped me a lot because I had to make sure that I knew what I was doing so that I could help the others. I think that interaction with other students is important to learning.

24. I did all my experiments with someone. Yes, I feel the interaction is important.

25. I got together with another person from another class and completed the experiments.

26. For all of the experiments I worked together with other students. This was very helpful to figure out how to perform the lab described in the instructions and to discuss the ideas behind the lab.

27. It is important if you don't understand the material and you don't really want to ask the instructor, but other than that you really don't need the interaction.

28. I felt that it was important in the whole scheme of things. For both types in class and out of class I worked with various partners and they were able to help me understand some of the ideas and I was able to help them with some of the ideas that we may not have been able to get with out the partner interaction.

29. I always did my experiments with at least one other person. I think this is very important because any items that you don't understand can be solidified by others in your group and vice versa.

30. I work with two other learners from the class on the experiments done outside of lab. I think this helped to confirm what we were doing was right.

31. I performed every lab outside of the physical lab room with at least two other partners, it was important to get their views and perspectives on the issues.
32. I really couldn't care. The first lab I did by myself, the second with guys in my dorm. Both times I finished in plenty of time, and do not consider their interaction essential to my learning experience.

33. I did both of the outside experiments with two other people, and I do believe that interaction was helpful as multiple opinions make for clearer answers.

34. For outside- I talked about the lab, but only after I did it. For inside- We did the lab together in a group.

35. I did both the experiments outside of lab completely on my own. I don't think that interaction with the other students is necessary, although for some it may be helpful. I think physics lab is more about understanding the relation of physics to the world than it is to students. If extra help is needed understanding something, then of course, I would ask someone else.

36. I asked a few of my friends that take the same class to see how they set the experiment up. It helps to have other people because you have a lot more ideas in one place.

37. I always worked with another student. I feel that interaction with other students is vital for understanding because mistakes go unchecked if you operate alone.

38. I had no interaction, though it might have been helpful, for time and effort's sake, as well as comparing results etc. with what other people/groups came up with.

39. I performed my experiments with another person, which I believe helped not only with motivation, but also in preparing for the experiments.

40. I did my labs with other people. It was great to have others to help me in aspects I didn't know, so we complemented each other. Doing it by yourself is a bit harder, and it's easier to make mistakes. We kept double checking our answers with each other.

41. The major thing that the "outside of class" labs have going for them is the fact that we can work with floormates and friends not in our lab section. I had a major interaction with other students outside of class, and I feel that it is very important to have people to bounce ideas off of, and to work things out so they can correct mistakes you make and vice versa.

42. I had no interaction with other learners. I think interaction can be beneficial but is not crucial.

43. Interaction was another learner was not necessary, but helped in the set up, the actual experiment, and take down of the experiment.
44. I had interaction with one other person and it was just to help us both get it done at the same time. It did not really help anymore than not having him there.

45. The group interaction was a big help and i was able to do it whenever i had the time with the group in general. I do feel the interaction with others is important because the way the instructor teaches something might not be an easy way to remember something but another learner could have better input on the matter to make things easier.

46. Once outside of the laboratory, I did not have nearly as much interaction with other physics students as I did in the lab. Outside of the lab I worked with one other person. Inside the lab, I worked with three other people. I think that interaction with other learners is extremely important, especially for set up purposes.

47. I worked with (the same partner) both times. It is hard to say.

48. I did all of my experiments in and out of lab with other students and I believe that it helped the learning process having other perspectives on the same problems.

49. I worked by myself for the experiments done outside of the lab.

50. Sometimes, it can help with questions.

51. Interaction is good. As long as you have help to assist you in the labs at home. Some experiments might require at least two people.

52. I basically did the lab with the same people outside of class as in class and there wasn't a difference. I think doing the other experiments with other learners is important.

53. I usually performed the lab with one other student from the class. There was more interaction in class with other students though, but is not necessary to complete the lab. It is important to a certain extent.

54. For both of the out-of-lab experiments, I worked with another classmate. We were able to talk through it and work through it together. I don't feel that I necessarily needed that interaction with other students; I probably would have been fine without anyone else.

55. Each lab I conducted was with another student. Each time we had good interaction as how to conduct and learn from the experiment.

56. I had interaction with two other students for the experiments. It was very important to have that interaction, as I would have gotten a whole lab wrong if I hadn't had someone to back me up.
57. I do not feel that interaction with other members of the class was necessary for me. Others may need to work in groups.

58. I did all my "outside" experiments with others in physics lab. YES, I feel interaction with other learners is important.

59. I performed the lab experiments with most of my lab group, so it was pretty much the same as being in lab. Interaction with others is very important to be able to confirm that you're thinking in the same way the others are.

60. I did all the outside labs with other people in the lab. Working together made it go faster, and easier to understand with all of our inputs on what was going on.

61. I had a lot of interaction outside the lab. The interaction definitely helped make things more clear.

62. Interaction helped me to stay focused on the experiment.

63. I had almost no interaction with others in the lab, I do think that physics experiments should be done with a collective mind.

64. For both experiments done outside of the classroom, I used other physics lab students to help split the work and make certain that we all understood how the assignment was done. It was very helpful to work with one or two other people outside of the classroom.

65. I did all the experiments on my own outside the lab. I learned all I needed to and I do not feel as if interaction between students is important.

66. On the outside labs, I worked only with one other person and that was only because we thought we could save time by working together instead of finding outside hands to help with some of the tasks.

67. Yes it was very important to work with other people because it helped to solve problems and we were able to talk through the situations and compare thoughts among one another.

68. None. Interaction was helpful to clarify things we did not understand.

69. I had no interaction with other learners, and I feel that it is important to have interaction with other learners, so that you have four minds working on one project rather than one.

70. There was essentially no interaction, and I did not feel that was important.

71. None, learning in the group helped my grade a little
Question 5

Indicate which laboratory format you preferred experiments performed outside of the laboratory or experiments performed inside the laboratory and why?

Learner Responses to Question 5.

1. Outside the lab. Because it allowed me to pick the time, place, and with whom I did the experiment.

2. Inside, due to the fact that we had the teacher to help.

3. I prefer labs done inside the lab. I have this opinion b/c I was able to complete the labs with equal understanding for both formats, yet the experiments done in lab were done much quicker. They were done quicker b/c of access to a teacher and an increase number of students to draw insights from.

4. Both worked just as well.

5. I preferred experiments performed outside of the lab because I could complete them on my own time and have Monday afternoons free.

6. I think that I learned the same amount in both labs so from a stand point of learning both are comparable. I liked working in the lab better though because I like to work together with other people so finding a time when everyone could get together was difficult some times.

7. Outside the lab was much better.

8. I enjoyed the experiments outside of the assigned lab because I was able to do them at my own time and that relieved some of my class schedule.

9. I liked being able to do it outside of the lab because I could do it on my own time--as long as I could still e-mail or ask questions

10. I feel that either way would work just fine.

11. I liked the outside of lab experiments because I could choose the time, instead of having to follow the school schedule and plan around that. I was able to do it in a less formal setting where I was more comfortable to voice my opinions and ideas. I feel like the group I was with shared more information about their understanding of the experiment then they would have if we had been in lab.
12. I prefered performing experiments inside the laboratory. The collective group that we were allowed to work in made things go a bit faster.

13. I prefered the experiments performed outside the lab because we could do them whenever it was convenient for us. There was no set time set-aside for it, so we could spend that time doing other things.

14. I prefer experiments inside the laboratory because you can communicate with the instructor and your group members and all the supplies that you could need are there at your disposal.

15. I personally prefer the experiments outside of the lab room. I prefer it because I can choose the time that best fits my schedule. Also, the labs seemed a little easier.

16. I prefered the out-of-lab experience 1) because my in-lab partners were not interested in learning from the lab and 2) because my presence in the lab did not afford me any extra benefit, largely because the lab was the exact same format as the out-of-lab experiments.

17. I actually preferred working in the lab because it was easier to get my group together at one time that was designated than trying to get everybody together at a different time outside of school. I also stayed more on task because I wanted to get the experiment done quickly and efficiently. Being outside of class, it was easy to have a lax attitude about getting it done.

18. Personally, I liked having lab inside because I sat down and did it in one sitting and one place. For both experiments outside the lab it was difficult to find a good place to perform the experiment because of the materials and space needed. I also tended to forget about lab and ended up doing the experiment the night before it was due so it added stress if there were conditions that did not fit as well.

19. I preferred experiments inside of the laboratory. Having a set time to get them done helps to stave off procrastination and late nights. Also, I enjoy the interaction with the other students as well as the teacher. I think more care may be taken in a lab setting just because it is a lab setting.

20. I preferred performing the experiments in the laboratory, because it allowed me to ask the instructor questions when I needed to; it also gave me the space I needed for each lab. Sometimes it was hard to find the space to perform the lab in the dorm.

21. I prefered the experiments outside the laboratory because I was able to do them at whatever time and place was most convenient for me.
22. I prefer the experiments performed outside of the laboratory. I was able to take my
time with the experiment and perform them at my own will. Inside the classroom,
my group rushes to get done.

23. I prefer experiments performed inside of class. Having a specified class time helps
to get the lab done on time and out of the way.

24. Experiments performed inside. The time spot is already there and you go in and do
your thing and then leave. It helps to have a set time.

25. Inside, because then I can't procrastinate.

26. Outside the laboratory was good because you are able to do it at anytime you are
available rather than showing up for class.

27. Outside the lab enables to perform the experiment when the time is right for you.

28. I prefer to perform experiments in the lab. There are more people to interact with to
be sure one is accomplishing the objectives. Furthermore, the facilities are generally
free to work in, whereas in a dorm room situation you have to deal with all the other
clutter around you.

29. Mainly the experiments outside of the class because i could choose whoever to help
me on the experiment but there was also the option to go into the lab room and ask
for help from the teacher so it was more of an opportunity.

30. I preferred doing the experiments in the lab because it gave me a set time to do the
lab and provided less distractions.

31. Outside, i could do them on the weekend when i had free time to do stuff.

32. Outside the lab were more convenient and yielded the same general results. I
enjoyed more experimenting with others and hearing their opinions.

33. I preferred experiments performed outside of the lab b/c I could do them on my own
time and with people that I wanted to.

34. I preferred out of class because I could do them when I had extra time in my day. I
don't like having lab every afternoon of the week and it is nice to have a break on
Wednesday afternoon.

35. Outside of the lab so i can pick the time when i do the experiments
36. I actually prefer working in the lab to be able to work with other students and not have to set everything up on my own and find a good space in which to work in my dorm room.

37. Outside was nice because I could do them on my own time.

38. I enjoy performing the labs outside of class because it lets me choose when I want to work on it.

39. I preferred inside because the group interaction was helpful to have a better understanding.

40. I preferred the laboratory setting because I could focus better.

41. I preferred the experiments outside of the laboratory because I could do them on the weekend and have the time off of lab during the busy week.

42. I preferred experiments done in the laboratory, because of instructor and learner interaction.

43. I preferred the outside labs, because it allowed me to work on them at times that were convenient to me and not at a set time. Meaning that I did my labs in the late evenings during my down time instead during the middle of the day when I have other classes on my mind.

44. I like the experiments done in the lab. I was able to spend time with friends, and I was able to get help when I needed it.

45. I preferred the labs outside of the classroom because they could be conducted at a time which best suited me and had sufficient room for instruction to be accomplished. While the laboratory experiments were nice because they were scheduled and had time for instructor help, I thought that the out-of-lab experiments had a better overall appeal.

46. I prefer inside the lab because the instructor is there to help, there are more people working together, it is at a set time and you're not scrambling to get the lab done, in general I just like the lab environment better.

47. I preferred doing the experiments outside of the lab, as it allowed me to choose when I wanted to do it and work around my time schedule. That was a huge advantage. Also I don't think I would have needed to be in the lab to understand or finish any of the experiments, although the ability to ask the professor questions in person probably sped up the last two labs a little bit. However, I would prefer the flexibility of out-of-lab experiments to the face-to-face contact with the professor in the lab.
48. I prefer the experiments in the lab. It's a set time that I already have on my schedule, so it's easier not to slack off and to put it aside. Also, the fact that the instructor is present is a big plus.

49. I preferred inside the lab since we were given better equipment for inside than outside.

50. Outside. The reason is because it was more loose, and I was free to do the experiment around my schedule.

51. I really appreciated the combination of the two because I was able to get to know my instructor and lab partners, and at the same time work on outside experiments when they were convenient.

52. Outside! It felt much less restricted, and I could take as much time as I wanted and get good results.

53. I actually enjoy having the mix of both in and out of class experiments.

54. I prefer the lab experiments outside the class because I could do them whenever I wanted. There was no set schedule I had to be someplace and do the experiment.

55. I like the experiments in the lab, but just because I was able to use some of the better equipment. I.e. the motion detector.

56. It was nice to have the labs on our own because we could complete them on our time instead of having to go to class. I prefer the outside labs.

57. I liked doing the labs outside of actual lab time because I could work at my own pace and when I was in the mood to do them. I could set aside time and work in a comfortable environment without feeling pressure to get everything done in a certain amount of time.

58. I prefer experiments inside the lab for 2 major reasons: 1) instructor help, support, and feedback, and 2) proper lab setting.

59. I liked the labs outside of the classroom because I could do them whenever I wanted and wasn't rushed along by other students.

60. Inside, I was able to get more precise experiments by reading the instructions and then asking the others if what I understood was what they understood.

61. I liked the ability to do the labs on my own time. However, that is a problem for some people, as they end up procrastinating a lot. It was also nice to have the student to student interaction in the in-lab projects.
62. I liked both. I think that some labs need to be done in the lab, such as (possibly) labs 3 and 4, just because some help might be needed that other friends can't give. But the first two labs were great to do by ourselves!

63. I actually preferred the labs performed inside the classroom. In the classroom we knew that we would have all the material and help that we needed.

64. Outside. Because they were not hard to understand, just like the ones inside, but I didn't have to go to a room at a certain time. I could do the experiment in the time that I wanted and if I needed help I simply asked another student.

65. I preferred the experiments outside of the laboratory because it allowed me to do them any time during the week instead of having to set apart the usual lab time.

66. I liked the out of class because we were able to do them on our own time at our own pace, and being able to do it in the comfort of our own rooms was a nice change from the classroom.

67. I liked the labs done outside of class because we were able to do them on our own time and not have to go and attend the lab at the specific time.

68. I preferred experiments performed out of the laboratory.

69. I like the last three the best. besides that, physics isn't really my favorite subject, and the fact that the three were enjoyable is saying alot. they are fast past, and demonstrate stuff pretty clearly. blowing up balloons was fun......

70. I prefer the experiments performed inside the lab only because I don't put it off to the last minute.

71. I think a mix is nice. You have the convenience of working at your own pace and working in groups.
Question 6

Describe your level of satisfaction with the learning you acquired from the laboratory experiments performed outside of the laboratory compared to the experiments performed inside the laboratory.

Learner Responses to Question 6.

1. I thought it was good, but I think that even though I enjoyed doing it on my own, I need someone whom I can e-mail, call, or meet with if something is not understood.

2. I was just as satisfied but personally liked being able to do the labs on my own time.

3. The labs were fun outside the class, but the help could of been needed.

4. I was more satisfied with the experiments done in the lab.

5. I learned the physics both ways—though this doesn't seem very high tech.

6. Learning was the same inside and outside the class

7. I think I learned about the same in both settings.

8. Well I enjoyed them both but, again, the outside of lab projects were more suitable because of time and scheduling issues. I am happy to have the chance to do the outside lab project experiments.

9. I was very satisfied with the experiments outside the lab.

10. I am satisfied with both equally.

11. I learned the same amount from the experiments outside the lab as I did from the experiments in the lab.

12. I feel that I learned the same in class as out of class. The lab basically reinforced and proved what was learned in class.

13. I found my level of learning both inside and outside the lab to be nearly identical.

14. The learning was about the same.

15. My level of satisfaction with the learning required is equal for both types of labs.

16. Both were satisfactory
17. I think the learning is about equal for both. Again, I never did one completely by myself so I always had a "lab partner" to work things out with. Both of the experiences were about equal in satisfaction. The major difference for me is that the lab outside of class was less convenient for me.

18. I think that I learned the same amount on doing both the in lab and out of lab experiments.

19. I was satisfied with how the experiments came out, regardless or where or when we did them. Being somewhere else besides the lab was nice in regards to comfort, but it was also less demanding than being inside the lab.

20. I feel equally satisfied with both the experiments done inside and outside of the classroom.

21. I think that the experiments outside weren't much different than the ones performed in the lab. Although the teacher was present in the lab, my group was confident enough to perform the experiment without the instructor.

22. Experiments done in lab are not bad, I was not dissatisfied with them, but I was more satisfied with the outside of class ones.

23. I learned the same amount from both

24. I feel I learned the same, whether the experiments were performed in the laboratory or out.

25. The learning inside the laboratory was more than adequate. It puts what we have learned inside the physics class towards actual models that we can calculate on.

26. I can't complain. I learned inside and outside, I just prefer the inside labs more.

27. I am equally satisfied with both forms of experiments. Personally I prefer doing them out of the lab.

28. I was very satisfied with all the labs and their quality.

29. I think I learned better in the lab setting because I was able to focus on what I was doing.

30. I thought that in both in-lab and out-lab experiments I learned the same amount of material.

31. I am enjoyed performing the labs outside of class and am satisfied with it and prefer it over the in class labs.
32. I was more satisfied inside the lab as the better equipment and guidance made the experiments more meaningful.

33. My level of satisfaction was low, because having a set time for lab forced me to get it done. I don't know if that makes me lazy, but I also required interaction with the lab instructor to get an A.

34. I think I may have learned a little more outside of lab because I was the only one doing the lab, but I learned a lot in lab and I had someone to explain it to me in lab.

35. I am completely satisfied with the learning done from the experiments performed outside the lab and inside the lab. I feel as if the learning was the same both places.

36. They were decent.

37. Average.

38. My learning inside and outside of the class were on an even level.

39. I learned the material equally, and I am very satisfied with the learning I acquired.

40. For me, one of the biggest limitations of the out-of-class experiments was that I felt they limited me to a certain set of guidelines and objectives and did not give me much freedom to work outside of them. If I was actually in the laboratory, on the other hand, I probably would have had the chance to experiment further with the help and advice of the professor if I so chose.

41. They were about equal.

42. I think I learned just as much from both.

43. I was more satisfied with the experiments done in the lab. I was able to really bounce ideas off the other students, which helped me to learn.

44. I feel that I have learned a moderate amount. My previous physics knowledge is not very extensive, so any added knowledge is a benefit to me.

45. I feel I learn more with the lab experiments performed inside of the lab compared to experiments outside of the lab. Being in the lab allows for teacher-student interaction. This interaction helped me to clarify certain areas that I misunderstood or did not completely understand. I felt like I was able to understand it better just because I knew that I could ask someone if I ran into a problem. In the experiments outside of the lab I felt like I just did them to do them and didn't actually take anything out of them. If I was ever confused I couldn't ask for help, so the confusion stayed and could never be corrected.
46. I will honestly admit that our learning level diminished outside of the classroom. We weren't as precise as we would've been if we had been in an actual lab setting.

47. I in no way mean to sound rude, but "level of satisfaction" isn't really high on my priorities when coming to physics lab. I want to learn my stuff... learn it well, or have it clearly observed. If that is accomplished, I am happy. In the second and fourth lab, I felt this was best demonstrated. The fact that one was on my own does not really figure in my feeling of "satisfaction."

48. I believe that I learned from the outside experiments just as easily as the experiments inside the lab, and I believe I did a fairly good job at mastering it.

49. It was adequate, I wouldn't say there is a difference between the labs done away to the ones done in the lab.

50. I honestly think that both were about equal with the inclass being a little bit more distracting with all of the people talking and trying to get their experiments done.

51. I am satisfied with the learning from the experiments outside of the laboratory.

52. I feel like I learned the same from the labs outside of lab as well as the ones performed in lab. I think that the instructions were good enough that it didn't make a difference in where I was when I did the lab.

53. I learned both equally as well. I don't think there was much difference in learning whether it was inside or outside the lab.

54. My satisfaction of learning was the same for both the experiments done both inside and out of lab. By just doing each experiment I was able to see what happens.

55. Some of those labs left questions left unanswered

56. As far as what I actually learned, I think the two were equal.

57. Yes, I don't think there is that much difference in the amount of learning if the student is willing to learn and determined.

58. I am very satisfied because I got to take my time and I don't mess up that much when I'm taking my time.

59. I think I learned the same way in and out of the laboratory, so I think either way would be a good learning experience.

60. I think I learned about the same amount in both cases.

61. My level of satisfaction was the same for both.
62. I learned just as much from the experiments performed outside of the lab than those performed inside.

63. I understood all of the experiments.

64. My level of satisfaction with my learning is the same with both the in-lab experiments and the out-of-lab experiments.

65. I am satisfied with the learning that occurred both outside and inside the lab. I think that I learned just as much outside of the lab as I learned inside the lab.

66. I was very satisfied with the learning that I acquired from the lab experiments that I performed inside the lab.

67. I am more satisfied with my out-of-lab experience that with the in-lab experiments. Unfortunately, I am not entirely satisfied with either.

68. I believe that I learned about the same in both situations, although being able to ask the lab instructor on a few questions helped me understand one or two concepts better.

69. I was completely satisfied with the amount that I learned from these experiments.

70. I was actually proud of myself that I accomplished and understood a physics experiment without having to lean on my instructor for help.

71. I like learning about the same in both settings.
Question 7

Thank-you for taking the time to complete this questionnaire your time and opinions are appreciated. Please provide any additional comments, suggestions, or experiences you would like to share.

Learner Responses to Question 7.

1. No comments. Thank you!

2. I think a combination of both formats is the way to go. Doing experiments outside of lab takes a little bit longer, but it is enjoyable and can be done at the students pace. Ultimately, both formats teach the lessons well.

3. Again, it was fun doing the lab outside of class, but I needed the extra help.

4. THANKS

5. Simple labs are good because you can apply different theories to simple experiments.

6. The instructor has been very nice to us in lab- and this research experiment was a great idea.

7. I enjoyed doing the experiments this way.

8. This is the way i think that a lab should be performed.

9. Thanks a bunch

10. Overall, the experiments were transferable to either setting, though some of the materials could have been a little better. (the masking tape was VERY uncooperative in the balloon experiment.)

11. I liked the labs and learned a lot from them

12. none. your welcome

13. None

14. I have no additional comments.

15. None
16. I think that doing the experiment outside of class is a good idea. I enjoyed not having the stress of attending another class while still learning. The experiments were good and demonstrated their ideas and concepts.

17. I think it would be a good idea to complete as many labs outside of the lab as possible in the future. I think that I learned just as much outside of the lab, and the convenience of being able to perform the experiment when I wished was an added bonus.

18. No suggestions.

19. I enjoyed the labs out of the laboratory and think that it would be a good idea to make that available as an option for the whole semester.

20. I don't have any additional comments.

21. I appreciate that you have the learning experience that is best for the students in mind.

22. I think this is a good idea to look into. My only thing is that you should always allow students to help each other. Cooperative learning is a wonderful tool.

23. The in-lab experience was different from my other labs. Usually, the professor explains the process and some of the theory behind it. I don't think this really happened in this lab. The lab handout did explain the theory, but I could not read it because my lab partners didn't allow time.

24. I wonder if this difference affects the research, since it appears to be comparing an independent experiment done out of the lab with the same type done in the lab, instead of a normal lab with instructor lecture/discussion with an independent experiment.

25. I kind of wish there were more of these labs to do.

26. I would like to see a lab that could be done completely outside of the laboratory.

27. I think that this course was a success, however, a turn-in schedule would have been helpful.

28. I have really enjoyed this lab.

29. Thank you very much!

30. It is a fine idea.

31. I enjoyed being able to work on the labs outside of lab.
32. I think doing physics lab as an independant study is a good idea. I enjoyed it.

33. none. thank you!

34. None

35. See above answers. Thank you!!

36. I think it could be really cool to do physics online. I would have taken that option last summer, if offered.

37. I would hope to see this in full swing as soon as possible.

38. I believe that this research is groundbreaking, and hopefully will be successful.

39. place candy/chocolate into the experiment bags for health/enjoyable learning environments!!

40. Thank you.

41. No extra comments

42. I would recommend that the lab be done outside of the lab for convenience reasons.

43. Well, Jesus Loves You.

44. I have already taken physics in high school and have done very similar experiments, so I believe that this helped me to understand the at-home experiments better than other students.

45. For me, doing it in the lab was much more pleasant

46. It's a good idea to make them available outside of class.

47. No Suggestions.

48. I think it is good to offer the labs as take home labs. I can tell that they aren't for everyone. I don't think that you will be able to get rid of the in lab option though.