Comparison of the Conceptual Understanding of Newton's Laws in an Online and Traditional Introductory Physical Science Course

Rex Robert Moak
University of Southern Mississippi

Follow this and additional works at: https://aquila.usm.edu/dissertations

Part of the Curriculum and Instruction Commons, Curriculum and Social Inquiry Commons, and the Science and Mathematics Education Commons

Recommended Citation
Moak, Rex Robert, "Comparison of the Conceptual Understanding of Newton's Laws in an Online and Traditional Introductory Physical Science Course" (2014). Dissertations. 238.
https://aquila.usm.edu/dissertations/238

This Dissertation is brought to you for free and open access by The Aquila Digital Community. It has been accepted for inclusion in Dissertations by an authorized administrator of The Aquila Digital Community. For more information, please contact Joshua.Cromwell@usm.edu.
COMPARISON OF THE CONCEPTUAL UNDERSTANDING OF
NEWTON’S LAWS IN AN ONLINE AND TRADITIONAL
INTRODUCTORY PHYSICAL SCIENCE COURSE

by

Rex Robert Moak

Abstract of a Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

May 2014
ABSTRACT

COMPARISON OF THE CONCEPTUAL UNDERSTANDING OF NEWTON’S LAWS IN AN ONLINE AND TRADITIONAL INTRODUCTORY PHYSICAL SCIENCE COURSE

by Rex Robert Moak

May 2014

The purposes of this study were to (a) determine if taking the Physical Science Survey I course in face-to-face (F2F) and online format statistically significantly improves Newtonian conceptual comprehension as measured by the FCI; (b) determine which course format, if any, has statistically significantly higher FCI post-means; and (c) determine if students’ satisfaction with learning is statistically significantly different in the two course formats.

Data for this study was collected from students and faculty in various course formats during the Fall semester of 2012 and the Spring semester of 2013. The researcher used two research tools: the Force Concepts Inventory (FCI), and a questionnaire measuring student attitudes toward course format (SAQ). Pre and post data were collected from students using the FCI, and post data were collected using the SAQ.

Results of the study suggest that both course formats resulted in an increase in conceptual understanding of Newtonian force concepts. Students enrolled in the F2F format experienced a more substantial increase in comprehension of force concepts. However, neither course format increased students’ conceptual understanding of force concepts to an extent that approached what experts call even an entry-level
understanding. The current study also suggests that students are just as satisfied with the online course format as they are with the F2F format.
The University of Southern Mississippi

COMPARISON OF THE CONCEPTUAL UNDERSTANDING OF
NEWTON’S LAWS IN AN ONLINE AND TRADITIONAL
INTRODUCTORY PHYSICAL SCIENCE COURSE

by

Rex Robert Moak

A Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

Approved:

Thomas V. O’Brien
Committee Chair

James T. Johnson

David P. Davies

Terrell Tisdale

Maureen Ryan
Dean of the Graduate School

May 2014
DEDICATION

To my wife, Betty, and my son, Nolan… You have been my inspiration throughout this entire process. Over the years, you took care of many things so that my work would be uninterrupted and endured countless hours of putting family time on the back burner. Your support and confidence in me never wavered, and for that, I am eternally grateful. My love for you both will never die.
ACKNOWLEDGMENTS

I would like to express my deepest appreciation to my committee chair, Professor Thomas O’Brien, who worked tirelessly to support my research and to be an invaluable mentor. Without his help, this dissertation would not have been possible.

I would like to sincerely thank my committee members, Dr. J. T. Johnson, Dr. Terrell Tisdale, and Dr. David Daves. Their professional commitment to excellence in research demonstrated to me that much more scientific research in the field of online education is needed to effectively meet the needs of today’s students.

I would like to thank Dr. Brad Bailey, Dr. Jalynn Roberts, Dr. Jessica L. Roberts, and Dr. Jonathan Woodward for their many hours of professional collaboration from inception to the completion of this project. Their strong friendship paved the way for this dissertation to be completed. I would also like to thank Mr. Bruce Layton, Physics Instructor, for his consultation on the finalization of this project. In addition, I would like to thank Jeanne Stewart, Graduate Reader, and Laura Hakala, doctoral candidate, for their work in the final formatting of this document.

I would like to thank Kelly Dye, Kathy Braun, Joshua Vanzile, and Suzan Bounds, Assessment Center Proctors at Mississippi Gulf Coast Community College (MGCCC) on the Jackson County, Perkinston, Jefferson Davis, and George County campuses respectively for their assistance in the distribution, testing, and collection of surveys at each point in my research.

And finally, I would like to thank Dr. James Dunn, Science Department Chair, MGCCC, Jackson County Campus for his continual support of my pursuit of this
doctorate. His leadership as department chairman and his interest in my research provided continual support and encouragement of my work.
# TABLE OF CONTENTS

ABSTRACT ........................................................................................................................................ ii

DEDICATION ....................................................................................................................................... iv

ACKNOWLEDGMENTS ....................................................................................................................... v

LIST OF TABLES ................................................................................................................................... ix

CHAPTER

I. INTRODUCTION ............................................................................................................................ 1
   Background of the Study
   Statement of the Problem
   Purpose of the Study
   Research Hypotheses
   Definitions of Terms
   Delimitations
   Assumptions
   Justification
   Summary

II. REVIEW OF RELATED LITERATURE ....................................................................................... 21
   Introduction
   Theoretical Framework
   Literature
   Summary

III. METHODOLOGY ......................................................................................................................... 64
   Introduction
   Research Design
   Participants
   Instrumentation
   Procedures
   Data Analysis
   Limitations

IV. RESULTS ...................................................................................................................................... 74
   Introduction
   Sample Characteristics
Overall Pre and Post FCI Scores
Pre and Post FCI Scores by Course Delivery Format
Satisfaction with Learning Experience
Statistical
Summary

V. DISCUSSION .................................................................................................................................................. 84

Introduction
Summary of the Study
Findings and Discussion
Summary of Findings
Limitations
Recommendations for Future Research

APPENDIXES .................................................................................................................................................... 93

REFERENCES ....................................................................................................................................................... 101
LIST OF TABLES

Table

1. Gender, Ethnicity, and Classification ..............................................................75
2. Pre and Post Test FCI Scores by Format ............................................................77
3. Descriptive Statistics for Satisfaction Items .........................................................78
4. Descriptive Statistics for Student Satisfaction by Course Format .......................79
5. Overall Satisfaction Means and Standard Deviations Based on Course Format ...82
CHAPTER I
INTRODUCTION

Background of the Study

Misconceptions in Science

College students rarely come to higher education classes with solid preconceptions about the content of the course. Few chemistry, foreign language, or psychology students have formulated distinct conceptions about the content and theory of those courses before they attend the class. The student is essentially free of any pre-conceived ideas regarding the substance of the course. Such is not the case with physics-based students. Physics and physical science students have spent their lifetimes observing dogs running, leaves falling, baseballs flying, cars crashing, and a host of other forms of motion. From these observations, certain beliefs commonly emerge: you need a force for motion (Bayraktar, 2009; Clement, 1982; Eryilmaz, 2002; Luangrath, Pettersson, & Benckert, 2011), heavy objects fall faster (Dilber, Karaman, & Duzgan, 2009; Gunstone & White, 1981; Stein, Larrabee, & Barman, 2008; Tao & Gunstone, 1999), projectiles garner a dissipating motive force from the air as they fly (Bayraktar, 2009, Dilber, Karaman, & Duzgan, 2009; Halloun & Hestenes, 1985b), and when two dissimilar objects collide the larger, stronger object exerts more force in the collision (Bayraktar, 2009; Luangrath et al., 2011; Maloney, 1984). These common sense beliefs are observed by the students many times over their formative years, instilling a basic system of belief in the way things work in the world. Unfortunately these preconceived beliefs often conflict with accepted scientific tenets in Newtonian mechanics. Students engaged in a physics-based course often lack the core Newtonian conceptions necessary for evaluating physical phenomena, and even after a course of instruction, many students hold on to the preconceived ideas
that have formed from a lifetime of observation of the physical phenomena around them (Luangrath & Vilaythong, 2010). The mistaken common sense beliefs, or misconceptions, of the physical principles governing force and motion that the student incorporates into their cognitive schema from an early age are continually reinforced over time and become strongly resistant to modification or change as the student grows older (Baser & Geban, 2008; Driver & Erickson, 1983; McDermott, 2001).

Misconceptions are not exclusive to physics; they have been widely identified across multiple areas of science and all are firmly rooted in the students’ cognitive framework (Pringle, 2006; Settlage & Goldston, 2007). Students with stable misconceptions will often resist attempts to alter their preconceived beliefs (Bayraktar, 2009; Clement, 1982; Halloun & Hestenes, 1985a; Luangrath et al., 2011). When confronted by a scientific conception that strongly conflicts with the robust misconceptions already rooted in the students’ cognitive framework, the student will frequently distort the scientific conception to fit into the existing structure rather than alter the framework of existing misconceptions. This phenomena has been extensively observed in scientific and educational literature in physics (Bayraktar, 2009; Clement, 1982; Halloun & Hestenes, 1985a; Gunstone & White, 1981; Luangrath et al., 2011; Sabella & Redish, 2007; Trowbridge & McDermott, 1980), the biological sciences (Deniz, Donnelly, & Yilmaz, 2008; Geraedts & Boersma, 2006; Nelson, 2008; Smith & Tanner, 2010), chemistry (Acar & Tarhan, 2007; Selvaratnam, & Canagaratna, 2008; Sozbilir, 2004; Sozbilar & Bennett, 2007), earth science (Trundle, Atwood, & Christopher, 2006), and astronomy (Kalkan & Kiroglu, 2007). Rarely will the student attempt to restructure their incorrect cognitive framework and thereby alter or replace the existing misconceptions with the conflicting scientific conceptions (Ormrod, 2008).
However, misconceptions must be challenged and the students’ cognitive framework reconciled as they may lead to increasingly divergent cognitive interpretations. This divergence may eventually result in an inability to effectively utilize past knowledge to construct new and valid conceptual schema (Klymkowsky, Taylor, Spindler, & Garvin-Doxas, 2006).

**Conceptual Change**

Students entering a physical science course have been exposed to physical phenomena over their entire lifetime and have formed misconceptions based on common sense beliefs to explain what they have observed, beliefs often at variance with scientific tenets, making these misconceptions highly resistant to change. Cognitive modification is a process of altering existing conceptual frameworks and is often based on cognitive conflict, whereby the student is placed into a state of cognitive dissonance (Eryilmaz, 2002; Obaidat & Malkawi, 2008; Posner, Strike, Hewson, & Gertzog, 1982; Smith, diSessa, & Roschelle, 1993). These cognitive conflicts frequently arise in physical science when Newtonian concepts of force and motion are introduced to the students that are inconsistent with the students’ established cognitive framework (Clement, 1982; Halloun & Hestenes, 1985a, 1985b; McDermott, 1984; Thornton & Sokoloff, 1998). However, the introduction of a cognitively dissonant event may not be enough to prod the student into modifying their conceptual beliefs. Although Bao, Hogg, and Zollman (2002) believe a single experiment may be enough to initiate concept modification, even instruction directly oriented toward conceptual modification may not be effective (diSessa, 1993; Tao & Gunstone, 1999; Zhou, Nocente, & Brouwer, 2008). Saglam-Arslan and Devecioglu (2010) researched higher education students’ comprehension of Newton’s laws and found significant weaknesses in the understanding of the core
concepts even following formal instruction. Their findings indicated students had constructed a variety of alternative models when incorporating new information and had used these models to explain the concepts behind a physical scenario, but few of the students had formulated a scientific model of understanding. von Aufschnaiter and Rogge (2010) in their analysis of phenomenon-based versus model-based concepts state that the sum of the students’ prior experiences as the framework for cognitive assimilation can either aid or hinder effective model construction, concluding “…all model-based concepts are difficult for students…” (p. 13).

There is wide-spread agreement that revision of the students’ cognitive framework is difficult. Scientific knowledge needs to be formed through structured methods with an emphasis on engaging the students in reflective critical thinking (Lai & Land, 2009; May & Etkina, 2002; Richardson, 2003; Yilmaz, 2008). By confronting the student with an event or question that elicits an inference based on scientific thought rather than common sense, a conflict between the scientific principle and the embedded misconception may ensue. If the dissonance of the event is strong enough, the student may then modify their cognitive framework to incorporate the correct scientific principles into their cognitive framework (Barrow, 2008; Chan, Burtis, & Bereiter, 1997; Limon, 2001; Posner et al., 1982). As difficult as it is for students to engage in this process in a traditional classroom, the process of knowledge assimilation and cognitive change is further complicated when the course delivery system is presented in a non-traditional online format via the Internet.

**Online Education**

Technological advances, the growth of the Internet, and the availability of effective course management systems have made the anytime, anywhere mantra of distance
learning a virtual reality (Allen & Seaman, 2008). Online education has brought the promise of a college degree within the reach of many that cannot attend traditional classes. The flexibility of the online learning environment coupled with the economic downturn, higher costs for basic amenities such as food and fuel, and rising tuition costs has led to increasing student demand for access to Internet-based distance learning (Allen & Seaman, 2008). However, online education also has its drawbacks: higher demand has led to more students, but without a corresponding increase in funds, online classes tend to have higher non-completion rates (Aragon & Johnson, 2008), students used to a more passive role in the classroom are required to be more self-motivated and self-managed (Nora & Snyder, 2009), and students in online classes may have a tendency to earn lower grades (Rolfe, 2007). A primary reason for student difficulty in online classes was cited as lack of time to adequately do the assignments (Aragon & Johnson, 2008). The ability of students to effectively transition to the demands of the online learning environment is directly related to their probability of completing the course: the higher the adaptability of the student, the more likely the student will persist in the online setting (Herbert, 2006; Wojciechowski & Palmer, 2005). For this reason, students that are self-directed and self-motivated are more likely to be successful with online course formats (Hartley & Bendixen, 2001; Song & Hill, 2007). The term andragogy was used by Malcolm Knowles (1975) to describe adult learning, as opposed to pedagogy that addresses the learning processes of children. According to Knowles, adults learn differently than children. The andragogical model differs from the pedagogical model in several ways: adults have a need to know why something needs to be learned; they have an intrinsic concept of self-direction; they bring to the higher education classroom a much wider and deeper set of experiences than children as well as a readiness to learn; they have an
orientation to life-centered learning and hold a stronger intrinsic motivation for learning (Knowles, Holton, & Swanson, 2011). These characteristics have been linked to increased success in the online learning environment (Chen, Jang, & Branch, 2010; Green & Kelso, 2006; Hong & Jung, 2011; Kerr, Rynearson, & Kerr, 2006; Oliveira & Simões, 2006; Song & Hill, 2007; Tallent-Runnels et al., 2006). The instruction of laboratory-based science courses online present challenges not found in non-lab courses.

The delivery of effective qualitative and quantitative critical thinking concepts is complicated by the distance factor in the course, while logistical difficulties in converting a hands-on laboratory from the traditional format to one that can be performed at home without a loss of integrity is a significant barrier. Because of these formidable barriers and the relatively new delivery system, few research efforts have been directed at examining the effectiveness of learning in online physical science classes. As Dunlap, Furtak, and Tucker (2009) state, “One issue in the development of online programs is whether online courses can achieve the same level of quality as the on-campus versions, that online education ‘does no harm’” (p. 67). Most literature suggests that traditionally taught courses and identical courses offered online show students in the online course perform at a level equal to or greater than those in the traditional classroom (Cavanaugh, 2001; Means, Yoyama, Murphy, Bakia, & Jones, 2010; Zhao, Lei, Yan, & Tan, 2005). Additionally, student satisfaction with the online experience appears to correlate positively with learning outcomes (Eom, Wen, & Ashill, 2006), but overall student satisfaction is often less than with the face-to-face traditional method of instruction (Rivera & Rice, 2002; Summers, Waigandt, & Whittaker, 2005).
Statement of the Problem

The advent of the World Wide Web has led to growth in the delivery of distance education courses over the Internet. This online learning environment has seen rapid growth in the past several years, with a 21% growth rate for online enrollment since 2007 compared to only a 2% growth for higher education overall (Allen & Seaman, 2011). The literature also points to a growing number of students taking online courses, including science-based courses, but there have been few studies examining effectiveness and satisfaction for a fully online lab-based science course.

The question of whether or not outcomes for online students are on par with traditional student outcomes is still debated, but research shows online students have a similar achievement level in their coursework as students in comparable courses that are taught in a traditional manner (Cavanaugh, 2001; Means et al., 2010; Russell, 1999; Zhao et al., 2005). However, this literature is largely based on non-science courses, and there is little substantial research on the delivery and effectiveness of lab-based science courses online. A major reason for the lack of literature appears to be the difficulty of replicating lab-based learning outcomes in the online environment (Boschmann, 2003; Casanova, Civelli, Kimbrough, Heath, & Reeves, 2006; Johnson, 2002; Patterson, 2000). This gap in the educational research is a problem for teachers as there is no guidance for the construction or delivery of the laboratory component in an online science course. While the learning outcomes associated with the traditional science laboratory are known, there are significant barriers to implementing and replicating those outcomes in an online course (Instructional Technology Council, 2010). It is also problematic for administrators who are faced with the evaluation of a lab-based science in a non-traditional online format that by nature has component outcomes that are not addressed in
a standard academic course and cannot be evaluated by standard procedures for non-science courses. The inability of administrators to effectively evaluate an academic course poses significant risk for students. To be enrolled in a course of instruction that fails to deliver on its promise of a quality education via an online format invalidates the educational process as a whole (Casey, 2008). The ripple of lower quality then affects society when non-qualified graduates enter the workforce with sub-par skills in their respective fields. As Coyner and McCann (2004) note, courses that require face-to-face interaction may not be good candidates for fully online instruction.

Courses in the physical sciences emphasize theoretical abstractions that are often counter-intuitive to the students and make conceptual learning difficult. Compounding the problem is that science courses present perhaps the most difficult of all courses to implement effectively online due to the laboratory component, and the application of concepts to laboratory work becomes more challenging. While students tend to form generalizations about the way things work around them from an early age, these generalizations are often in error and lead the students to incorporate flawed conceptions into their cognitive framework. As time passes, these misconceptions are continually reinforced and become deeply embedded in the students’ cognitive schema, resisting attempts to be modified or replaced by new, scientifically accurate conceptions (Bayraktar, 2009; Clement, 1982; Halloun & Hestenes, 1985a; Luangrath et al., 2011).

In fact, conceptual change is considered to be one of the most difficult aspects of learning abstract representations such as are found in physics or physical science (Pringle, 2006; Settlage & Goldston, 2007). Students will not generally attempt a revision of an established misconception on their own, and failure to effectively initiate and complete the conceptual change process may result in the student using flawed premises to make
shaky inferences to explain new events or information, continually constructing and reinforcing unsound misconceptions (Klymkowsky et al., 2006). In the age of technology, it is of paramount importance that all citizens be scientifically literate to make informed, accurate decisions regarding issues in their life and in society (Holbrook & Rannikmae, 2007). Without a solid base in scientific conceptions, any decisions made based on flawed conceptions renders the entire cognitive decision-making process invalid, and any conclusions drawn worthless (Klymkowsky et al., 2006).

Online expansion in the sciences will continue to grow and the arena of online physics and physical science must be further explored to provide research-based answers regarding its effectiveness. Administrators, faculty, and students need to have a clear understanding of the potential strengths and liabilities of the online format. Understanding the strong points allows for the construction of a substantive delivery system for the course, while acknowledging its weaknesses can point to ways to minimize drawbacks. Increasing the information available to make evaluations of the effectiveness of the online environment for delivery lab-based science courses will lead to more tailored instructional processes and a more rewarding experience for the students. This study will contribute to the knowledge base for online delivery of laboratory-based science courses as well as add to the literature regarding the levels of Newtonian misconceptions in both the online and traditional formats for non-science students.

Purpose of the Study

As the number of online courses continues to expand and the number of online students increases, it behooves faculty and administrators to fully grasp the strengths and weaknesses of this instructional process. Particularly, there are specific areas regarding online instruction of a Physical Science course that should be addressed:
Point 1: A literature review illustrates a number of community colleges, both in Mississippi and nationwide, are offering online coursework for academic credit. The studies that have been performed on the degree of effective learning in the online environment have largely been in areas outside the sciences, and there is a distinct paucity of research involving laboratory based science classes offered totally online. This research helped fill that void and provided a point of reference for comparatively evaluating the degree of effective learning in online science courses.

Point 2: Student achievement in online courses has been documented with the majority of research investigations showing the no significant difference standard, indicating that students in the online courses did as well or better than their counterparts in the traditional bricks-and-mortar classrooms. Again, these studies involve primarily non-science courses. The few evaluations involving laboratory-based online science courses also generally report no significant difference in student achievement (Boschmann, 2003; Johnson, 2002; Reeves & Kimbrough, 2004), although there are exceptions (Meisner, Hoffman, & Turner, 2008). It was of significant value to determine the relationship that exists between the qualitative (conceptual) aspects of Physical Science Survey I students in the online versus those in a traditional learning environment.

Point 3: The limited research involving science instruction and student achievement in science classes online has focused almost exclusively on science majors. Although non-science majors make up a substantial proportion of students enrolled in beginning lower level science courses, there appear to be no studies that explore the conceptual learning components of non-science majors in the online environment. This study helped fill a gap in online science effectiveness research and helped determine if
scientific concepts are internalized by online non-science majors as well as or better than by traditionally taught face-to-face non-science majors.

Force is a central concept in physical science, and its understanding is necessary to grasp later concepts in the course. A widely accepted instrument that measures student comprehension of Newtonian mechanical concepts, the revised Force Concept Inventory (FCI), is projected to be used in this research project. The FCI is a criterion referenced test developed and tested by Hestenes, Wells, and Swackhamer (1992) and revised in 1995. It has been utilized by a number of researchers nationally and internationally since its introduction and was used in this research project to provide a comparison between the conceptual development of students in the online and traditional classes.

The Student Attitudes Questionnaire (SAQ) is a Likert-scale student response instrument that assesses students’ perceptions of satisfaction with the online course. The SAQ is an instrument devised and reviewed by a panel of experts in both communication studies and in science, then tested to confirm its validity and reliability. The SAQ was used in this study to evaluate the level of students’ satisfaction with the course delivery through the online environment.

Data were collected from students enrolled in online and traditionally taught Physical Science Survey I classes by the researcher. The online courses were offered through the Mississippi Virtual Community College, while the traditional classes were taught at a community college located in the South. All classes were instructed by the researcher. This allowed for control of extraneous variables, which would not be possible if other instructors were involved in teaching sections of the course that were used in the research project.
Research Hypotheses

Findings in the literature indicate the revised Force Concept Inventory (FCI) is a valid and reliable assessment of student conceptual comprehension across six conceptual dimensions of Newtonian concepts of force and motion and has been widely used in the physics education community. The SAQ has been shown to be both valid and reliable in its assessment of students’ satisfaction levels with online course delivery. Finally, a review of the related literature regarding online and traditional courses indicates a majority of research studies have found no significant difference in the achievement between online students and traditional face-to-face students enrolled in equivalent courses. Based on these findings, the proposed hypotheses for this study were

- There is a statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the online format through the MSVCC.
- There is a statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the traditional face-to-face format at a community college in the South.
- There is no statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI post-test assessment between students who take Physical Science Survey I in the traditional face-to-face format and those who take the course in the online format through the MSVCC.
• There is no statistically significant difference in student satisfaction scores as measured by the Student Attitudes Questionnaire between students who take the Physical Science Survey I course in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

Definitions of Terms

**Accommodation** – where the individual alters the framework of the pre-existing mental schema to accommodate new information (Piaget & Inhelder, 1969).

**Andragogy** – the art of teaching adults (Knowles et al., 2011).

**Assimilation** – where the individual fits new information or events into a pre-existing cognitive schema consisting of prior knowledge (Piaget & Inhelder, 1969).

**Aristotelian conception** – a flawed conceptual belief that parallels classical thought first delineated by the Greek philosopher Aristotle (Halloun & Hestenes, 1985b; Knight, 2004).

**Asynchronous** – an online course design that allows the student and instructor to interact with the course delivery system at any time of the day or night from anywhere around the world served by the Internet. Therefore, the students and instructors do not have to be online at the same time (Hiltz, 1997).

**Baby Boomers** – a broad classification of learners based on age, Baby Boomers are those born from 1943 through 1960. Also known as the Boom Generation or Boomers (Howe & Strauss, 2000, 2003).

**Cognitive Dissonance** – a condition of mental conflict or confusion between existing internal cognitive information and new external information (Festinger, 1957). See also Disequilibrium.
**Cognitive Model** – the internal mental construction of representations of ideas or concepts a student forms when thinking about those ideas. Also called a mental model (Duit & Treagust, 2012).

**Cognitive Schema** – the active organization of concepts into a meaningful and coherent mental system. Also called cognitive frameworks, mental frameworks, or mental schema (Piaget & Inhelder, 1969).

**Concept** – an abstraction or idea inferred from experience or observation (Donald, 2002).

**Conceptual change** – a design for restructuring a student’s cognitive framework to incorporate non-intuitive anomalies (Chinn & Brewer, 1993).

**Constructivism** – a learning theory that emphasizes using prior learning experiences as a base for building new knowledge through active learning processes (Koohang, Riley, Smith, & Schreurs, 2008).

**Course Management System (CMS)** – content delivery software systems such as Blackboard, Moodle, or Desire-to-Learn (D2L) that are used to deliver course content and assignments to students online. Also called Learning Management System (LMS), E-Learning Platforms or Web-Based Instructional Platforms (WBIP) (Vovides, Sanchez-Alonso, Mitropoulou, & Nickmans, 2007).

**Digital Immigrants** – members of the Baby Boomer and Generation X categories; these students were not born into the modern technology age of computer use and had to learn these applications later in life (Prensky, 2001a, 2010).

**Digital Natives** – the first generation to grow up immersed in the use of digital tools and digital technology such as computers, the Internet, cell phones, and video
gaming. Digital natives are considered part of the Generation Y or Millennial Generation cohort (Prensky, 2001a, 2010).

*Discovery learning* – the process of the student finding the answers for himself by utilizing prior knowledge in conjunction with new information in a guided inquiry (Bruner, 1961).

*Discrepant Event* – a predicted event that has an unexpected result. Usually occurs when the student bases their prediction of the event outcome on flawed mental models (Bruner, 1961).

*Disequilibrium* – the mental disruption that occurs when external information is presented that is at variance with established schema resulting in an intrinsic need to resolve the conflict (Piaget & Inhelder, 1969). See also *Cognitive Dissonance*.

*Domain* – the sphere of influence of a concept within a field or discipline, such as the domain of Newtonian mechanics (Treagust & Duit, 2008).

*Face-to-Face (F2F) format* – See *Traditional format*.

*Generation X* – broad classification of learners based on age, Generation X students are those born from 1961 through 1981. Also known as Gen-Xers (Howe & Strauss, 2000; 2003).

*Generation Y* – See *Millennial Generation*.

*Inquiry Learning* – the process of engaging the student in an inferential process via a scenario, event or experimental procedure (Bruner, 1961).

*Impetus theory* – the flawed conceptual belief that a motivating force is imparted to a moving object and is gradually lost as the object moves through its flight (Halloun & Hestenes, 1985b; Knight, 2004).
**Lab-Based Science Course** – a science course that involves the use of hands-on manipulatives in a laboratory setting to demonstrate and reinforce the core content of the discipline. Examples are courses in the areas of chemistry, physics, and the biological sciences (Donald, 2002).

**Learning Management System (LMS)** – See Course Management System.

**Mental model** – See Cognitive Model.


**Millennial Generation** – broad classification of learners based on age, the Millennial Generation are those born from 1982 through 2000. Also known as Millennials, Generation Y, or the NetGen (Howe & Strauss, 2000; 2003).

**Misconceptions** – preconceptions that are erroneous, inconsistent with scientific thought, and difficult to change through traditional instruction. Also known as common sense beliefs, preconceptions, pre-conceived false beliefs, mistaken beliefs, flawed conceptions, alternative conceptions, naïve primitives, and intuitive knowledge (Wandersee, Mintzes, & Novak, 1994).

**Mississippi Virtual Community College (MSVCC)** – a consortium of 15 independent community colleges in the state of Mississippi that merged their online capabilities to form a single unified entity for online course delivery. Students can register and attend any online course taught by any of the community colleges that are part of the consortium (MSVCC website).

**Model** – a conceptual representation that acts to bridge theory and empirical evidence (Koponen, 2007).

**Newtonian concept** – a scientifically tested concept based on Sir Isaac Newton’s laws of force and motion (Halloun & Hestenes, 1985a).
**Online course** – a course presented through the Internet as a medium for online learning where at least 80% of the course is delivered via the World Wide Web. Also called a Virtual Learning Environment (VLE) (Kerr et al., 2006).

**Online learning** – student learning achieved in formal university courses in which all instruction occurs online using the internet. Also known as web-based learning, distance learning, e-learning, or web-based instruction (Kerr et al., 2006).

**Pedagogy** – the art of teaching children (Knowles et al., 2011).

**Scientific conception** – conception based on accepted scientific principles, not on everyday observations (Posner et al., 1982).

**Scientific literacy** – the degree to which a teacher imparts the central concepts of a core field (e.g. physics, biology, chemistry) and how well the student integrates the premises, concepts, and models of that field (von Laugksch, 2000).

**Synchronous** – an online course design that requires the instructor and students to be online simultaneously to interact with each other in real-time (Bernard et al., 2009).

**Traditional format** – instruction, usually lecture based, that takes place in a traditional format in an on-campus classroom. Also called face-to-face (F2F) instruction or *bricks and mortar* instruction (Wuensch, Aziz, Ozan, Kishore, & Tabrizi, 2008).

**Delimitations**

The study findings did not generalize to other institutions as it was limited to only undergraduate students that were 18 years of age or older and enrolled in an on-campus face-to-face Physical Science Survey I course at a single community college in the South or in an online section of Physical Science Survey I instructed through the Mississippi Virtual Community College. In addition, data collection was restricted to the limited time periods of the Fall 2012 semester and the Spring 2013 semester.
Assumptions

Participants in this study were assumed to follow the directions given to them for completing the FCI and SAQ instruments. They were further assumed to answer all questions on the FCI pre- and posttest to the best of their abilities with attention to carefully reading and reflecting on each question before answering. Likewise, they were assumed to truthfully respond to the SAQ survey questions so as to provide a valid representation of student opinions. Finally, the participants were assumed to be representative of the overall population of students enrolled in both the on-campus and online Physical Science I courses at the community college and the MSVCC.

Justification

Non-science majors are frequently required to complete at least one lab-based semester-long science class for their undergraduate degree. With the advent of web-based course management systems such as Blackboard/WebCT, Moodle, and Desire2Learn, many students are turning to the online environment for the convenience and flexibility these classes offer. The purpose of this study was to determine if any significant differences exist for the comprehension of specified qualitative scientific concepts between traditionally taught students in a face-to-face classroom and online students in a non-traditional web-based learning environment.

Literature suggests student achievement in the online environment is generally equal to or greater than the achievement of students in a face-to-face classroom (Everson & Garfiled, 2008; Sitzmann, Kraiger, Stewart, & Wisher 2006; Summers et al., 2005). However, most studies focus largely on non-science areas. The few evaluations involving laboratory based science courses delivered online also generally report no significant difference in student achievement (Boschmann, 2003; Johnson, 2002; Reeves
& Kimbrough, 2004). However, the studies in the literature comparing online and traditional learning, whether science related or not, focus primarily on achievement as a function of grade average, not of conceptual integration. The lack of research examining concept comprehension as well as the deficiency of inquiries addressing online science courses, for majors and non-majors alike, is a significant gap in the overall body of research for online delivery effectiveness.

Although non-science majors make up a significant proportion of students enrolled in beginning lower level science courses, there appear to be no studies that explore the learning components of non-science majors in the online environment. This study serves to help fill a gap in online science effectiveness research to see if scientific concepts may be internalized by online non-science majors as well as or better than by traditionally taught face-to-face non-science majors. Research in both science and non-science areas seems to indicate there will be no significant difference between the achievements of the two groups, but the degree of concept integration for non-science majors in an online science class has yet to be explored. This study will be beneficial to instructors who design and develop online courses to better serve the needs of their students, administrators who plan and implement curricular formats to determine if online science courses are effective modes of instruction, legislators involved in appropriations and education who desire a benchmark for determining effectiveness to justify cost versus return for online science courses, and students who are interested in participating in an effective online science class as part of their course of study.

Summary

Laboratory-based science classes tend to be among the most difficult of classes for the higher education non-science major. When a student utilizes flawed reasoning to
generate a system of misconceptions, the incorporation of scientific concepts becomes much more difficult for the student, especially when these scientific concepts are counterintuitive to their life experiences and conflict with their established misconceptions. Recognizing that misconceptions exist and are firmly embedded in the students’ cognitive schema is an essential prerequisite to altering them. By allowing the students to experience new or more thorough explanations for events, the student may be motivated to initiate a conscious change in their cognitive framework and modify their existing conceptual beliefs.

As difficult as cognitive restructuring can be in a traditional classroom, the delivery of an asynchronous lab-based science course online heightens the obscurity of scientific concepts that are resisted by established misconceptions. Even students in a traditional classroom have significant difficulty in modifying their conceptual models when prompted by a discrepant event or scenario. Students in an asynchronous online environment must not only recognize the flaws in their misconception but frequently must initiate their conceptual change process in the absence of a cued stimulus from the instructor or fellow classmates. While there is much debate regarding the most effective way to confront student misconceptions and how those misconceptions can be changed, there is little debate about the robustness of these misconceptions. They exist deeply rooted in the students’ cognitive schema, and restructuring them is a time-consuming and difficult process.
CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

For the physics and physical science student, a core comprehension of fundamental Newtonian conceptions is essential for the evaluation of mechanical systems, processes and problems. Students arrive in class with a variety of preconceived ideas about how the world works based on their state of interaction with the physical phenomena around them. These conceptions are frequently at odds with the sometimes counter intuitive nature of Newtonian mechanics and are often incomplete or flawed but still deeply ingrained in the psyche of the student (Driver & Erickson, 1983; Luangrath & Vilaythong, 2010; McDermott, 2001). As part of their core belief systems, these misconceptions are very resistant to modification or change, even when confronted with an event that cannot be explained by the existing mental framework (Baser & Geban, 2008; Clement, 1982; Halloun & Hestenes, 1985a). The cognitive framework of the student has to be redesigned to allow the student to integrate the new information and resolve the conflicting views being experienced, a process that requires learning new constructs. Research (Hake, 1998a, 1998b; May & Etkina, 2002; McClosky, Caramazza, & Green, 1980) indicates students appear to learn better and are often more willing to adjust their convictions when they are actively engaged in an interactive inquiry instructional format that allows them to experience, observe, and reflect on events, whether the event fits or contradicts their belief systems. However, conceptual change using interactive engagement can take many forms (Hake, 1998b). Most current science education strategies such as peer instruction, inquiry learning, and problem-based learning, employ tenets from constructivism, where the student *constructs* mental
frameworks to incorporate new knowledge based on past knowledge or experiences (Windschitl, 2001).

Theoretical Framework

Constructivism and Piaget

Cognitive science research forms the theoretical basis of modern science instructional methods that are based on the epistemology of constructivism, whereby the student acts to incorporate new knowledge or meaning by integrating it with past knowledge and experiences; the student builds or modifies internal cognitive schemata and constructs meaning (Windschitl, 2001). Largely based on the work of Piaget, constructivism theorists believe learning is an active process, an idea extending back to Dewey (1906). These active learning processes have the learner actively engaged in an experiential process or activity that confronts their established beliefs (Richardson, 1997).

This confrontation is derived from Jean Piaget’s principle of cognitive disequilibrium in which an observed event contradicts information that is already held in an individual’s mental framework, producing confusion, or disequilibrium (Piaget & Inhelder, 1969). According to Piaget, human cognition is actively organized into meaningful and coherent systems called schema. When external information is presented that does not fit the pattern already set in the schema, a situation of disequilibrium, or mental confusion, manifests itself resulting in a compelling urge to resolve the conflict. Piaget states this resolution is essentially accomplished in two ways: 1) through assimilation where the individual fits new information or events into a pre-existing cognitive schema consisting of prior knowledge and events and 2) through accommodation where the individual actually alters the framework of the pre-existing mental schema to accommodate the new information. According to Piaget, these
functions co-exist: for assimilation to occur one must accommodate the information, and vice versa. There is a dynamic balance between the two that is a result of focused, active mental processing and requires continual construction and deconstruction of various aspects of the mental schema to incorporate new, unfamiliar, and sometimes dissonant knowledge. As these processes become more complex and sophisticated, the individual begins to progress through various stages of cognitive development, culminating in a formal operational stage characterized by abstract thought processes. Piaget’s view stressed the importance of adaptive intelligence when assimilating new knowledge and that cognitive structures formed early in life will change to accommodate new information as the learner grows older and moves through the different stages of cognitive development. For Piaget, the move from a more concrete learning methodology to an abstract process is necessary for conceptualization and higher order reasoning skills.

Festinger and the Theory of Cognitive Dissonance

Science pedagogy utilizes the conflict of discordant or discrepant events to stimulate the learner into re-examining their core beliefs. That process has its roots in Piaget’s theory of disequilibrium, an idea of mental disruption that is complemented by Festinger’s Theory of Cognitive Dissonance, which holds we intrinsically desire to have our belief systems aligned and harmonious and will avoid a disharmonious, or dissonant, state (Festinger, 1957). Cognitive dissonance occurs when two conflicting yet competing ideas compete for acceptance in a person’s mental framework that in turn produces a state of tension, inducing a person to act to relieve that anxiety by attempting to resolve the inconsistency. Festinger postulated the Principle of Cognitive Consistency to account for these discordant reactions. People strive for a consistent balance in their beliefs and
attitudes when confronted with a discrepant situation that induces mental tension. If the conflict between the event and the existing cognitive schema cannot be resolved logically in the mind, this drive for cognitive consistency may lead to a conditional rejection of the validity of the event or, in the event it is incorporated into the mental schema, a cognitive accommodation that may manifest itself as a maladaptive behavior or non-rational belief. Subsequent researchers have focused on attitude change as a function of cognitive dissonance theory (Gawronski & Strack, 2004; Schultz & Lepper, 1996; Van Overwalle & Jordens, 2002) and have found student attitudes toward dissonant topics tend to reduce their dissonance levels when the student has an outlet for discourse with others grappling with the same issues. Student mental approaches regarding conceptual integration of knowledge is based on explicit attitudes or attitudes that are consciously controlled and require cognitive effort. Research indicates explicit attitudes are susceptible to modification by cognitive dissonance techniques and can act to modify perceptions, beliefs, and conceptual ideas (Gawronski, & Strack, 2004).

**Bruner and Discovery Learning**

The conceptual component of learning outlined by Piaget was the focus of Jerome Bruner’s work on active learning. Bruner defined the structure of a concept in terms of key elements that addressed concept learning as an organizational process where the complexity of a system is progressively reduced to manageable attributes that can more easily be assimilated into the learner’s existing cognitive framework (Bruner, 1964). For Bruner, conceptualization was acquired by categorization, or the sorting of ideas, objects and events into differentiated groups based on similarities and differences. In Bruner’s view, categorization was a fundamental process necessary for integrating conceptual ideas into a workable mental scheme. To complement the process of concept integration
and cognitive analysis, he emphasized discovery learning, an essential component for the conceptual development of intellectual effectiveness and inductive-deductive reasoning processes. In his view, discovery learning was the process of the student finding the answers for himself by utilizing prior knowledge in conjunction with new information in a guided inquiry. For Bruner, discovery learning allowed the learner to see patterns and relationships that connect together in a cohesive whole. These regularities in the environment could be objectively discerned, categorized, and further used to find solutions to new problems, leading to new constructs of learning and assimilation (Bruner, 1961; Bruner, Wallach, & Galanter, 1959). It was through the use of discovery learning, especially with discrepant events that provoked the learner into reassessing their long-held beliefs and considering new, valid beliefs that could cognitively reconcile the discordant phenomena. This process of constructivist inquiry learning is effective in enhancing student learning and reducing flawed mental conceptions (Bryant, 2006; Wilhelm, Thacker, & Wilhelm, 2007).

**Self-Directed Learning Theory**

Learners in higher education are not children. Unfortunately, pedagogies are primarily directed at the child and the child’s learning environment. While similarities exist between younger and older learners, the adult learner has different requirements and different motivations than do children. Malcolm Knowles (1975) used the term *andragogy* to distinguish the art of teaching adults from pedagogy, the art of teaching children, although he does not view the two as mutually exclusive but as *parallel* models. As Merriam and Caffarella (1984) state, “learning in adulthood can be distinguished from childhood in terms of the context, the learner, and the learning process” (p. 302).
Knowles (1984) enumerates these core characteristics that differentiate the adult learner, and first among them is the ability to be self-directed. Adults are no longer dependent learners as is a child in elementary school but set their own directions and agenda. Adults come to the higher education environment willingly, as opposed to the forced education of the child in the K-12 system, and with a readiness to learn. Knowles postulates that adult learners bring with them a wider variety and different perspectives than does a child due to the richness of life experience and states adults are generally more motivated to learn when they identify a need to gain new knowledge enabling them to “perform a task, solve a problem, or live in a more satisfying way” (Knowles, 1984, p. 12). While adults can be motivated by extrinsic rewards, Knowles emphasizes the deep-seated intrinsic motivation of the adult learner as a key driving mechanism for acquiring new knowledge in the andragogical model. These characteristics of the adult learner are also important when instruction is to occur via the internet in an online academic course. The ability to be self-directed in a less structured arena and motivate one’s self by intrinsic means is characteristic of successful online learners (Chen et al., 2010; Kerr et al., 2006; Song & Hill, 2007).

Literature

Student Conceptions

The physical sciences (chemistry, physics, physical science) have traditionally been courses of study that emphasize analytical reasoning and critical thinking skills to enable the student to assess abstract ideas and principles. Such classes require the student to internalize concepts and ideas, often mathematically, and apply those concepts to different situations. It is common knowledge that students in a traditional classroom setting often have trouble incorporating these concepts into a cognitive schema and as
such, find it difficult to extend these concepts to physical situations (Bayraktar, 2009; Clement, 1982; McClosky, 1983). Every student in higher education that enrolls in a beginning physical science course will bring with him beliefs that are formed from the sum of their life experiences about the way things work in the physical world and will incorporate new experiences into their cognitive schema by referencing past knowledge and events (Halloun & Hestenes, 1985a). In fact, solid conceptions regarding movement and the physical world are ingrained by observation no later than late elementary school, and these early beliefs maintain their dominance in the person’s mind through adulthood unless effectively changed by exposure to new knowledge (Dykstra, 1987). These core common sense beliefs allow the students to form a coherent view of physical phenomena and make sense of new information that may or may not correlate with their formulated beliefs (Bayraktar, 2009; Clement, 1982; Driver & Erickson, 1983; McClosky, 1983; Prince, Vigeant, & Nottis, 2010; Wandersee et al., 1994). These preconceptions about how the world works are a result of the students’ observations of their environment and the interactions the students have with the physical phenomena around them (Clement, 1982; Halloun & Hestenes, 1985a, Eryilmaz, 2002; von Aufschnaiter & Rogge, 2010).

Unfortunately, these ideas are often incomplete or flawed but still deeply ingrained in the psyche of the student (Baser & Geban, 2008; Driver & Erickson, 1983; McDermott, 2001; Pringle, 2006; Settlage & Goldston, 2007).

Difficulties arise when students experience a cognitive conflict as they experience a disjunctive event and attempt to incorporate the experience or concept that conflicts with their prior beliefs (Eryilmaz, 2002; Posner et al., 1982; Obaidat & Malkawi, 2008; Watson & Konicek, 1990). As part of their core belief systems, these misconceptions are very resistant to modification or change even when confronted with an event that cannot
be explained by the existing mental framework (Bayraktar, 2008; Clement, 1982; Eryilaz, 2002; Halloun & Hestenes, 1985a; Luangrath et al., 2011; Luangrath & Vilaythong, 2010; Sabella & Redish, 2007; Tsaparlis & Papaphotis, 2008). This dissonant experience may alter the underlying schema, to allow it to fit into a student’s existing framework, but more often the event itself will be rejected outright since the prior concepts integrated into the cognitive structure are deeply imbedded and strongly resistant to change (Ormrod, 2008; Tsaparlis & Papaphotis, 2008: Wandersee et al., 1994). When confronted with incongruent new information that is incompatible with the existing cognitive schema the student will attempt to integrate the discordant event into the pre-existing knowledge schema in an effort to hold on to their pre-conceived beliefs, even when an event is shown to be inconsistent with a student’s conceptual framework and has been completely illustrated with new concepts, (Clement, 1982; Halloun & Hestenes, 1985a; Tsaparlis & Papaphotis, 2008). As Dykstra and Sweet (2009) point out, the tendency to maintain a consistent snapshot view of a motion concept is ingrained early in life and undergoes little change through the college years. As time passes and the student continues to reinforce the initial common sense belief system, the ability of the student to modify that belief system and incorporate new beliefs is severely restricted (von Aufschnaiter, 2006). Most students hold these epistemological beliefs without actually having a conscious awareness of the depth of their conceptions. Stathopoulou and Vosniadou (2007) postulate that the framework of a student’s concepts is narrowly defined and tends to fragment as new information is ingrained, but may not change all previously held beliefs.

These misconceptions can be precursors to a variety of failed reasoning skills, not the least of which is the inability of students to engage actively in effective critical
thinking. To conduct an analysis based on false assumptions and derive conclusions based on those assumptions only results in invalid conclusions and intellectual confusion for the student (Klymkowsky et al., 2006). Each student’s cognitive framework has to be internally redesigned to allow the student to integrate the new information and resolve the conflicting views being experienced, a process that requires learning new constructs. Research indicates students appear to learn better and are often more willing to adjust their convictions when they are dynamically engaged in an instructional format that allows them to experience, observe, and reflect on events, regardless of whether or not the event fits or contradicts their belief systems (Hake, 1998a; McClosky et al., 1980; Tao & Gunstone, 1999; Zhou et al., 2008).

One of the most difficult areas of modification in physics involves motion and force. A number of studies have documented the failure of students to integrate non-intuitive Newtonian concepts into their cognitive schema despite showing apparent significant achievement via traditional assessment (Clement, 1982; Halloun & Hestenes, 1985a, 1985b; McDermott, 1984; Martin-Blas, Seidel, & Serrano-Fernandez, 2010; Thornton & Sokoloff, 1998). Halloun and Hestenes (1985a) state two general conclusions can be reached as a result of students’ common sense beliefs. The first are beliefs about motion that are contrary to Newtonian theory. The second are beliefs that are well-established and fixed and not that alterable by conventional physics instruction.

Physics education research has shown that for some students, their commonly held beliefs of motion and force may have less in common with Newtonian laws than with Aristotelian dynamics. According to Knight (2004), Aristotelian thinkers frequently employ mistaken beliefs such as motion requires a force, forces may be inherent in the object thus causing or perpetuating motion, and heavier bodies fall faster than less heavy
ones, conceptions characteristic of Greek philosophical thought of more than two millennia ago.

While the Aristotelian view dominates the thought processes of some students, a quite larger number of students utilize what is known as the impetus theory characteristic of medieval scientific thought. Aristotle believed every motion must have a cause, but medieval scientists rejected the motive force of air or water in favor of a belief that an inherent sustaining power was imparted to a moving object by an active causative agent (the person or thing throwing, pushing, or pulling the object), and this sustaining power was dissipated by increments as it moved through a medium until it was finally used up (Butterfield, 1957). This *impetus theory* was first categorized by Jean Buridan, a 14th century French priest, and is imprinted in a number of students’ common sense beliefs today. Students do not characterize their beliefs as part of impetus theory but will generalize the action of pulling or throwing as the *force of the pull* or the *force of the throw* implying the object retains some intrinsic property that perpetuates the motion of the object beyond the action that initiates the movement (Knight, 2004). This intrinsic impetus usually manifests itself as a common sense belief that the impetus diminishes over time and space, eventually losing its intrinsic character causing the object to slow down or come to a stop. While at odds with modern conceptions of Newtonian mechanics, these common sense beliefs regarding causative factors and impetus were widely held by learned scientists in the Middle Ages as these conceptions explained the phenomena observed in the environment (Halloun & Hestenes, 1985b). It is not surprising that about two-thirds of students tested in beginning college physics classes hold at least some similar common-sense ideas that invoke Aristotelian and impetus theory (Halloun & Hestenes, 1985a).
**Significant Early Studies**

Clement (1982) provided engineering students with three situations involving force and motion. In the first situation, students were asked to examine a diagram of a pendulum as it swings from side to side. At a given point between the minimum and maximum height of the swing, the students were asked to draw arrows showing the direction of action of each force acting on the pendulum. Students consistently employed a pre-Newtonian impetus model to erroneously explain that a continuing force was acting in the direction of the pendulum’s motion to cause the pendulum to swing upward. Clement called this a “motion implies force” misconception (p. 67). In a follow-up problem, students were shown a diagram of a coin being tossed upward from a point and asked to use arrows to draw the forces acting on the coin after it had left the thrower’s hand. The results were that 90% of the engineering students incorrectly drew an arrow representing a force directing the coin upward when the coin was no longer in contact with the hand. Interviews with the students identified the impetus concept of an intrinsic force acting to propel the coin upward as part of the students’ reasoning, stating “‘the force of the throw,’ the ‘upward original force’ the ‘applied force’ “ was responsible for the continued upward motion of the coin” (p. 7). Finally, students were given a diagram of a rocket moving through space with the engines off and asked to draw what would happen to the motion of the rocket if the engines were turned on for two seconds. Of 150 engineering majors, 89% drew incorrect diagrams representing the rocket’s path. A number of students actually drew the rocket returning to its original horizontal direction after the engines had shut off, with the apparent belief that a continually acting force in the original direction of the rocket brought the rocket back in line with its original path, even though the problem plainly stated no other forces were present (p. 68). Regardless
of instruction, a significant number of students on a posttest still tended to hold on to their misconception of “motion implies force” and frequently continued to exhibit the same patterns of non-Newtonian analysis, with 75% holding on to erroneous beliefs in the coin toss problem and 44% in the pendulum problem (pp. 69-70).

Halloun and Hestenes (1985a) found similar results when they introduced and administered a multiple choice Mechanics Diagnostic Test (MDT) that utilized distracters characteristic of pre-Newtonian thought, namely Aristotelian dynamics or medieval impetus theory. They administered the MDT to physics students in both University Physics (calculus-based) and College Physics (algebra-based), as well as 80 high school students enrolled in a beginning secondary physics class. In an analysis of almost 1500 students, all scores on the diagnostic test were below 20 with the exception of one student that scored 28 of the 33 questions correct. The average score on the physics diagnostic test was reported to be only slightly above the random guess chance score of 7.3.

According to the Halloun and Hestenes (1985a),

A low score on the physics diagnostic test does not mean simply that basic concepts of Newtonian mechanics are missing; it means that alternative misconceptions about mechanics are firmly in place. If such misconceptions are not corrected early in the course, the student will not only fail to understand much of the material, but worse, he is likely to dress up his misconceptions in scientific jargon, giving the false impression that he has learned something about science. (p. 1048)

In a companion article, Halloun and Hestenes (1985b) identified students’ common sense beliefs, or misconceptions, according to beliefs that resembled classical Aristotelian, middle-ages impetus, or Newtonian thought processes. According to the
authors, common sense beliefs regarding the description of motion are characterized by confusion between an “instant of time” and “a time interval” (p. 1063), where the student believes an instant is an abbreviated time interval, leading to a lack of differentiation among acceleration, velocity, and distance. Secondly, students tend to believe that objects must be at rest if there are no forces acting on them and adopt this attitude by using the earth as a frame of reference. As with Clement (1982), students in this analysis believe every motion must have a cause, is started by some initial external force, and is maintained by the continuous application of that external force or by an internal impetus force intrinsic to the object. In alignment with Maloney (1984), students tend to recognize a dominance principle whereby larger, heavier objects exert more force against smaller, less massive objects, and by extension the object with the greater force overcomes the opposition of the other object causing the motion of the object with lesser force. Students believe an applied force must mean contact with the causative agent and the object to be moved, and some limit this causative agent to only living things.

Students fail to distinguish between an object’s weight and its mass, and believe a constant velocity is the result of a constant force being continuously applied to the object, and this force may dissipate over time or distance. By extension, an object undergoing acceleration must require a continually increasing force. For an object to maintain its motion, there must be an intrinsic force, or impetus, that is a characteristic component of the object that is independent of any external forces. When gravity is involved, it is often not thought of as a force but as the intrinsic tendency of an object to fall to the earth, and that the heavier the object is, the faster it must fall, a confirmation of the finding of Gunstone and White (1981).
Students’ concepts of position, velocity, and acceleration were examined in two studies by Trowbridge and McDermott (1980, 1981). In their initial study they looked at velocity in a single direction. Utilizing a graph that illustrated two balls rolling in the same direction, with one ball rolling faster and overtaking the other ball, they asked students if the two balls ever had the same speed and if so, at what position. Forty-one percent general physics students failed to accurately identify the positions where there were identical velocities while calculus-based physics students failed 32% of the time. Some of these students tended to believe that the ball in front was moving faster despite being overtaken by the ball behind it, and many predicted the two balls had the same speed when they were in the same position side by side, despite one ball being in the process of passing the other. In their second study, Trowbridge and McDermott (1981) examined the concept of acceleration in one dimension by rolling separate balls down a track and inquiring about the actions of the balls. Again, many students generalized using similar reasoning found in the first study, with more than 80% of physics students unable to differentiate velocity and speed pre-instruction, and more than 60% still evidencing problems post-instruction. Common misconceptions included ascribing identical accelerations to the two balls when they were in the same position, attempts to use final velocity as the determinant for acceleration, belief that the faster movement of a ball infers a greater acceleration, and the opinion that the ball traversing the greater distance per unit time must have a greater acceleration.

Gunstone and White (1981) investigated students’ understanding of gravity concepts by presenting the students with eight separate scenarios involving gravity. One of the situations involved the release of an iron sphere and a plastic sphere of identical size from a vertical distance of 2.0 m above the laboratory bench. Students were asked to
compare the time it would take for the iron sphere to fall versus the time for the plastic sphere. Although Newtonian physics indicates there is no difference in the acceleration of the balls, more than one-fourth of 176 students predicted there would be a significant difference in speed for the fall of the two spheres. Further, of those predicting different speeds, 40% indicated a sphere with a greater weight would have the larger acceleration, and those who had predicted a significant difference in the time for the fall of the spheres were more likely to state that they had seen the iron sphere hit first despite direct observation of both spheres hitting simultaneously on the laboratory bench. This process of observing the prediction was evident in several of the tested instances. The authors suggested the individual students’ minds were familiar with many physical principles based on daily observations, but the mind itself maintained its erroneous predictions to the extent of discounting what had been seen, thus reinforcing the predicted erroneous conceptions. In the discussion of their results, the authors draw two general conclusions: that “students know a lot of physics, but do not relate it to the everyday world” (p. 298) and that several students showed a “failure to resolve discrepancies between predictions and observations” (p. 299), indicating a reasoning process that was based largely on circular reasoning or intuition and emphasized less reliance on logical considerations.

The Force Concept Inventory

Identification of common misconceptions in physics-based courses has been traditionally approached by physics education researchers in a two-pronged process (Beichner, 1994; Champagne, Klopfer, & Anderson, 1979; Clement, 1982; Frank, Kanim, & Gomez, 2008; Gunstone & White, 1981; Halloun & Hestenes, 1985b; Hestenes & Wells, 1992; Luangrath et al., 2011; Thornton & Sokoloff, 1998; Trowbridge & McDermott, 1980, 1981). The first step is an intensive interview process of student
understanding of a conceptual process whereby the student is given a situation or physical apparatus and asked a series of probing questions about the set-up to draw out predictions of outcomes from the student who must conceptualize the end result of the scenario to make their predictions. These predictions reveal ingrained student beliefs about the way the physical world should work based on the student’s prior experiences that have formed and reinforced these beliefs. Following the interview a series of conceptual multiple choice questions are generated that have distracters linked to the incorrect pre-conceptions commonly found in the student interviews. While many of these conceptual questions have initially been criticized by physics professors as too simplistic for use in a college assessment, the results have been remarkably consistent: Students that have recently completed the course of study often still have the incorrect pre-conceptions deeply rooted in their belief systems, despite having been given instruction in the correct conceptions, and evidence little gain in conceptual knowledge (Halloun & Hestenes, 1985a, 1985b; Martin-Blas et al., 2010; Thornton & Sokoloff, 1998).

In response to concerns about the conceptual integration of students in physics, Halloun and Hestenes (1985a) composed a diagnostic test composed of a set of multiple choice questions designed to measure the conceptual understanding of force in secondary and post-secondary students of physics. Originally conceived as the Mechanics Diagnostic Test (MDT), its purpose was to probe students’ understanding of basic Newtonian concepts of force. The MDT underwent extensive testing for validity, which was established by expert agreement on the content, correct answer agreement from testing with graduate physics students, posttest interviews with the introductory physics students, and the careful examination of answers from high scoring students for
misunderstandings due to the content of the questions. The reliability of the MDT was established through post-test interviews with students to see if there were variations in their answers compared to those they had originally chosen and by a statistical analysis of comparable groups using the Kuder-Richardson test. Student responses on the posttest interview were consistent with their test answers indicating stable beliefs rather than uncertain concepts. Kuder-Richardson reliability coefficients for the MDT were 0.86 for pretest and 0.89 for posttest analysis, indicating a good reliability for the test (p. 1044).

The gap between what instructors believe their students learned and what the students actually retained led to the development of the Mechanics Baseline Test (MBT) that used both conceptual questions and mathematical problems to probe the depth of student understanding in physics following formal instruction (Hestenes & Wells, 1992). However, the MBT was designed with both quantitative and qualitative questions to test mechanics understanding after instruction in an introductory physics class, presumably when the student had a base of mechanical knowledge to solve the situations and problems presented.

Simultaneous with the publication of the Mechanics Baseline Test, Hestenes et al., (1992) published the Force Concept Inventory (FCI). The FCI was modeled after the original 1985 version of the Mechanics Diagnostic Test and addressed the same conceptual domain as the Mechanics Baseline Test. However, the FCI was unique because it required no mathematical calculations to find an answer, only a set of reasoning skills that effectively addressed the core concepts of force and motion. The authors identified these core concepts in 1992 across six conceptual dimensions within the Newtonian force concept domain for the FCI. These conceptual dimensions were updated for the revised FCI by Savinian and Scott (2002).
The intent of the FCI was to provide a series of easily identifiable situations relevant to the student and ask a series of multiple choice questions with one correct Newtonian answer accompanied by a set of research-based distracters that drew on known misconceptions that were commonly found in beginning physics students. In this way the test could not only identify if the student selected the correct answer due to a fundamental understanding of Newtonian concepts but also could statistically determine from an incorrect selection the degree of misconception of Newtonian force and motion concepts held by the student.

A slightly revised version of the FCI was published on the web in 1995 to account for perceived ambiguities in some of the questions (Hake, Halloun, Hestenes, & Mosca, 1995). Suggestions for improving question clarity from professors and instructors that had used the 1992 version of the FCI were incorporated into the revised version.

**FCI Controversy**

The Force Concept Inventory has been widely accepted and used by physics instructors and professors from its inception (Hake, 1998b). However, since there was no formal validity or reliability study by the authors of the FCI, questions arose regarding what exactly the FCI measured.

Foremost in their criticism were Huffman and Heller (1995a), who affirmed their belief in the impressive consistency of the FCI and stated their belief in the reliability and validity of individual items on the inventory. However, they questioned the coherence of the FCI based on a factor-analysis of the inventory. A factor analysis is the process of determining the correlation that exists between test items. Items that relate to the same factor should show higher correlation than those that do not, thereby allowing a grouping of items that are representative of a particular factor. That is, when analyzed, test items
that focus on the conceptual domain of velocity should group together as one factor (velocity) and be separate from test items that group together for a separate factor, such as acceleration. Huffman and Heller (1995a) found factor analysis for high school physics students resulted in a total of ten factors, but only two were significant due to their variability. An analysis of university physics students found nine factors with only one being significant (p. 140). The authors concluded “the large number of insignificant factors produced…indicates that the questions on the FCI are only loosely related to each and do not necessarily measure a single force concept or the six conceptual dimensions of the force concept” (p. 140). While they concede the six conceptual dimensions as put forth in the FCI are reasonable and cohesive to a physics instructor, they state there is no evidence of a logical linkage for concepts represented by the individually grouped questions on the FCI from the students’ point of view.

In their reply, Hestenes and Halloun (1995) stated the use of the FCI must be taken as a synergistic whole since individual pieces of the inventory are not as reliable and informative as when the inventory is interpreted in its totality. They assert that Huffman and Heller had neglected to take into account issues that Hestenes and Halloun had previously published, citing special features in the design of the test to minimize false positive answers (selection of Newtonian answers without an understanding of the Newtonian mechanics involved) and false negative answers (selection of a non-Newtonian answer despite an understanding of the underlying Newtonian mechanics). They maintain that, when viewed from the standpoint of the FCI as a tool for evaluating students’ understanding of the Newtonian force concept, the face validity of the FCI and its six conceptual dimensions were established by multiple inspections of many physics professors over the years of use. According to Hestenes and Halloun (1995), the data
used to criticize the FCI was irrelevant as it was derived from non-Newtonian responders. They maintained that a statistical factor analysis of the Newtonian force concept required results from a Newtonian population, such as established physics instructors and professors, who were familiar with the concepts being tested. Hestenes and Halloun (1995) state the FCI was not intended to evaluate the structure of student concepts but to identify the “disparity between student concepts and the Newtonian force concept” (p. 504). In essence, they state the FCI was devised as a standard against which student conceptual beliefs could be compared, not as a test of student conceptual coherence.

In their response, Huffman and Heller (1995b) again disputed the cohesiveness of the FCI, reiterating their belief that the test items on the FCI showed only a weak correlation from the students’ viewpoint. They interpret these results as the FCI measuring pieces of students’ knowledge that exist in a non-coherent framework rather than a coherent system of force theories, a response seemingly at odds with the stated purpose of the FCI by its authors. Despite their concerns, Huffman and Heller state, “Comparable physics courses across the country have obtained very similar results using the inventory…. The authors have also gone to considerable lengths to …confirm the validity of responses to individual items. All of these finding lead to the general conclusion that the FCI is one of the most reliable and useful physics tests currently available” (1995a, p. 138) and acknowledge the FCI is “the best test currently available” (1995b, p. 510).

Savinainen and Viiri (2008) addressed the validity question of conceptual coherence for the FCI by dividing the conceptual coherence of students into three components: Representational coherence, which is the ability to shift from one situational representation, such as a graphical depiction, to another representation, such as diagram
or verbal image; Contextual coherence, or the ability to extend a concept or principle to both well-known and new circumstances; and Conceptual framework coherence in which students combine multiple concepts to form an integrated conceptual framework. Their results contradicted the assertions of Huffman and Heller (1995a, 1995b) that the FCI measured only fragmented pieces of student knowledge. Post-test interviews indicated that students who were successful in responding to the FCI items also had a grasp of Newtonian force concepts, lending additional support to the validity of the instrument.

The acceptance of the validity and reliability of the FCI as a diagnostic tool by the physics educational community is evidenced by the scope of its use. Since its publication in 1992 and its subsequent revision in 1995, professors around the world have used the FCI as the premier diagnostic of student comprehension of Newtonian physical concepts. Over 50 thousand students have been tested with it at Arizona State University, approximately 10 thousand students at Harvard, and, globally by estimate, up to one million students from high school to university level have been evaluated by the instrument with remarkably similar results, making it perhaps the most widely used science concept inventory in use (Lasry, Rosenfield, Dedic, Dahan, & Reshef, 2011).

**Conceptual Change**

Physics education research literature uses a number of different terms to identify the existence of preconceived common-sense beliefs by students that are at odds with established Newtonian principles. The term *misconception* is widely used to mean preconceptions that are erroneous and in conflict with scientific thought (Clement, 1982, 1989; Halloun & Hestenes, 1985a, 1985b, 1992; McClosky, 1983; Wandersee, Mintzes, & Novak, 1994). However, the literature contains a variety of terms other than *misconceptions* to identify flawed common-sense beliefs: Champagne and Klopfer (1980)
label these flawed common-sense beliefs as naïve conceptions while diSessa (1993) calls them p-primts, a shorthand version of the term phenomenological primitives. Other terms include intuitive knowledge (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001), facets (Minstrell, 1982), and alternative conceptions (Dykstra, Boyle, & Monarch, 1992). All refer to the inherent beliefs about physical processes formed by the student through a lifetime of observation of physical phenomena and daily interaction with their environment, and all signify incompatibility with accepted Newtonian theory. Once imbedded in the student’s cognitive framework these misconceptions are very stable in the students’ knowledge framework and are difficult to change even in the face of cognitively dissonant events that violate the premises of the misconception, and act to provide the students with false premises for inductive or deductive reasoning (Bayraktar, 2008; Caramazza, McClosky, & Green, 1981; Champagne & Klopfer, 1980; Chi, 2005; Clement, 1982; Driver & Erickson, 1983; Gunstone & White, 1980; Lightman & Sadler, 1993; McClosky, 1983; McDermott, 2001; Prince et al., 2010; Sabella & Redish, 2007; Streveler, Litzinger, Miller, & Steif, 2008; Wandersee et al.,1994). The act of conceptual change requires the construction of new cognitive frameworks or the revision of existing ones (Carey, 1999; Chi, 2005; Ioannides & Vosniadou, 2002; Posner et al., 1982). The incorporation of new or dissonant concepts requires a change in the student’s conceptual ecology that Posner et al. (1982) defined as “an individual’s current concepts” and then proposed four conditions necessary to revise the student’s conceptual ecology for an accommodation of new information to potentially occur within the cognitive framework (p. 214):

1. The student must experience dissatisfaction with a currently held conception. Unless there are over-riding reasons to revise or abandon a currently held
conception, such as anomalous events or irreconcilable conflicts that cannot be explained by the existing conception, then an accommodation is unlikely to occur.

2. The student must feel the new concept is intelligible. Students try to make sense of their world, and the new conception must have enough meaning for the student to investigate its potential to explain their world experiences.

3. The student must believe the new conception is plausible. New conceptions must be able to adequately address prior problems that were unexplainable by the initial conception as well as appear consistent with existing knowledge.

4. The student must feel the new concept will be fruitful. That is, it will provide a method of investigation and inquiry that is superior to the prior conception.

This process of “radical conceptual change,” as the authors termed it, or accommodation, does not mean a complete revision of the student’s conceptual organization, but rather some concepts will be altered or replaced while others will maintain their current state, acting to direct the conceptual change process (p. 213). They postulate it is the features of the student’s conceptual ecology that oversee the radical conceptual change in the mental framework. The basis for these conceptual ecologies are varied and range from analogy and metaphor to epistemological allegiance and speculative metaphysical beliefs, elements of the student’s cognitive methodology to analyze the level of justification for a concept and its change (Hewson & Thorley, 1989). Carey (1991) delineates three processes whereby conceptual change may then occur: Replacement, where the initial concept is in essence replaced by a competing concept representing a different core model: Differentiation, when a single concept is modified and divided into two or more complementary concepts, and Coalescence, when two separate but complementary concepts merge into a single, more generalized concept.
However, the development of a more sophisticated mental model that can be modified and realigned with new and sometimes contradictory information as the result of formal instruction may not result in complete conceptual change but instead may lead to a mental model inconsistent with accepted scientific thought (Ioannides & Vosniadou, 2002; Tsaparlis & Papaphotis, 2008; Vosniadou et al., 2001). Chi (2008) states that mistaken categorization is a rare event in everyday life but is the root of major misconceptions in science, postulating that students have a difficult time with conceptual change due to the new concept being cognitively assigned to an ontological category different from the scientific model formed through formal instruction or because the new concept is so different from the student’s prior experiences and conceptual categorizations that there is no category within the hierarchical cognitive framework to which it can be assigned.

The conceptual change process has also been compared to a mosaic in which students’ conceptual knowledge is composed of multiple elements that act semi-independently. These knowledge pieces are collectively referred to as phenomenological primitives (p-prims), facts, or facets (Clark, 2006; diSessa, Gillespie, & Easterly, 2004; Minstrell, 1994; Smith, diSessa, & Roschelle, 1993). The unstructured assemblages of knowledge elements are a reflection of past experiences with the learner’s environment and are not organized into a highly structured framework within the conceptual ecology of the student (Clark, 2006; diSessa, 1993; Southerland, Abrams, Cummins, & Anzelmo, 2001). As such, these elements may then maintain many individualized and loosely connected ideas that may be consistently in conflict with each other and are generally context sensitive (Thaden-Koach, Dufresne, & Mestre, 2006). That is, the synthesis of a conceptual idea may be situation dependent and therefore, not consistent or transferable.
across broad categories (diSessa, 1993; diSessa et al., 2004). This knowledge-in-pieces view emphasizes a consistent use of knowledge within defined parameters of the students’ cognitive framework that is situation specific based on the relevance the student attaches to the circumstances. In this view, conceptual change is not a radical reorganization or replacement of existing cognitive schema but a gradual process of reinforcement, addition, subtraction, and elimination of individual elements that occurs very slowly (diSessa et al., 2004)

Regardless of nuanced differences, conceptual change researchers are in agreement that conceptual knowledge is a result of daily interactions between the learner and the surroundings, that naïve knowledge is a function of prior misconceptions and has a significant influence on the learning of non-intuitive scientific concepts, and that misconceptions are difficult to modify or change, and if they change, they are assimilated only over time (Ozdemir & Douglas, 2009). The mechanism of conceptual change, whether knowledge as a coherent framework, as a series of disconnected elements or as some other intrinsic mechanism, is still widely debated in the literature (Kang, Scharmann, & Noh, 2010; Ozedemir & Clark, 2007; Zhou, 2010).

**Online Education**

The introduction of distance education through internet-based online delivery systems has led to an unprecedented growth in access to higher education coursework for people who logistically would not be able to pursue a degree at a traditional university. Allen and Seaman (2007) report online enrollment has grown at a faster rate than higher education as a whole, with over three million students taking online courses in 2005 and showing an increase of more than twice the number of new enrollees that year as compared to any year prior. This seems to confirm Oakley’s contention that the number
of courses offered through online formats has continued to increase as colleges and universities embrace the new technologies as a future paradigm of education (Oakley, 2004).

Instruction online has grown substantially in Mississippi as well over the past several years, especially at the community college level. Beginning in 2000, the Mississippi Virtual Community College (MSVCC), a consortium of fourteen community colleges in the state of Mississippi, was created to provide a cohesive structure for online instruction. It currently claims to serve up to 20,000 students each semester and offers a growing number of courses that can be taken completely online (MSVCC website, 2011), including an online version of Physical Science I adapted from the traditional course taught to students at Mississippi Gulf Coast Community College.

The online format presents unique challenges to the delivery of course content, especially in the laboratory-based sciences (Boschmann, 2003; Casanova et al., 2006; Johnson, 2002; Landau, 2006; Patterson, 2000; Reeves & Kimbrough, 2004). In their 2010 Distance Education Survey Results analysis, the Instructional Technology Council ranks lab-based sciences as the most difficult of all course formats to deliver effectively online (Instructional Technology Council, 2010).

A unique part of higher education in Mississippi is the Mississippi Virtual Community College (MSVCC) system, a consortium of community colleges that joined together to offer instruction via the Internet. Starting with an enrollment of 1,382 students in January of 2000, it has grown rapidly to service over 20,000 students as of 2011 (MSVCC website). While online colleges like the MSVCC have provided access to higher education for many who could not attend traditional courses on campus, the online learning atmosphere presents unique learning challenges for students (Elvers, Polzella, &
Students that enter an online class expecting it to mirror a traditional classroom in form and function are quickly forced to adapt to the protocols of the new learning environment or withdraw from the class. It is largely the ability of the student to accommodate the new demands of online learning that will contribute to their persistence in a web-based learning system (Herbert, 2006; Wojciechowski & Palmer, 2005). New technologies, especially the internet, have made it possible to reach and teach students who in the past would never have had access to a traditional college education (Corich, 2005). With the advent of the online Learning Management Systems (LMS), such as Blackboard, Sakai, Desire2Learn, and Moodle, tools for communication, course management, and course delivery are readily available (Blythe & Verhaart, 2007). In fact, college instructional models that confine themselves to little or no technology, as in the traditional lecture method, are rapidly being transformed into a new paradigm of online delivery, supported by studies that show online instruction is as effective as traditional lecture formats (Means et al., 2010).

Reynold (2011) outlines four models representing current practices that make up a continuum from low to high of technology use in the higher education classroom: Model A is the traditional, lecture-based model used in the majority of colleges and universities where students sit passively and receive the information from the sage on the stage for memorization and regurgitation on a test. Interaction is limited, especially in large lecture hall classes. Research has shown that this manner of learning is limited in its effectiveness when trying to teach deep conceptual topics as found in physics (Bayraktar, 2009; Clement, 1982; Halloun & Hestenes, 1985a, 1985b; McDermott, 1984).

Model B is an augmentation of Model A. Students receive the traditional lecture but the Internet is used as an ancillary source for posting of assignments and the syllabus,
to provide external links to information, and for communication through e-mail. Additionally, video streaming, discussion and chat rooms, and access to campus and off-campus resources are components of this model. This model design is the web-enhanced or blended (hybrid) model. According to Kim and Bonk (2006), a survey of college instructors and administrators predicts that this model of blending face-to-face instruction with online delivery will become the dominant method of instruction, surpassing even completely online courses.

Model C is a combination model where the student will take some courses entirely online to satisfy requirements for their program or degree. The majority of courses in a given degree program will be completed by the student in a Model A or Model B format, with a subset of courses being completed entirely online.

Finally, Model D is where the student completes their coursework completely online, perhaps never having set foot on a campus. This method is indicative of many online universities and offers ultimate flexibility for the distance learner. The completely online format does, however, present challenges to laboratory based science courses (Boschmann, 2003; Casanova et al., 2006; Johnson, 2002; Patterson, 2000; Reeves & Kimbrough, 2004).

Over the past decade there has been a perceptible shift toward education offered over the internet. More recently, the trend toward taking online classes in the United States is growing at a rate exceeding the growth of traditional classes, maintaining an increase of about 10% per year as opposed to 1.5% for higher education as a whole (Allen & Seaman, 2007). The driving force behind the push for online instruction, from the administrative viewpoint, is that there is a population that can be served by this technology that is not being served in the traditional methods, namely those adults with
full-time jobs, demands of family, and no close access to an institution of higher learning (Mayadas, Bourne, & Bacsich, 2009). Asynchronous delivery of course content along with a delivery mechanism largely unrestrained by learner location has allowed access to higher education for diverse segments of the population. The issues of inflexible class times and juggling of work versus academics has been mediated by the ability to offer access to all with a computer and Internet connection. Some authors laud the perceived benefits of an online experience, such as the potential for engaging higher order critical thinking skills due to the asynchronous nature of the class that allows the student time to reflect on answers to open-ended questions or conceptual tenets of the topics surveyed (Garrison, Anderson, & Archer, 2001; Hawkes, 2001).

The delivery of online coursework through the Internet has taken distance learning forward a quantum leap; it is the quality of the coursework that is now being scrutinized by higher education professionals and stakeholders (Casey, 2008; Rabe-Hemp, Woollen, & Humiston, 2009). Dykman and Davis (2008) believe the revolutionary potential of online delivery, its potentially wide audience, and its impetus for new teaching or learning paradigms make it a potential juggernaut in higher education if the quality issues with online coursework can be resolved. Quality issues aside, there are other pressures being brought to bear on institutions of higher learning. According to Wergin (2005), higher education is finding itself in the demanding position of greater accountability and greater transparency, a situation that mandates a need for effective quality benchmarks in all aspects of the academic institution.

Quality issues in teaching and learning have been dynamic in their quest to keep up with the design of the new technologies, especially online delivery. The online environment has many things in common with the traditional classroom but also has
components unique to the web-based setting. The format of the classroom has begun transforming from the teacher-centered straight lecture format to a learner-centered model that casts the instructor in the role of facilitator and places a larger responsibility for learning and achievement on the student (Abbott, 2005). One of the most challenging areas for online students is the lack of a physical classroom of people to interact with verbally and physically. The visual and verbal cues relied upon by students in a traditional classroom are not available to the online student. The physical and social limitations of the online course means students must be largely self-motivated and self-directed and must exercise a greater degree of autonomy in completing assignments while assuming a larger share of the responsibility for meeting their educational goals (McLauren, 2004).

The “No Significant Difference” Phenomenon

The past two decades have produced a number of mixed research results on the efficacy of online learning. In probably the most widely known meta-analysis of distance education, Russell (1999) examined 355 studies of distance learning ranging from 1928 to 1998 and reported there was no significant difference in the outcomes of learning between technology enhanced delivery and traditional methods. Russell noted that there is no decided benefit to delivery by technology, but it is this study that many have pointed to in support of technology-driven online delivery of coursework, primarily since several of the studies Russell included dealt with online vs. face-to-face instruction. However, Russell stated he used no scientific methodology in selecting the studies but simply generated a compilation of every study he could find that showed no significant difference, curiously omitting studies that showed a difference. In fact, Russell seemed primarily concerned with delivering the most cost-effective instruction possible, and his
focus appears to be on utilizing the lowest-technology based system for the best return in outcomes. The question of whether that technology should be web-based is not appreciably addressed in his book, although he does advocate technology as a viable alternative to traditional instruction.

Russell’s analysis does have its detractors. Phipps and Merisotis (1999) cite four major problems with Russell’s methods: 1) there was a lack of control for extraneous variables that negates cause and effect conclusions. Many studies in Russell’s compendium were poorly designed and had no basis to assign causality; 2) there was no random assignment of subjects to groups in most of the studies. They tended to use intact groups, thus introducing attributes that could be contributable to variables other than distance technology; 3) the validity and reliability of the instruments used in the various studies were questionable. The effectiveness of the instruments was rarely tested for validity or reliability, and without these two components the confidence in the various instruments was compromised; and 4) the reactive effects were not controlled for in a number of the studies; there was a focus on individual technologies, not effects from multiple interactions. Regardless of these criticisms, Russell is still quoted as an authority in the literature. Kanaka (2008) states the primary difference in the debate between online and on-campus learning environments is that online proponents persist in claims that the online environment can be superior in learning effectiveness than on-campus face-to-face classrooms, despite literature following the “No Significant Difference” publication where several authors performed meta-analyses of available comparative studies for distance versus face-to-face education and essentially came to the same conclusion: that while online instruction via the internet can be just as effective as
traditional classroom instruction, it does not generate superior learning or outcomes (Cavanaugh, 2001; Means et al., 2010; Zhao et al., 2005).

While the online environment is becoming more widely accepted by mainstream higher education, difficulties and skepticism still exist in certain areas, notably science. The barriers to reproducing a quality lab-based science course in an online format are formidable. A recent survey indicates that, while higher education administrators and faculty seem to be holding a more favorable view of online education, the most difficult courses to provide online are lab-based sciences (Allen & Seaman, 2007).

*Characteristics of Online Learners*

Instructors of online courses face a multitude of challenges that go beyond traditional learner characteristics of gender, religion, race or ethnicity. The modern online course contains a diverse mix of generational learners ranging from older, mature individuals to young, sometimes teen-aged, students (Dabbagh, 2007; Erickson & Noonan, 2010; Holyoke & Larson, 2009; Kerr et al., 2006). Among the predominant generational divides for online students are technology and the degree of technological savvy a student brings to the online environment (Dabbagh, 2007; Howe & Strauss, 2000; 2003; Oblinger, 2003; Prensky, 2010; Reeves, 2008). The primary generations engaged in online learning fall into three broad classifications (Howe & Strauss, 2000; 2003): the Boom Generation, or Baby Boomers, born from 1943-1960; Generation X, also called Gen-Xers, born from 1961-1981; and the Millennial Generation, better known as Millennials but sometimes referred to as Gen-Y or Net-Gen, born from 1982-2000. Each generation brings with it certain defining characteristics in the literature. While there are several other generalized divisions based on years of birth (Lancaster & Stillman, 2002; Martin & Tulgan, 2002; Oblinger & Oblinger, 2005; Tapscott, 1998), the
divisions of Howe and Strauss are representative of the literature. Within these groupings, Boomers are generally typified by a strong work ethic, loyalty, idealism, and an openness to change (Gibson, Greenwood, & Murphy, 2009). However, they are regarded as being at best only moderately technologically savvy as they learned technological skills later in adult life, a condition Prensky (2001a, 2010) identifies as digital immigrants. Prensky also classifies members of Generation X as digital immigrants as their technological skills began in adolescence, but Gen-Xers are considered to have greater skills in technology-based media as compared to Boomers. As a whole, Gen-Xers are characterized as being computer savvy, more self-reliant, independent, and more cynical than their Boomer parents (Gibson et al., 2009). In contrast, the Millennial generation tends to be creative multi-taskers requiring challenges and opportunities to remain engaged. They are very comfortable with technology and technology-based media in a collaborative role, as evidenced by their interactions with online networking (Gibson et al., 2009). Prensky (2010) coined the term Digital Natives to describe this group of students that have always been immersed in the computer and technology age. They grow up learning the technology skills as part of everyday life, not as new skills that are outside their learning environment.

It would seem that the millennial student would be the archetypical learner in the online learning class, but the typical online learner presents a demographic that is older than the typical undergraduate Millennial student: a white male who is 29 to 35 years of age and a digital immigrant (Bocchi, 2004; NSSE, 2006). Despite this characterization in the literature, the accepted demographic of the online student may be changing (Dabbagh, 2007; Reeves & Oh, 2007). There is a mix along the age-generational gradient that results in online classes being a very diverse melting pot of students. Additionally,
Reeves (2008) advocates caution in applying generalities to generational groups since much of the defining characteristics delineated in books and articles (Howe & Strauss, 2000; 2003; Prensky, 2001a, 2001b, 2010) are the result of surveys that are limited in scope; none utilize a broad-based national survey that includes all levels of generational and socioeconomic groups. Bennett, Maton, and Kervin (2008) echo this concern stating there is no empirical evidence to support the contentions that the Millennial generation has any significantly different learning styles or higher degree of sophistication than previous generations, despite their technological immersion.

Regardless of generational classification, perhaps the greatest challenge online learning presents to the student is the shift from the traditional teacher-centered environment, where the learner assumes a primarily passive role in a lecture-based classroom, to the learner-centered paradigm that necessitates a substantially more active and engaged undertaking for the online student (Craig, Goold, Coldwell, & Mustard, 2008). Online learners now make up more than one-fifth of higher education students, with projected growth of online students to continue in the coming years (Allen & Seaman, 2008). However, not all the students that enroll in an online course will be successful in passing or completing the course.

As a group, successful online learners tend to share certain characteristics, and the literature points to two characteristics that appear ubiquitous: communication and motivation. Proficiency in interpersonal and intrapersonal communication skills is critical to online success (Dabbagh, 2007; Hong & Jung, 2011; Kerr et al., 2006; Song & Hill, 2007; Williams, 2003). The ability to read and write effectively is an absolute necessity to function effectively in the online environment since the primary method for transfer of information for the foreseeable future continues to be text-based (Kerr et al.,
Additionally, the ability to coherently translate thoughts into written form that conveys the essence of the principles or concepts is a vital skill for communicating with other students in the course or with the course instructor.

Motivation is also vital to success in the online environment. The ability to self-motivate and perform as an autonomous learner is crucial for online learner success (Chen et al., 2010; Green & Kelso, 2006; Hong & Jung, 2011; Kerr et al., 2006; Song & Hill, 2007; Tallent-Runnels et al., 2006). While traditional bricks-and-mortar classrooms have an instructor available for instantaneous pacing and feedback, the online learners have no readily accessible instructor and must rely on self-management and self-discipline to regulate their learning environment. Self-regulating students with higher levels of independent learning skills, such as time management and goal setting, are more likely to be successful in online courses than those with lower levels of (Cheurprakobkit, Hale, & Olsen, 2002; Kerr et al., 2006; Yukselturk, & Bulut, 2007).

The literature also identifies several other beneficial characteristics of online learners, including social affiliations, internal locus of control, collaborative learning, and familiarity with technology and online delivery systems (Dabbagh, 2007; Kerr et al., 2006; Puzziferro, 2008; Tallent-Runnels et al., 2006). Hong and Jung (2011) further identified fifteen online learner competencies across five clusters that are characteristic of successful online learners but note that it is unlikely any individual student would exhibit all fifteen competencies. Rather, each student utilizes those competencies most beneficial to that learner. However, they did affirm the results of prior research that learner autonomy and motivation appear to be among the most important of successful online learner characteristics.
Effective Instruction

Effective instruction, whether in the traditional bricks and mortar classroom or the online learning environment share certain necessary instructional components. Chickering and Gamson (1987) in their meta-analysis of effective teaching methods identified seven best practices for undergraduate instruction:

1. Encourages contact between students and faculty: Considered by Chickering and Gamson to be the most important component for student motivation and involvement.

2. Develops reciprocity and cooperation among students: Students in isolation are not as committed or involved with the process as those who experience interaction with others.

3. Uses active learning techniques: Students do not learn passively, but must be active in their acquisition and analysis of the learning experience.

4. Gives prompt feedback: Students need to know if their assumption and deductions are accurate and need prompt, constructive responses so they will have time to reflect on what they are learning.

5. Emphasizes time on task: To quote Chickering and Gamson (1987), “Time plus energy equals learning. There is no substitute for time on task” (p. 3). Time management is a skill that every student must acquire. Allocating the time needed to effectively incorporate new ideas and concepts is essential to successful learning.

6. Communicates high expectations: Students act based on instructional expectations. If those expectations are low, there is a concomitant low level of effort by the student. Communicating high expectations challenges the
student to rise to a level above their comfort zone, stretching them intellectually.

7. Respects diverse talents and ways of learning: Students bring with them the experiences of their life. Some are better prepared academically, some better versed in physical manipulation in a lab, and others with varying degrees of expertise in given areas. All, however, have talents that will help them learn in their own way.

Chickering and Gamson emphasize the seven practices act synergistically when all are applied to bring to the instructional process six powerful forces in education: activity, cooperation, diversity, expectations, interaction, and responsibility (Chickering and Gamson, 1987). These practices are effective in the traditional lecture format and have been found to be effective in online instruction as well (Brew, 2008; Graham, Cagiltay, Lim, Craner, & Duffy, 2001; Young, Cantrell, & Shaw, 2001)

Physics-Based Instruction Online

The instruction of physics-based courses online presents singular difficulties due to the qualitative and quantitative aspects of the course content. Physics is composed of a bewildering interplay of both abstract and concrete concepts, a mix that is often daunting to students used to thinking in one arena or the other, not both simultaneously (Donald, 2002). Couple the difficulties of learning the core concepts of physics with the distance aspects of online instruction, and the student can become quickly overwhelmed (Means et al., 2010; Meisner et al., 2008). Compounding the difficulties, there are inherent impediments to translating a hands-on lab-based science from the traditional academic laboratory to an online delivery format that can be effectively performed at a student’s home (Boschmann, 2003; Casanova et al., 2006). Because of these formidable barriers
and the relatively new delivery system, few research efforts have been directed at examining the effectiveness of learning in online physics classes. A recent meta-analysis of over one thousand studies found traditionally taught courses and identical courses offered online show students in the online course generally perform at a level equal to those in the traditional classroom (Means et al., 2010). Additionally, student satisfaction with the online experience appears to correlate positively with learning outcomes (Eom et al., 2006), but overall student satisfaction is often less than with the face-to-face traditional method of instruction (Rivera & Rice, 2002; Summers et al., 2005).

The construction of a web-based course in physics is centered on the ability to communicate effectively as the student is required to interact with all components of the online structure, including the instructor, other students, and the media content itself. Scientific literacy is a goal of the physics framework for an online course and inquiry is a key component of that structure. Students must be able to demonstrate and communicate competencies that assess current and relevant past scientific issues, evaluate physical phenomena via scientific investigation, and analyze scientific facts to draw valid conclusions (Bybee, Mcrae, & Laurie, 2009). The online media structure must be designed to challenge the student’s cognitive framework by utilizing the tools of scientific inquiry to encourage an examination of core beliefs and confront any pre-existing misconceptions (Meisner et al., 2009). The ability to devise a scientific investigation, interpret data, hypothesize outcomes, and engage in inductive-deductive reasoning must all scaffold together in a cohesive whole for the online student.

Regardless of the method of delivery, many students have difficulty in physics-based science courses. Conceptual abstractions are very difficult for students to internalize, especially when they conflict with pre-conceived ideas already ingrained in
the student (Baser & Geban, 2008; Caramazza et al., 1981; Champagne & Klopfer, 1980; Clement, 1982; Halloun & Hestenes, 1985a; 1985b; Pringle, 2006; Settlage & Goldston, 2007). In response to those problems researchers have devised teaching methodologies based on theories of how students learn science (McDermott, Heron, Shaffer & Stetzer, 2006; Redish, 1994; Sabella & Redish, 2007). However, implementing strategies based on research has mixed results. Henderson and Dancy (2009) surveyed physics faculty in higher education across the country and found that, of 24 identified instructional strategies in physics, such as problem-based learning, interactive lecture, peer instruction, inquiry learning, and Socratic dialogue, most faculty members were aware of the existence of these strategies, and many had attempted to incorporate them into their instructional process with generalized success but frequently discontinued them citing time constraints, lack of familiarity with the strategy, lack of motivation to adopt the strategy, and a lack of fit with their department or institution.

*The Physical Model: Conceptual Change*

The scientific community views scientific literacy as the degree to which a teacher imparts the central concepts of a core field (e.g. physics, biology, chemistry) and how well the student integrates the premises, concepts, and models of that field (Laugksch, 2000). Science instruction focuses on developing scientific literacy in the student. The ability to acquire inquiry skills and differentiate between fact and opinion lies at the core of scientific literacy. If a student is unable to think critically about ideas and events, to process information based on evidence, and to question the beliefs of themselves and others, then he or she is unable to make informed, valid decisions about the quality of information or evaluate arguments and draw reliable conclusions from the premises of those arguments (Rutherford & Ahlgren, 1991). The purpose of an introductory physics-
based course is to give students the relevant scientific concepts and ideas to allow scientifically literate decision-making.

Conceptual change does not necessarily refer to the incorporation of a scientific model of cognition as a replacement for a student’s pre-instructional concepts, although that is sometimes required. Instead, it is often the case that a structural modification of the pre-instructional conceptual framework can be accomplished using inquiry methods in such a manner as to allow for the integration of the scientific concepts being introduced (Chinn & Brewer, 1993). Chinn and Brewer designate conceptual change as a design for restructuring a student’s cognitive framework to incorporated non-intuitive anomalies. They identified six ways a student might react to an event that exploited cognitive dissonance in a discrepant event for re-structuring or replacing established schema. However, they acknowledge the possibility of limited success and submit that changing the ingrained mental schema is difficult and may only result in a peripheral conceptual change. Learning to formulate effective cognitive strategies to process and analyze information is often a difficult process for the science student in a classroom.

Regardless of the strategy, all incorporate one central theme: the student must be an active participant in the learning process (Hake, 1998a, 1998b; Lai & Land, 2009; May & Etkina, 2002; Richardson, 2003; Yilmaz, 2008). Studies have shown the passive acceptance of course material through a purely lecture-based teacher-centered format is ineffective at conveying deep understanding of complex conceptual material in physics (Clement, 1982; Eryilmaz, 2002; Halloun, & Hestenes, 1985a, 1985b; Luangrath et al., 2011; McDermott, 1984; Saglam-Arsian & Devecioglu, 2010). Therefore, the challenge is to involve the physics student as an active stakeholder in their search for conceptual understanding. This process enhances the construction of mental models by the student
to incorporate and retain physical concepts, models that can only be structured if there is sufficient interactive engagement through effective communication.

Dancy and Henderson (2007) proposed an instructional framework for effective physics instruction that emphasizes active student participation in a shared decision-making process. The student is empowered to construct their own skills and information base relating to physics concepts using inquiry methods along with interactive communication practices with the constituents in a physics course, including the instructor, other students, technology, and the course content. This theoretical framework emphasizes an intrinsic motivational process where the instruction is student centered and stresses problem-solving skills using progressive critical thinking models employing dissonant methods to stimulate reflection and engagement. The student develops as an independent thinker both quantitatively and qualitatively with the ability to extend their conceptual framework to new and unfamiliar experiences. Dancy and Henderson also note the important role of self-monitoring and student autonomy, stating, “Student autonomy is more consistent with this goal [of scientific literacy] because students need the opportunity to think independently if they are to become independent thinkers” (p. 8). Because of the distance component of online education, there is a degree of isolation for the student from the social aspect of the traditional classroom, so self-autonomy is a key to student success.

Inherent in Dancy and Henderson’s framework are Chickering and Gamson’s model of seven principles for good teaching that centers about effective communication (Chickering & Gamson, 1987). Graham et al. (2001) extended these principles into the online environment, emphasizing the single most overarching design component of a successful online course of study is communication. Communication interactions online
may take one of three forms: 1) Student-student interaction, where the students employ a discussion board, instant messaging, e-mail, or telephone (cell phone) to communicate directly with each other; 2) Student-teacher interaction, where the student interacts directly with the instructor via any of the aforementioned media; and 3) Student-content interaction, where the student interacts with audio clips, video clips, online blogs, posted pedagogical content from the instructor, and postings of student-generated content (Moore, 1989). Research shows student achievement in online courses correlates directly with the perceived level of communication: the higher the level of communication, the higher the level of achievement (Moreno & Mayer, 2004).

The focal point of a web-based course in physical science is the ability to communicate as both the student and instructor are required to interact with all components of the online structure. Scientific literacy is a goal of a physics-based framework for an online course and inquiry is a key component of that construct, so students must be able to demonstrate and communicate competencies that assess current and relevant past scientific issues, evaluate physical phenomena via scientific investigation, and analyze scientific facts to draw valid conclusions (Bybee et al., 2009).

Summary

Physical concepts can be difficult to absorb into one’s mental framework; some of the concepts seem counter-intuitive on their face, and true understanding only comes from a deeper probe of the material. Challenges to a student’s established cognitive schema represent challenges to a student’s life lessons, and difficulties incorporating physics concepts into that schema are compounded by innate beliefs that must be altered and transformed, difficult processes that are magnified when the course is offered online. A course design with appropriate media components, the condition that students self-
monitor, and the opportunity for students to reflect on processes and outcomes are key components for any success in the online classroom.
CHAPTER III

METHODOLOGY

Introduction

This chapter describes the data associated with the participants, instrumentation, and procedures of this study. Data collection occurred during the Fall 2012 and Spring 2013 semesters with students enrolled in the Physical Science Survey I course in the Mississippi Virtual Community College (MSVCC) and students who took the course in a traditional bricks and mortar face-to-face format at a community college campus in the South. Participants were assessed with the Force Concept Inventory (FCI) two times during the semesters. The FCI was given as a pretest at the beginning of the course and then as a posttest at the end of the unit on Newtonian mechanics, which occurred near the half-way point in the respective semesters. Participants in the study in both the online and traditional formats of the Physical Science Survey I course were asked to complete a student satisfaction survey, the Student Attitudes Questionnaire, near the end of the course. The data collected from the traditional, face-to-face student group were then compared to the data collected from the online student group to determine if the students in each group demonstrated improvement in student comprehension of Newtonian mechanics as measured by the FCI at the end of the course as compared to the beginning. Post-FCI scores for the traditional face-to-face student group were then compared to the post-FCI score of the online student group to determine if a significant statistical difference existed. Student satisfaction scores as measured by the SAQ were also compared between the two groups to determine if a significant statistical difference existed.
Research Design

The independent variable utilized in this research study was the course format by which students took the FCI, whether online or face-to-face. For this research study, the dependent variables were two-fold: the pretest and posttest Newtonian mechanics concept comprehension scores as measured by the FCI for both the traditional face-to-face student group and the online student group; and the level of student satisfaction with the Physical Science Survey I course as measured by scores on the SAQ. The pretest conceptual comprehension scores were collected at the beginning of the Fall 2012 and Spring 2013 semesters and the post conceptual comprehension scores were collected following completion of the instructional unit on Newton’s laws later in the same semesters for both course formats. Student satisfaction scores were collected from students in both course formats at the end of the Fall 2012 and Spring 2013 semesters.

Participants

Research study participants were students 18 years of age or older who were enrolled in and attended Physical Science Survey I in the traditional face-to-face format of course delivery at a community college in the South or enrolled and attending class via the online format through the MSVCC. As this research study sought to measure conceptual comprehension and student satisfaction in the Physical Science Survey I course, these two separate formats of course delivery were chosen for comparison. The traditional face-to-face physical science course met in one of two ways: either three mornings per week for 53 minutes each meeting with an additional two-hour laboratory section that met one afternoon per week or class meetings that occurred two mornings per week for 80 minutes each meeting with an additional two-hour laboratory section that met one afternoon per week. The online sections had all content delivered
asynchronously online so the student was not required to be in attendance at any particular time of any particular day during the week. The attendance policy for the online sections stated that the student was to log in to the course and spend at least five hours per week working in the online course content and assignments as to be equivalent to the time requirements for the traditional face-to-face course. The exam covering Newton’s laws was given in the classroom for the traditional face-to-face students with oversight by the researcher. Online students were given the same exam in a proctored, face-to-face format with oversight by an approved, designated college proctor. This research study was completely voluntary in nature, and all students who acted as participants self-selected themselves as doing so voluntarily. Any student that chose not to participate in the research study did not incur penalties in any form as a result of non-participation in the study.

Instrumentation

Common-sense beliefs, or misconceptions, regarding force and motion are ubiquitous among beginning physics and physical science students. However, these beliefs are irreconcilable with scientific Newtonian concepts. Even following formal instruction in a classroom, these common-sense beliefs persist, meaning the students have failed to assimilate the bulk of the material presented in the course. The need for an instrument that would effectively probe and identify these robust misconceptions was devised and introduced by David Hestenes, Malcolm Wells, and Gregg Swackhammer in 1992. The Force Concept Inventory (Appendix A) is a multiple choice test designed to have students make a forced choice between scientific Newtonian concepts and the students’ own common-sense preconceptions. It assesses the students’ conceptual
knowledge across the Newtonian domains of kinematics, Newton’s first, second, and third law, superposition of forces, and types of forces.

After three years of use and feedback from physics instructors nationwide the FCI was slightly revised in 1995 by Hake et al. to eliminate perceived ambiguities in some of the questions. The core concepts tested by each question in the revised version were carefully left intact. Hake (1998b) reported no statistically significant difference between the revised 1995 version and the original 1992 version in his comparisons of student responses. The FCI is perhaps the most widely used diagnostic tool for assessing student comprehension of core Newtonian mechanical concepts (Lasry et. al., 2011). This instrument was developed for use by researchers and may be used for instructional purposes with no individualized permission (Hestenes et al, 1992). The authors allow unconditional use of the instrument by instructors, stating in their article, “A copy of the instrument, the Force Concept Inventory, is included here for teachers to use in any way they see fit” (p. 142). A permission request to use the revised FCI was sent to the FCI website (Appendix B) and a response received, indicating no permission is required for use of the revised version (Appendix C). The revised version was used in this research study. The revised FCI contains 30 multiple-choice items, each with four distracters and one correct answer, testing conceptual comprehension of core Newtonian concepts in kinematics and force. Hestenes and Halloun (1995) define scoring for the FCI as 80% correct or greater indicating confirmed Newtonian thinking while scores of 60% correspond to the entry level Newtonian thought. Scores below the 60% threshold indicate a lack of conceptual comprehension of Newtonian concepts.

The authors of the FCI did not subject it to the same rigorous validation and reliability process used for the MDT, citing the fact that the FCI is not substantially
different from the MDT as they have similar designs, employ the same or similar questions, and produce similar scores. An analysis of student scores on the FCI showed they closely paralleled scores on the MDT, with more than 1,000 students from seven different professors having similar posttest average class scores (Hestenes et al., 1992, p. 146). Given these results, the authors of the FCI did not repeat the exhaustive validation process for the FCI that had been done for the MDT, stating, “Considerable care was taken to establish the validity and reliability of the Diagnostic (MDT). Formal procedures to do the same for the Inventory (FCI) are unnecessary because the test designs are so similar” (p. 147). The reliability of the FCI has been further confirmed by a number of other researchers (Hake, 1998a; Henderson, 2002; Lasry et al., 2011; Planinic, Ivanjek, & Susac, 2010). Zhou et al. (2008) utilized the revised FCI to which they added three other questions from the literature about motion and gravity in space, a topic not covered by the standard FCI. In their analysis of the FCI they obtained a Kuder-Richardson 20 reliability of 0.89, further showing a high reliability for the instrument.

Validity concerns were not significant for the authors of the FCI as it was derived from the MDT, which had undergone a rigorous validation process. Regardless, as a precaution, the authors had physics instructors and professors examine the FCI to verify the validity of the instrument and confirm it did measure the constructs across the six domains of conceptual comprehension as intended. Additionally, they conducted post-test interviews with a subset of students (n=36) regarding their answer choices for the questions on the instrument to determine if question structure may have been a factor in their choice of non-Newtonian answers (Hestenes et al., 1992, p. 148). As with the MDT, no anomalies were discovered and the authors found highly predictable response
patterns that consistently aligned with the results of their original Mechanics Diagnostic Test. As noted in Chapter II, there were initially some concerns regarding the coherence of the FCI (Huffman & Heller, 1995a; 1995b). However, these concerns were addressed by Hestenes and Halloun (1995) in a published response and further refuted by Savinainen and Viiri (2008) in their examination of the FCI for conceptual coherence. The consensus of the physics education community is that the FCI is a highly reliable and valid measure of students’ conceptions of Newtonian force and motion concepts (Lasry et al., 2011).

Student satisfaction with their learning experiences was measured at the end of the semesters by the Student Attitudes Questionnaire (SAQ). The SAQ is located in Appendix D. This instrument, developed by Bailey, Moak, Roberts, and Stout (2011), measures student satisfaction with their learning experiences in college courses. This instrument has been pilot-tested and has a reliability of .75, so it is considered to produce reliable scores.

For this research study, a data file containing the following information for each participant was created in SPSS: Student ID number, classification variables, course format type, each student’s pre- and post-FCI responses, and student satisfaction scores. The student’s ID number was used to match the student’s pre- and post-FCI scores. While the FCI has a scoring scale based on the percentage of questions answered correctly, the researcher is to compute the number of questions answered correctly on the FCI, so potential scores can range from 0 to 30. In order to be included in analysis, each participant had to have a pre- and post-comprehension score.

Additionally, participants were asked to respond to the SAQ, which includes six demographic questions and six questions measuring student satisfaction with their
learning experience in the college course. The six questions measuring student satisfaction are on a 5-point Likert scale with a range from strongly disagree to strongly agree. Each student had an average satisfaction score calculated by averaging their responses to the six Likert-type items. This data were also placed into the data file.

For the purposes of this study, a paper version of the FCI was administered. The FCI was renamed “Diagnostic Test for Physical Science I” for the pretest and “Unit 2 Test” for the posttest to comply with the instructions of the Modeling Instruction Staff at Arizona State University that oversees the distribution of the revised FCI (see Appendix C). The researcher administered the FCI at the beginning of the Fall 2012 and Spring 2013 semesters then again following the unit on Newton’s laws. All testing took place at approved college proctoring centers with proctor oversight for the online students and in the classroom for the traditional face-to-face students with researcher oversight. At the end of each semester, participants were asked to complete the SAQ.

Procedures

For this study, the researcher collected data during the Fall 2012 and Spring 2013 semesters from students taking Physical Science Survey I through the MSVCC and at a community college in the South. Approval from the community college’s Executive Council and the University’s Institutional Review Board (IRB) was submitted before beginning the research study (Appendix E). Following University IRB approval for the research study, the chief academic officer for the community college was contacted and details regarding the dates for administration of the FCI and the SAQ were communicated. Students in the traditional face-to-face sections had the FCI and SAQ administered in class by the researcher. MSVCC online students had the instruments administered by official college staff at an approved proctoring center. The pre-FCI was
administered to students during the week of class after the final drop/add date, the post-FCI was administered following the unit on Newton’s laws, which occurred approximately half-way through the semester. The SAQ satisfaction survey was administered to the students near the end of the semester.

The researcher picked up the pre- and post-FCI tests from the institution’s proctors. The SAQ was administered via a secure online server for students in the online classes and in class for the traditional face-to-face students. Data collected via the FCI and SAQ from students taking the Physical Science Survey I course in online or traditional formats were input into a SPSS data file for the purpose of analysis.

An informed consent statement (Appendix F) was included. This statement explained nature of the research study, the level of confidentiality of the data, procedures for contacting the researcher if necessary, and emphasized that participation in the research study by the student was entirely voluntary and that non-participation in the study did not result in penalty.

Data Analysis

A repeated measures multivariate analysis of variance (MANOVA) was used with an alpha level set at .05 to test the following hypotheses:

- A statistically significant difference exists in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the online format through the MSVCC.
- A statistically significant difference exists in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the
Physical Science Survey I course in the traditional face-to-face format at a community college in the South.

An independent t-test was used with an alpha level set at .05 to test the following hypotheses:

- No statistically significant difference exists in conceptual comprehension scores of Newtonian mechanics as measured by the FCI post-test assessment between students who take Physical Science Survey I in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

- No statistically significant difference exists in student satisfaction scores as measured by the SAQ between students who take the Physical Science Survey I course in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

Limitations

Limitations of the research study included the possibility the participants were not representative of the population of students enrolled in the community college systems as a whole in the southern region of the country. Student attrition between the pre- and post-FCI testing was also a factor. The design of the study utilized repeated measures; therefore, any student who withdrew from the courses before the conclusion of the FCI assessments and SAQ survey for that semester limited the extent of the study as they did not have complete, reportable scores. As always, there was the possibility of distractions that may have occurred, either internally or externally, to the student while completing the FCI or the SAQ, which may lead to unpredictable effects on the results of the assessments. Likewise, students may have misread instructions and marked their
answers in error (such as “agree” instead of “disagree”). Finally, students must have actually completed the FCI assessments and SAQ survey in a responsible and honest manner for valid results to be obtained.
CHAPTER IV

RESULTS

Introduction

The purposes of this study were to: (a) determine if taking the Physical Science Survey I course in face-to-face and online format statistically significantly improves Newtonian conceptual comprehension as measured by the FCI; (b) determine which course format (face-to-face or online), if any, has statistically significantly higher FCI post-means; and (c) determine if students’ satisfaction with learning is statistically significantly different in the two course formats (face-to-face and online).

Data collected from participants in January 2012 and in May 2012 and in January 2013 and April 2013 were entered into a data file for analysis using SPSS. Before completing the FCI, participants were asked a series of questions for the purpose of creating a unique ID that was used to link students’ pre- and post-scores while maintaining anonymity. Post data survey administration also included satisfaction questions about participants’ learning experiences in addition to the FCI. Pre- and post-data were collected from 183 participants taking the Physical Science Survey I course in the Mississippi Virtual Community College (MSVCC) or in a face-to-face format at a community college in the South. This was an acceptable sample (86%) of the original population of approximately 213 potential participants at the beginning of the Fall 2012 and Spring 2013 semesters. However, a large number of participants (n = 105) did not report demographic information.
Sample Characteristics

The student participants in this study covered a wide variety of demographics. The majority of the respondents ranged in age from 18 to 25 years. The majority of the respondents were males, while the two most reported ethnicities were Caucasian and African American. The majority of members reported that they were sophomores and non-science majors. Table 1 presents detailed information for these items.

Table 1

*Gender, Ethnicity, and Classification*

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>47</td>
<td>60.2%</td>
</tr>
<tr>
<td>Female</td>
<td>31</td>
<td>39.8%</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>59</td>
<td>75.6%</td>
</tr>
<tr>
<td>African American</td>
<td>14</td>
<td>17.9%</td>
</tr>
<tr>
<td>Native American</td>
<td>1</td>
<td>1.3%</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>1</td>
<td>1.3%</td>
</tr>
<tr>
<td>Asian/Pacific</td>
<td>3</td>
<td>3.8%</td>
</tr>
<tr>
<td><strong>Student Classification</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freshman</td>
<td>11</td>
<td>14.1%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>54</td>
<td>59.2%</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
<td>16.7%</td>
</tr>
</tbody>
</table>
Table 1 (continued).

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Major</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>17</td>
<td>21.8%</td>
</tr>
<tr>
<td>Non-Science</td>
<td>61</td>
<td>78.2%</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 – 25</td>
<td>37</td>
<td>47.4%</td>
</tr>
<tr>
<td>26 – 35</td>
<td>17</td>
<td>21.8%</td>
</tr>
<tr>
<td>36 – 45</td>
<td>11</td>
<td>14.1%</td>
</tr>
<tr>
<td>46 – 55</td>
<td>10</td>
<td>12.8%</td>
</tr>
<tr>
<td>56 or older</td>
<td>3</td>
<td>3.8%</td>
</tr>
<tr>
<td><strong>Course Format</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional</td>
<td>71</td>
<td>39.0%</td>
</tr>
<tr>
<td>Online</td>
<td>111</td>
<td>61.0%</td>
</tr>
</tbody>
</table>

Overall Pre and Post FCI Scores

For the purpose of analysis, the items were grouped according to the pre and post FCI administrations, and then a conceptual comprehension score for each respondent was calculated. Scores for each respondent were measured by the number of correct items out of a total number of 30 items. Using Hestenes and Halloun’s (1992) cut-offs, scores below 18 indicate an absence of understanding of Newtonian concepts while scores between 18 and 23 indicate a beginner’s level of Newtonian thinking. Scores of 24 or
higher, according to the two researchers, indicate a significant amount of proper Newtonian thought. The average FCI score for the pre-test was 6.37 with a standard deviation of 2.77 (n = 182). The average FCI score for the post-test was 9.65 with a standard deviation of 4.42.

Pre and Post FCI Scores by Course Delivery Format

Descriptive analysis was done on FCI scores for pre and post administrations data by course delivery format. The first group analyzed was face-to-face respondents. The mean for the FCI pre-test was 6.73 and a standard deviation of 2.60. The mean for the FCI post-test was 11.68 and a standard deviation of 4.51. Next, the means for the online students were analyzed. The mean for the FCI pre-test was 6.10 and a standard deviation of 2.84. The mean for the FCI post-test was 8.36 and a standard deviation of 3.86.

Table 2

<table>
<thead>
<tr>
<th>Course Format</th>
<th>n</th>
<th>Pre-Mean</th>
<th>SD</th>
<th>Post-Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face-to-Face</td>
<td>71</td>
<td>6.73</td>
<td>2.60</td>
<td>11.68</td>
<td>4.51</td>
</tr>
<tr>
<td>Online</td>
<td>111</td>
<td>6.10</td>
<td>8.36</td>
<td>8.36</td>
<td>3.86</td>
</tr>
</tbody>
</table>

Satisfaction with Learning Experience

Items measuring student attitudes regarding their learning experiences in their physical science course collected during post-survey administration were analyzed. Responses for each question could range from 1 (Strongly Disagree) to 5 (Strongly Agree). Means for these items ranged from 4.28 to 4.59. Means and standard deviations for these items are provided in Table 3.
Table 3

*Descriptive Statistics for Satisfaction Items (N = 78)*

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am satisfied with my learning experience</td>
<td>4.54</td>
<td>0.72</td>
</tr>
<tr>
<td>My confidence in public speaking has improved</td>
<td>4.32</td>
<td>0.81</td>
</tr>
<tr>
<td>I learned a lot about the subject area in this course</td>
<td>4.59</td>
<td>0.69</td>
</tr>
<tr>
<td>My critical thinking skills have improved</td>
<td>4.28</td>
<td>0.80</td>
</tr>
<tr>
<td>I am more comfortable with subject area concepts</td>
<td>4.38</td>
<td>0.76</td>
</tr>
<tr>
<td>This course met my overall expectations</td>
<td>4.58</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Note. Scale: 1 = Strongly Disagree…5 = Strongly Agree

Next, items measuring student attitudes regarding their learning experiences in their physical science course collected during post-survey administration were analyzed by course format. Ninety percent (n = 37) of the respondents who took the course in face-to-face format reported that they would take the course in the same format if given the opportunity. Eighty-nine percent (n = 31) of the respondents who took the course in online format reported that they would take the course in the same format if given the opportunity. For respondents who took the physical science course face-to-face, means for items ranged from 4.26 to 4.55. For respondents who took the physical science course in online format, means for items ranged from 4.28 to 4.64. All item means for both groups were above 4.0. Means and standard deviations for satisfaction items by course format are provided in Table 4.
**Table 4**

*Descriptive Statistics for Student Satisfaction By Course Format (N = 78)*

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfied w/ learning</td>
<td>4.55</td>
<td>0.63</td>
<td>4.53</td>
<td>0.81</td>
</tr>
<tr>
<td>Confidence in concepts</td>
<td>4.36</td>
<td>0.76</td>
<td>4.28</td>
<td>0.88</td>
</tr>
<tr>
<td>Learned a lot</td>
<td>4.55</td>
<td>0.55</td>
<td>4.64</td>
<td>0.83</td>
</tr>
<tr>
<td>Critical thinking improved</td>
<td>4.26</td>
<td>0.67</td>
<td>4.31</td>
<td>0.95</td>
</tr>
<tr>
<td>Comfort with concepts</td>
<td>4.43</td>
<td>0.63</td>
<td>4.33</td>
<td>0.89</td>
</tr>
<tr>
<td>Course met expectation</td>
<td>4.52</td>
<td>0.63</td>
<td>4.64</td>
<td>0.83</td>
</tr>
</tbody>
</table>

Note. Scale: 1 = Strongly Disagree…5 = Strongly Agree

**Statistical**

A repeated measure analysis of variance (ANOVA) was used with an alpha level set at .05 to test the following hypotheses:

*Hypothesis 1:* There will be a statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the traditional format through the MSVCC.
Among students in the traditional face-to-face format, the mean pre Newtonian mechanics FCI score was 6.73 (SD=2.60) and the post Newtonian mechanics FCI mean was 11.68 (SD=4.51). These scores indicate that students in the traditional face-to-face format started the course with scores that indicated a lack of conceptual comprehension of Newtonian concepts, and that by the end of the course, improvements in conceptual comprehension of Newtonian concepts were realized. The results of a repeated-measures ANOVA indicated that there was a statistically significant difference between the pre- and post-means for respondents who took the physical science course in face-to-face format, \( F(1, 70) = 70.46, p < .001 \).

**Hypothesis 2**: There will be a statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the online format through the MSVCC.

Among students who took the course in the online format, the mean pre FCI score was 6.10 (SD=2.84) and the post FCI mean was 8.36 (SD=3.86). These scores indicate that students in the traditional face-to-face format started the course with scores that indicated a lack of conceptual comprehension of Newtonian concepts, and that by the end of the course, improvements in conceptual comprehension of Newtonian concepts were realized. The results of a repeated-measures ANOVA indicated that there was a statistically significant difference between the pre- and post-means for respondents who took the physical science course in online format, \( F(1, 110) = 50.78, p < .001 \).

For the following hypotheses, independent samples t-tests were used with Alpha set at 0.05.
Hypothesis 3: There will be no statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI post-test assessment between students who take Physical Science Survey I in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

Among students who took the Physical Science Survey I course in the traditional face-to-face format, the mean post Newtonian mechanics FCI score was 11.68 (SD=4.51) and the post Newtonian mechanic FCI mean for the online students was 8.36 (SD=3.86). These scores were showed that students enrolled in the traditional face-to-face format had higher Newtonian mechanic FCI post-means than those students taking the course in online format. Levene’s test did reveal an issue with homogeneity of variance. The results of independent samples t-test indicated that there was a statistically significant difference between the post-means between students who took the Physical Science I Survey course in traditional face-to-face and online formats, $t(132.29) = 5.11, p < .001$.

Hypothesis 4: There will be no statistically significant difference in student satisfaction scores as measured by the SAQ between students who take the Physical Science Survey I course in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

To test this hypothesis, overall satisfaction means for each participant’s responses for the six satisfaction items. The overall satisfaction mean for students who took the traditional face-to-face course was 4.44 (SD=0.50) on a scale of 1 (strongly disagree) to 5 (strongly agree), indicating that most students were satisfied with the traditional face-to-face course format. Students in the fully-online course format reported overall satisfaction mean scores of 4.45 (SD=0.79), indicating that students, on average, were
just as satisfied with the Physical Science Survey I course in online format as face-to-face format. The overall satisfaction means and standard deviations are reported in Table 5.

Table 5

*Overall Satisfaction Means and Standard Deviations Based on Course Format*

<table>
<thead>
<tr>
<th>Course Format</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face-to-Face</td>
<td>42</td>
<td>4.44</td>
<td>0.50</td>
</tr>
<tr>
<td>Online</td>
<td>36</td>
<td>4.45</td>
<td>0.79</td>
</tr>
</tbody>
</table>

Note. Scale: 1 = Strongly Disagree…5 = Strongly Agree

Next, an independent samples t-test was run to test for statistically significant differences between satisfaction of the face-to-face and online students. Levene’s test revealed no homogeneity of variance issues. The results of the independent samples t-test were not statistically significant, \( t(76) = -0.063, p = .950 \).

**Summary**

In summary, three purposes existed for this study: (a) determine if taking Physical Science Survey I course in traditional, face-to-face and online format statistically significantly improves Newtonian conceptual comprehension as measured by the FCI; (b) determine which course format (face-to-face or online), if any, improves Newtonian conceptual comprehension to the greatest extent; (c) determine if students’ satisfaction with learning is statistically significantly different in the two course formats (face-to-face and online).

Four research hypotheses were tested in this study. Three of the four hypotheses tested had statistically significant results. All course formats statistically significantly
improved Newtonian conceptual comprehension as measured by the FCI. The results indicated that FCI post-scores for the traditional, face-to-face students were statistically significantly higher than the post-scores for the online students. Lastly, the results indicated no statistically significant difference in satisfaction level with the face-to-face format when compared to the online format.
CHAPTER V

DISCUSSION

Introduction

Statistical analyses of the data collected in the study were reported in the previous chapter. This chapter will begin with a summary of the study. Second, the researcher will discuss the findings of the study. Third, the researcher will suggest additional research. Finally, the researcher will close with an overview of the findings and conclusions reached in the study.

Summary of the Study

The researcher summarized pertinent literature germane to this study. Nine general themes in the literature were explored, including (1) theoretical framework; (2) student conceptions; (3) early studies; (4) instrumentation (FCI); (5) student conceptual change; (6) online education; (7) the no significant difference phenomenon; and (8) characteristics of online learners; and (9) effective instruction.

Data for this study were collected from students and faculty in various course formats during the Fall 2012 semester and the Spring 2013 semester. The researcher used two research tools: the Force Concepts Inventory (FCI) and a questionnaire measuring student attitudes toward course format (SAQ). Pre and post data were collected from students using the FCI, and post data were collected using the SAQ. The study utilized statistical analysis to report findings of the following hypotheses:

Hypothesis 1: There will be a statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the online format through the MSVCC.
Hypothesis 2: There will be a statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI between the pre- and post-test assessments among community college students who take the Physical Science Survey I course in the traditional face-to-face format at a community college in the South.

Hypothesis 3: There will be no statistically significant difference in conceptual comprehension scores of Newtonian mechanics as measured by the FCI post-test assessment between students who take Physical Science Survey I in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

Hypothesis 4: There will be no statistically significant difference in student satisfaction scores as measured by the SAQ between students who take the Physical Science Survey I course in the traditional face-to-face format and those who take the course in the online format through the MSVCC.

Findings and Discussion

The findings of hypotheses one through three will be summarized individually. The related discussion of these three hypotheses, however, will be discussed concurrently. The section will close with the findings and discussion of hypothesis four.

Hypothesis one sought to find differences in pre and post scores measuring conceptual comprehension of force Newtonian concepts among students who took the physical science course in the traditional course format. The analysis suggests that students in the traditional face-to-face format started the course with scores that indicated a lack of conceptual comprehension of Newtonian concepts and that by the end of the course, improvements in conceptual comprehension of Newtonian concepts were
realized. Although differences were statistically significant, the scores still do not indicate a substantial increase in the comprehension of force concepts, as the post scores do not approach the threshold established for even entry-level understanding based on the scale established by the FCI.

Hypothesis two sought to find differences in pre and post scores measuring conceptual comprehension of force Newtonian concepts among students who took the physical science course in the online course format. The analysis suggests that students in the online format started the course with scores that indicated a lack of conceptual comprehension of Newtonian concepts, and that by the end of the course, improvements in conceptual comprehension of Newtonian concepts were realized. Although differences were statistically significant, the scores still do not indicate a substantial increase in the comprehension of force concepts, as the post scores do not approach the threshold established for even entry-level understanding based on the scale established by the FCI.

Hypothesis three sought to find differences in post scores measuring conceptual comprehension of force Newtonian concepts among students who took the physical science course in the traditional course format and the online course format. The analysis suggests that students enrolled in the traditional face-to-face format had higher conceptual comprehension of force mechanics than did the students who were enrolled in the online course. Even though the statistical analysis indicates a more substantial increase in the conceptual understanding of students enrolled in the traditional course, it is still important to point out that post scores, according to the scale established by the FCI, still do not approach the threshold established for even entry-level understanding of force Newtonian concepts.
The findings for hypotheses one, two, and three indicate that although both formats increase students’ conceptual understanding of Newtonian force concepts, neither treatments increase students’ understanding in such a way approaches even an entry-level understanding of the concepts. This lends support for Luangrath and Vilaythong (2010) who posit that the commonly held but incorrect beliefs of students develop early in life regarding force concepts are extremely difficult to change even after a course in physical science. As stated in prior literature, students entering a physical science course have been exposed to physical phenomena over their entire lifetime and have formed misconceptions based on common sense beliefs to explain what they have observed—beliefs often at variance with scientific tenets—making these misconceptions highly resistant to change. Students develop their own schemas for how the world around them works (Pringle, 2006; Settlage & Goldston, 2007) and these beliefs are extremely resistant to modification (Bayraktar, 2009; Clement, 1982; Halloun & Hestenes, 1985a; Luangrath et al., 2011). The current study seems to support the aforementioned prior findings.

The current study also offers support for the assertions of Saglam-Arsian and Devecioglu (2010) who studied students’ comprehension of Newton’s laws and found significant weaknesses in the understanding of the core concepts even following formal instruction. This is perhaps because students’ common sense beliefs about force and motion are generally incompatible with Newtonian theory (Halhoun & Hestenes, 1985a). Students’ pre-existing beliefs are often incomplete or flawed but still deeply ingrained in the psyche of the student (Baser & Geban, 2008; Driver & Erickson, 1983; McDermott, 2001; Pringle, 2006; Settlage & Goldston, 2007) and provide a barrier for conceptual learning (Klymkowsky et al., 2006). Thus, even after a well-directed course emphasizing
force concepts which conflict with a student’s accepted beliefs, students are still apt to manipulate the new information gained in order to fit it into their existing schema for understanding (Bayraktar, 2009; Clement, 1982; Halloun & Hestenes, 1985a; Gunstone & White, 1981; Luangrath et al., 2011; Sabella & Redish, 2007; Trowbridge & McDermott, 1980). The current study supports the contentions of Ormrod (2008) who states that the student will rarely attempt to restructure their incorrect cognitive framework and thereby alter or replace the existing misconceptions with the conflicting scientific conceptions. Students’ seeming resistance to reframing their conceptual understandings of force and motion in the current study seems to support these prior studies.

The aforementioned misconceptions of Newtonian force concepts were surely challenged in the current study via course content and experiences which conflict with the students’ schema and understandings of the workings of the physical world around them. However, as the literature asserts, challenges to the students’ cognitive framework is erroneously reconciled and lead to increasingly divergent cognitive interpretations. This divergence in the minds of the students may eventually result in an inability to effectively utilize past knowledge to construct new and valid conceptual schema (Klymkowsky et al., 2006). The current study supports these past assertions.

The cognitive modification that was desired during the implementation of the courses of study offered during the current study were aimed to alter students’ existing conceptual frameworks and cause cognitive conflict, resulting in a state of cognitive dissonance (Eryilmaz, 2002; Obaidat & Malkawi, 2008; Posner et al., 1982; Smith et al., 1993). This dissonance is common in physical science courses when Newtonian concepts of force and motion are introduced to the students that are inconsistent with the
students’ established cognitive framework (Clement, 1982; Halloun & Hestenes, 1985a, 1985b; McDermott, 1984; Thornton & Sokoloff, 1998). However, the introduction of a cognitively dissonant event may not be enough to prod the student into modifying their conceptual beliefs. It is assumed by this researcher that these same phenomena occurred within the current study.

The findings of von Aufschnaiter and Rogge (2010) are also supported. Their analysis of phenomenon-based versus model-based concepts state that the sum of the students’ prior experiences as the framework for cognitive assimilation can either aid or hinder effective model construction. The researchers concluded that “…all model-based concepts are difficult for students…” (p. 13). The current study, via course content and lab experiences of students desired to set up the same type learning experiences for students in order to reframe their conceptions of force concepts, but, as in past studies, real change in students’ pre-existing schemas are difficult to alter, as their prior beliefs tend to hinder cognitive reappraisal.

Hypothesis four sought to find differences in the levels of self-reported satisfaction with perceived learning within the students enrolled in the traditionally taught course and those students who took the course online. The analysis suggests that most students were satisfied with both the traditional face-to-face course format and the online course format. This conflicts with prior literature (Rivera & Rice, 2002; Summers et al., 2005) which has found that overall student satisfaction is often less in online courses than with the face-to-face traditional method of instruction. The current study does seem to support, though, the contentions of Eom et al. (2006) who found that satisfaction with the online learning experience appears to correlate positively with learning outcomes.
Summary of Findings

The purposes of this study were to: (a) determine if taking the Physical Science Survey I course in face-to-face and online format statistically significantly improves Newtonian conceptual comprehension as measured by the FCI; (b) determine which course format (face-to-face or online), if any, has statistically significantly higher FCI post-means; and (c) determine if students’ satisfaction with learning is statistically significantly different in the two course formats (face-to-face and online).

Results of the current study suggest that both the traditional and the online course format both resulted in an increase in conceptual understanding of Newtonian force concepts. The current study suggests that students enrolled in the traditional course format experienced a more substantial increase in comprehension of force concepts. However, neither course format increased students’ conceptual understanding of force concepts to an extent that approached what experts call even an entry-level understanding. The current study also suggests that students are just as satisfied with the online course format as they are with the traditional course format.

Limitations

Due to this being a one-institution study, students surveyed might not have been representative of the entire college student population. Another limitation of this study was that of attrition. A student might have dropped out of school or the course between the administration of the pre-FCI and the post-FCI administration. Since the research design entailed repeated measures, any student who dropped out before the end of the study could not be considered because they were not able to report their post-anxiety scores or their satisfaction with selected course format. Other limitations include potential distractions that students might have had while completing the FCI and
satisfaction questionnaires, which could have impacted their responses. There was a chance that participants misread the directions on the questionnaire and/or marked their answers incorrectly. Students were not randomly assigned to a treatment group, but rather self-selected their course formats. Lastly, students willingly participated in the questionnaires; thus, Hawthorne Effect might have come into play.

**Recommendations for Future Research**

The current study seems to suggest that the traditional course format might have a slight edge in increasing students’ conceptual understanding of Newtonian force concepts. Faculty who teach fundamentals of physical science courses in the online and face-to-face environments are challenged to create learning experiences that are more equivalent. The problems and difficulty of replicating lab-based learning outcomes in the online environment are well-documented (Boschmann, 2003; Casanova et al., 2006; Johnson, 2002; Patterson, 2000). It behooves faculty to seek strategies to close this gap. It has been suggested that technology might be the tool that closes the gap and allows instructors to provide meaningful and effective laboratory demonstrations utilizing ever-improving technology to close the gap between what can be accomplished in the laboratory experiences of online students. Prensky (2010) asserts that today’s students are very comfortable with technology and technology-based media, and that technology utilized in online learning might not only equalize the learning experience offered but might enhance it.

The gap in educational research on the online delivery of lab-based sciences is a problem for teachers as there is no guidance for the construction or delivery of the laboratory component in an online science course. While the learning outcomes associated with the traditional science laboratory are known, there are significant barriers
to implementing and replicating those outcomes in an online course (Instructional Technology Council, 2010). It is imperative that more research is accomplished that will help to close the gap in the learning experiences which can be offered to online students and that they be made equivalent through further studies in technological solutions aiding in teaching in the online environment.

The researcher recommends that this study be repeated using a larger sample size, as, for control purposes, this study only considered the experience of students in the researcher’s own classes. It is also recommended that this study be extended to students taking the Physical Science Survey I course in other institutions, as this study was limited to one community college in the South. Further, it is recommended that the study be extended to students in four-year college settings.

Additionally, since this study collected data from only two semesters, it may be beneficial to collect data over multiple semesters in order to see if the results remain similar over time. A longitudinal study may be beneficial in order to keep up with student learning outcomes as ever-improving technology allows for further enhancement of online courses.
APPENDIX A

PRETEST/POSTTEST

To help maintain the integrity of the assessment, the Force Concept Inventory is not reproduced here per the request of the test provider, the Modeling Instruction staff at Arizona State University. An authorized copy of the Force Concept Inventory is available to educators and researchers through the password protected site at:

<http://modeling.asu.edu/R&E/Research.html>

If you are a qualified educator or researcher you may request the password from the site administrator.
APPENDIX B

REQUEST FOR PERMISSION TO USE

THE FORCE CONCEPT INVENTORY IN THE STUDY

From: rex moak
Sent: Thursday, July 15, 2010 7:44 PM
To: FCIMBT@verizon.net
Cc: rex moak
Subject: Force Concept Inventory/Mechanics Baseline Test Request - Rex Moak

Dear Mr. Koch,

I am currently a physics instructor at the Jackson county campus of the Mississippi Gulf Coast Community College in Gautier, MS. I am pursuing a Ph.D. in Higher Education at the University of Southern Mississippi, and as part of my dissertation research I would like to use the revised Force Concept Inventory (FCI) developed by Halloun, Hake, Mosca, and Hestenes and possibly the Mechanics Baseline Test (MBT) by Hestenes and Wells to do a comparison of student conceptual understanding and comprehension between those physical science students enrolled in online classes and students in the traditional bricks and mortar classroom.

I understand from the FCI website you are supervising the release of passwords to access the FCI and I would like to obtain a password from you for the Force Concept Inventory as well as the Mechanics Baseline Test. I would also appreciate any information as to whom and where to contact the appropriate individuals for permission to use either the FCI and/or the MBT as part of my research design. I believe the conceptual basis for the FCI and MBT are tailored to my research, and with their well-established history I think they would be ideal for my needs.

Thank you for your time and I look forward to hearing from you.

Respectfully,

Rex Moak
APPENDIX C

REPLY TO PERMISSION TO USE

THE FORCE CONCEPT INVENTORY IN THE STUDY

From: David Koch, Ph.D. [mailto:fcimbt@verizon.net]
Sent: Thursday, July 15, 2010 10:34 PM
To: rex moak
Subject: Re: Force Concept Inventory/Mechanics Baseline Test Request - Rex Moak

Rex,

You do not need permission to use the FCI or MBT in your research, however, please heed the following cautions.

The Modeling Instruction staff at Arizona State University respectfully denies permission to include the FCI in any doctoral dissertation or master’s degree thesis.

We specifically ask you NOT to include the FCI or MBT in your appendix. Rather, we suggest that you give the URL for our web site <http://modeling.asu.edu/R&E/Research.html>, and state that interested parties can request a download password from us.

The FCI and MBT are valuable resources for our profession; thus we must do our utmost to keep them out of student files.

I've included information about both the FCI and the Mechanics Baseline Test.

You can download the FCI at <http://modeling.asu.edu>. Click on 'research and evaluation', or go directly to: <http://modeling.asu.edu/R&E/Research.html>.

The password to open it is [REDACTED].

Please keep this confidential, of course, so that students won't get access to the test. And when you give the FCI, please don't call it that! Rather, give it a generic title, like 'mechanics survey', or the like.

The FCI is a valuable resource for our profession; thus we must do our utmost to keep it out of student files. The test sheets should be collected and kept under lock and key, or shredded; and answers should never be given out.

The force concept is a unified concept; thus the FCI should be used in its entirety.

Download Revised Table I and/or Revised Table II from David Hestenes’ FCI article.

Here’s the FCI key. Please maintain confidentiality. If anyone asks you for the answer key, please tell them to e-mail me. [REDACTED]
You can download the Mechanics Baseline Test at <http://modeling.asu.edu>, Click on 'research and evaluation'.

The password to open the MBT is [REDACTED].

The MBT is an effective instrument for determining 11th & 12th grade & college students' problem-solving ability. It is ordinarily used at the end of a first-year physics course.

Below is the MBT key. Please maintain confidentiality. If anyone asks you for the answer key, please tell them to e-mail me. [REDACTED]

Sincerely,

David Koch, Ph.D. FCIMBT@verizon.net

On behalf of Jane Jackson, Ph.D., Co-Director, Modeling Instruction Program
Box 871504, Dept. of Physics, ASU, Tempe, AZ 85287
480-965-8438/fax:965-7565 <http://modeling.asu.edu>
STUDENT ATTITUDES QUESTIONNAIRE
Thank you for completing this survey. Your responses will be used to determine students’ satisfaction with their learning experiences in the course. Be assured that throughout this process your identity and any data obtained will remain confidential. Your participation is voluntary, and you may stop your participation at any time.

The following questions are used in order to create a unique ID#. This is very important!

- How many siblings do you have? ----------------------------------------------
- What is the first letter of your mother’s maiden name (if not known enter X) __
- What is the first letter of the name of the last high school you attended? ______
- What is the number of your birth month (ex. January=1, February=2, etc.)? ____
- What is the first letter of the city where you were born? ---------------------

Please answer the following questions accurately and honestly.

1. Reading from the top blank down, what is your Unique ID# from the box above?_________________

2. Please select your age group (in years) from the following:
   - □ under 18
   - □ 18-24
   - □ 25-30
   - □ 31-40
   - □ 41-50
   - □ 51 or older

3. Please indicate your ethnicity.
   - □ Asian American/Pacific Islander
   - □ Native American/American Indian
   - □ Caucasian
   - □ Hispanic/Latino
   - □ African American
   - □ Other ________________________

4. Please indicate your gender.
   - □ Male
   - □ Female

5. What is your student classification?
   - □ Freshman
   - □ Sophomore
   - □ Other ________________________

6. Which of the following best describes your major?
   - □ Science based (Biology, Chemistry, Physics, Engineering, pre-medical,
7. Please select your course format:
- Traditional Face-to-Face (less than 25% of content delivered online. Most content delivered live in a traditional classroom setting)
- Online (more than 75% of content online delivered online)

| Circle whether you strongly agree (SA), agree (A), are neutral (N), disagree (D), or strongly disagree (SD) with the following statements. |
| 1. I am satisfied with my learning experience in the course. | SA A N D SD |
| 2. My confidence in applying concepts has improved because of this course. | SA A N D SD |
| 3. I learned a lot about the subject area in this course. | SA A N D SD |
| 4. My critical thinking skills have improved because of this course. | SA A N D SD |
| 5. I am more comfortable with subject area concepts as a result of this course. | SA A N D SD |
| 6. This course met my overall expectations. | SA A N D SD |

If given the opportunity, would you recommend someone take this course in the same format?
- Yes
- No

Why or why not?

Please share any other information about your learning experience in this course you consider important.
APPENDIX E

IRB APPROVAL

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the “Adverse Effect Report Form”.
- If approved, the maximum period of approval is limited to twelve months.
- Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 12632901
PROJECT TITLE: Comparison of the Conceptual Understanding of Newton’s Laws in an Online and Traditional Introductory Physical Science Course
PROJECT TYPE: Dissertation
RESEARCHER(S): Rex Moak
COLLEGE/DIVISION: College of Education & Psychology
DEPARTMENT: Educational Studies & Research
FUNDING AGENCY: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF PROJECT APPROVAL: 04/12/2012 to 04/11/2013

Lawrence A. Hosman, Ph.D.
Institutional Review Board Chair
APPENDIX F

INFORMED CONSENT

STUDENT CONSENT FORM

The course you are enrolled in, Physical Science Survey I, instructed by Mr. Rex Moak, has been selected for participation in a research study for this semester that will compare conceptual understanding of students in online and traditional class formats for his doctoral dissertation study at the University of Southern Mississippi. All students registered in the Physical Science Survey I class for this semester have the opportunity to participate.

Participation in this research study is completely voluntary. You may choose not to participate if you wish. There is no penalty for non-participation. If you choose to participate, you may request none of your responses be used in the study. If at any time you want to withdraw as a participant in this study, you may do so by notifying Mr. Moak via e-mail or telephone. His e-mail address is rex.moak@mgccc.edu and his phone number is 228-497-7661.

If you agree to participate in the research study you only have to complete the Unit #2 Test as you would normally do for the class. Near the end of the course you will be asked to fill out a Student Attitudes Questionnaire that should take less than five (5) minutes to complete. You may skip or not answer any or all of the questions on the questionnaire. There will be no additional work or tests other than what is normally scheduled for the class. The information supplied by the questionnaire and by the Unit #2 Test that you are about to take will be used as data sources for the study that Mr. Moak is overseeing.

There are no known risks associated with this study. All results from this study will remain confidential. Any information you provide will be kept completely confidential nor will any identifying information be used in the final published form of this research. Neither your name nor any other identifying information will be disclosed to anyone other than the researcher, Mr. Moak. The only person with access to your responses will be the researcher, who is also your instructor, Mr. Moak.

If there is any aspect of the study or your participation in it that is unclear to you, or if there is a research-related problem you want to report, contact Mr. Moak at 228-497-7661.

Please mark one of the boxes below:

☐ I agree to participate in this study
☐ I do not agree to participate in this study

________________________________________
Participant Signature                                                    Date

_______________________
Print Name


Elvers, G. C., Polzella, D. J., & Graetz, K. (2003). Procrastination in online courses:


constructivists analysis of knowledge in transition. *Journal of the Learning Sciences, 3*(2), 115-163. doi: 10.1207/s15327809jls0302_1

Smith, J. I., & Tanner, K. (2010). The problem of revealing how students think: Concept
inventories and beyond. *CBE Life Sciences Education, 9*(1), 1-5.
doi: 10.1187/cbe.09-12-0094

learning in online environments. *Journal of Interactive Online Learning, 6*(1), 27-42.


Sozbilar, M., & Bennett, J. (2007). A study of Turkish chemistry undergraduates’
understanding of entropy. *Journal of Chemical Education, 84*(7), 1204-1208.


knowledge in the engineering sciences: Overview and future research directions.


