USING SIMULATIONS IN PHYSICS TO TEACH NEWTON'S THIRD LAW TO HIGH SCHOOL LEARNERS WITH LIMITED ENGLISH PROFICIENCY: A MIXED METHODS STUDY

A Dissertation

by

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ABSTRACT

My intent in this study was to investigate computer simulations as an instructional approach for high school physics English Language Learners (ELLs). Comparison-group research was employed to assess differences in ELLs' learning with computer simulations demonstrating Newton's Third Law in comparison to learning with a traditional hands-on laboratory approach. My expectations were that computer simulations would be advantageous to ELLs, regardless of the individual learners' language proficiency levels. I expected that a comparison ELL group engaged in hands-on laboratory experiments would not perform as well as learners in the computer simulations group.

A total of 44 ELL students were randomly assigned to two treatment groups (computer simulations group, n = 22; traditional laboratory group, n = 22). Within each treatment group, smaller groups of 3 to 4 students were randomly assigned to work together, resulting in 7 smaller computer simulations groups and 7 smaller traditional hands-on laboratory groups (Appendix D). Attrition resulted in a total of 30 students distributed into treatment groups (computer simulations group, n = 20; traditional laboratory group, n = 10). Data collected for comparison included two measures of conceptual understanding. Gain scores were calculated for pre- and posttest FCI questions. Student journal entries and videotaped speech transcriptions were analyzed and transformed into quantitative frequencies and percentages.

Results confirmed simulations assisted ELLs in grasping concepts but didn’t support simulations as encouraging conceptual conversation. Results indicated that ELLs learning with simulations were not at a disadvantage in understanding concepts even though they discussed and made fewer journal entries than ELLs learning with traditional hands-on approach. Exploratory in nature, this comparative study was the first of its kind to explore ELLs’ conceptual understanding comparing computer simulations and hands-on instructional approaches. The results of this study lead to recommendations for a more extensive examination of ELLs' use of computer simulations to reinforce ELLs' learning of abstract physics concepts. However, several implications for classroom practices emerged from the findings of this exploratory study. Implications, which are discussed in the final section of the dissertation, include classroom practices related to misconceptions, scaffolding, assisting learners in grasping abstract concepts, and reinforcing conceptual understanding.

DEDICATION

I dedicate this dissertation to my husband, children, grandchildren and parents who believed in me and encouraged me throughout this process. Thanks.

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Finally, thanks to my children, grandchildren, and parents for their encouragement and to my husband for his patience and car time.

NOMENCLATURE

AAAS	American Association for the Advancement of Science
AAPT	American Association of Physics Teachers
FCI	Force Concept Inventory
ELLs	English Language Learners
ELPS	English Language Proficiency Standards
ESEA	Elementary and Secondary Act
LEP	Limited English Proficiency
NCLB	No Child Left Behind
NRC	National Research Council
SBOE	State Board of Education
STAAR	State of Texas Assessment of Academic Readiness
TAC	Texas Administrative Code
TEA	Texas Education Agency
TEC	Texas Education Code
TELPAS	Texas English Language Proficiency Assessment
TEKS	Texas Essential Knowledge and Skills

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CHAPTER I

INTRODUCTION

Applying successful learning strategies, developing conceptual understanding and mastering process skills is required for “science literacy for all learners.” Critics contend that not all learners are literate in science. Standards were created and implemented to develop conceptual understanding in the sciences for every student. Alternate teaching strategies are still required to achieve science literacy for all learners including English Language Learners (ELLs). Successful outcomes of science literacy include the following three ideas; knowledge and skills for a career or careers, cultivate an interest in lifelong learning and develop an educated society. This research is to investigate an alternate teaching strategy to improve science literacy for English Language Learners who are often low performing (Bybee, 1997).

This concern, of science for all, however, is not new. In the nineteenth century, some educators began to view science as content suitable for all learners (Fradd, Lee, Sutman, & Saxton, 2001). This view was exemplified in the phrase “science for all,” which first appeared in 1847 (Hurd, 1993). This suggests that for some time those involved have viewed science literacy as an important outcome in the education of learners (American Association for the Advancement of Science [AAAS], 1989; Fradd et al., 2001; Lee, 2005; National Research Council [NRC], 1996). Evidence of this continued view can be found today in the mission statement for the AAAS, which contains the phrase “science for all” (AAAS, 2013).

Even in the midst of this latest wave of reform, "science for all" remains a significant outcome, sharing emphasis for science education that also attends to society's needs for a science-literate workforce. "STEM" is the new buzzword indicating the preparation of all individuals to assume positions requiring proficiencies in science, technology, engineering, and mathematics (STEM; National Research Council, 2013).

In the twentieth century, policymakers in the federal government became more involved in supporting science literacy for all learners. For example, policymakers in 1965 passed the Elementary and Secondary Education Act (ESEA, 1965) which provided federal funding for the science education of all learners regardless of race. In 1967, many of these same policymakers amended the ESEA to provide funding for learners with limited English skills (Baker & de Kanter, 1983). As a result of involvement on the part of policymakers in the twentieth century, actors in the arena of education during the first two decades of the twenty-first century have begun to focus more attention on how science literacy effectively addresses learners with limited English skills (Lee, Buxton, Lewis, & LeRoy, 2006; Lee, Deaktor, Hart, Cuevas, & Enders, 2005; Lee, 2004; Lee & Fradd, 1998).

As the twenty-first century began, policymakers reauthorized the ESEA as the No Child Left Behind Act (NCLB, 2001). Although NCLB continued funding for all learners with limited English skills, the act also initiated standardized assessments to determine the effectiveness of local education practices (Paige, 2006). As a result, some academics have begun to study the influence of policy on education outcomes in science literacy (Kali, Linn, & Roseman, 2008). One particular area of study involves learners having limited English skills in secondary science classrooms (Barton, 1998; Lee, 2005; Lee & Fradd, 1998).

For over 150 years, education actors have worked to apply the intent of the phrase “science for all” to all learners (Fradd et al., 2001). However, some critics contend that a disconnect currently exists between the implementation of effective local practice leading to the science literacy of all learners, and the academic achievement of learners with limited English skills (Lee, 2004; Lee et al., 2006; Lee et al., 2005; Lee & Fradd, 1998). Current federal policy guarantees all K-12 learners equal access to science education; however, learners with limitations (e.g., learners with limited English skills) require accommodation through instructional intervention. This dissertation provides results from this study of computer simulations as one such intervention.

The first chapter of this dissertation presents an introduction to this study of an instructional intervention for learners having limited English skills who are situated in a secondary physics classroom. In the first part of this chapter, I discuss four issues related to learners in this study: (a) policy actions pertaining to K-12 learners with limited English skills, (b) physics learners in Texas, (c) physics learners in Texas with limited English skills, and (d) education policy pertaining to physics learners and limited English skills. In the second part of this chapter, I specify four research concepts related to this study: (a) statement of the problem, (b) significance of the study, (c) purpose of the study, and (d) research questions. In the third part, I identify four concerns related to this study: (a) definitions, (b) testing limitations, (c) assumptions, and (d) implications (see Figure 1.1).

Four Issues Related to Learners in This Study

The primary focus of this dissertation is the relationship of an instructional intervention on the development of science literacy for learners with limited English skills situated in a secondary science classroom. In the first area of Chapter I, I discuss four issues related to the learners in this study. These issues include: (a) policy actions pertaining to K-12 learners with limited English skills, (b) physics learners in Texas, (c) physics learners in Texas with limited English skills, and (d) education policy pertaining to physics learners and English language learners. These are important issues to discuss, as each one has some influence on or relationship to development of science literacy for all K-12 learners (Fradd et al., 2001), including learners in this study.

Policy Actions Pertaining to K-12 Learners with Limited English Skills

Education actors involved in cognitive research have identified policy as an important factor in the development of science literacy for K-12 learners (Kali et al., 2008). In the United States, policy for education emanates primarily from two government sources: federal and state. Policy actions reflect the relationship between policymaking bodies (i.e., federal and state governments), the implementation organizations (i.e., school districts and schools), and individuals influenced by policy (i.e., teachers and learners). In this section of Chapter I, I discuss in more detail federal and state policy actions pertaining to K-12 learners with limited English skills. I begin the discussion by focusing on federal policy actions and conclude with state policy actions in Texas. Discussion of state policy actions is focused on Texas, as the instructional intervention in this study occurred in a Texas secondary school.

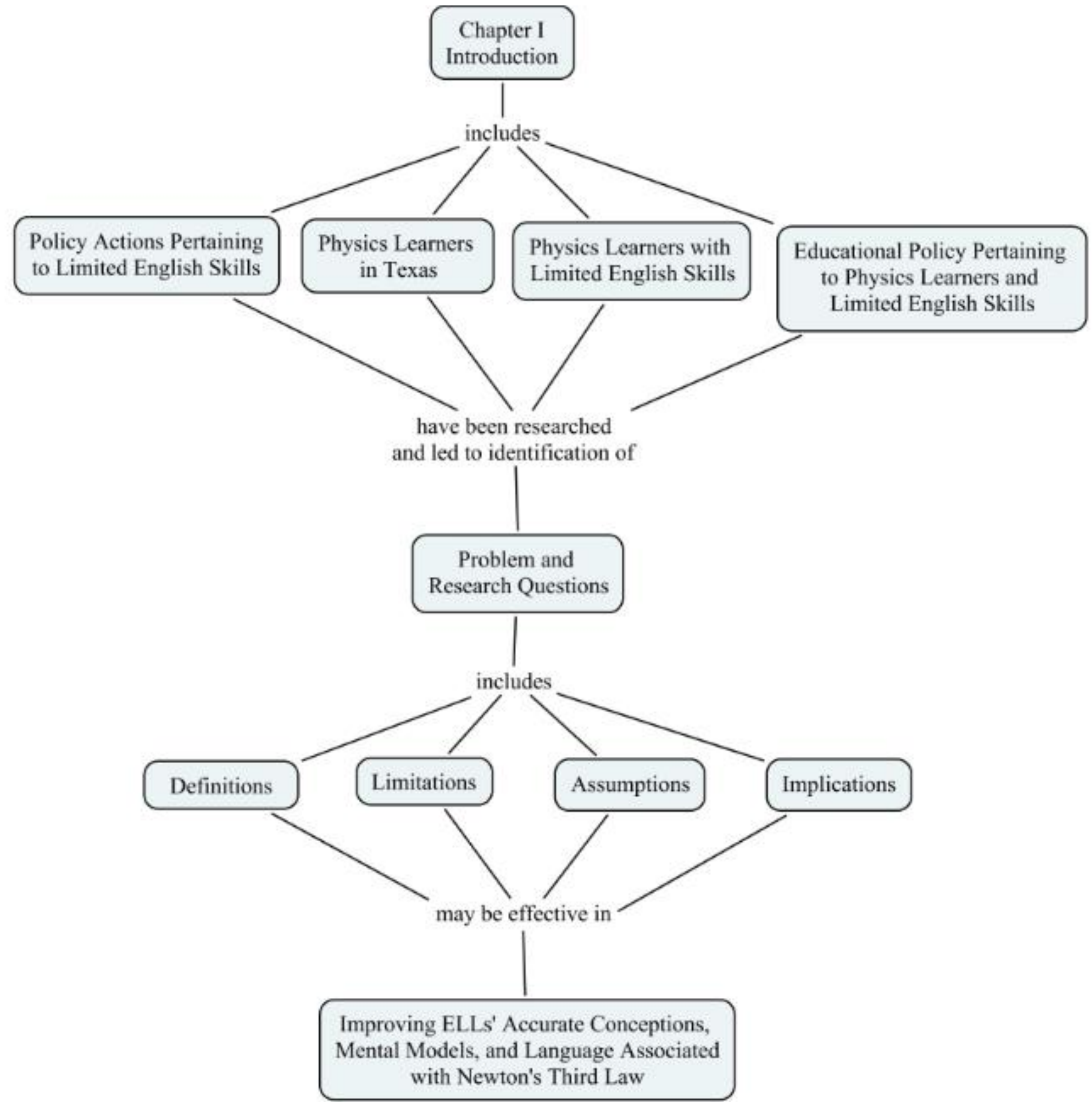

Figure 1.1. Outline of chapter I.

The United States federal government has a history of being involved in the development of science literacy for K-12 learners (Lee, Maerten-Rivera, Penfeld, LeRoy & Secada, 2007; NRC, 2008; NRC, 2007; Lee, 2005; Fradd & Lee, 2001; Barton, 1998).

The following two examples of policy actions reflect science literacy pertaining to learners with limited English skills. The first example comes from a judicial decision made in 1974 by justices on the United States Supreme Court, and the second example comes from legislation created in 2001 by members of the United States Congress. In 1974, justices on the Supreme Court decided that publicly funded schools must create policy to ensure an equal education for all learners (Lau v. Nichols, 1974, 414 U.S. 563). In Lau v. Nichols, the justices wrote that schools must provide instructional assistance for learners with limited English skills. In the second example, in 2001, members of Congress passed NCLB to assist in the academic achievement of all learners (NCLB, 2001). In section 1032 of NCLB, members identified learners with limited English skills as one of many “historically underrepresented” learner groups found within urban, suburban, and rural schools. Both of these examples of federal policy actions in the last quarter century reflect federal involvement in education as well as increased interest in the science literacy of K-12 learners.

The Texas state government also has an extended history of involvement in the science literacy of K-12 learners. Two state policy actions in Texas are examples of Texas’ involvement in education pertaining to learners with limited English skills. The first example relates to the Texas Education Code (TEC) and the function of public funding and accreditation of school districts in Texas, whereas the second example relates to how districts are expected to educate learners with limited English skills. The TEC was created by members of the Texas state government in 1969 to provide guidance for districts within the state. As the TEC itself does not constitute state law, districts are under no legal obligation to follow the provisions within the code; however, compliance with provisions within the TEC on the part of districts is required to receive public funding and state accreditation. The majority of public funding for education in Texas and the accreditation of schools comes from the state and not local school districts, so most districts are financially compelled to follow provisions within the TEC. The second example relates to Chapter 29, Section 61 of the TEC provides guidance for the education of learners with limited English skills. Specifically, when 20 learners with limited English skills are identified within one grade, districts must provide instructional assistance (TEC, §29.053). Each of these examples of state policy actions in Texas reflects both how states can influence district decision-making and the development of science literacy for K-12 learners.

Policy actions pertaining to K-12 learners with limited English skills are important factors in the development of science literacy for all learners (Kali et al., 2008). Policy actions, however, often begin from decisions made in federal or state policymaking bodies, not at a local level. Although I did not provide an exhaustive explanation, in this section I have discussed federal and state policy actions having the potential to influence the science literacy of learners with limited English skills. I have provided this discussion to convey the complexity of the system in which these learners work to develop their science literacy. In the next section, I discuss issues related to physics learners in Texas and provide contextual information about the learners involved within the instructional intervention in this study.

Physics Learners in Texas

State Board of Education (SBOE) in Texas has an extended history of involvement in science literacy for K-12 learners (SBOE §28.002.c). Important to this dissertation is the SBOE's history of involvement in education policy for physics learners. For example, since 2001, the SBOE's Texas Essential Knowledge and Skills (TEKS) requirements have been the primary source for policy in Texas schools, including the primary source of policy for physics learners (TAC, §112.39). Additionally, the SBOE recommends all learners in Texas take physics as one of the four science courses required for the recommended high school diploma known as the 4 x 4 (SBOE, §74.63.b.3). Policy is influenced by federal and state governments as well as the SBOE. The three areas I focused on in this study are education standards, education assessment, and learner demographics.

Education standards. Education standards provide the blueprint for instructional content in K-12 classrooms. In Texas, the standards for physics are found in the TEKS. According to the standards in the TEKS, all learners should take physics between the ninth and twelfth grades. In addition, the TEKS standards consist of three science process skills (i.e., learners conduct investigations; learners use a systematic approach; and learners use critical thinking, scientific reasoning, and problem solving) and five content standards (i.e., learners know and apply laws governing motion; learners know the nature of forces in the physical world; learners know that changes occur within a physical system and can apply the laws of conservation of energy and momentum; learners know the characteristics and behavior of waves; and learners know simple examples of atomic, nuclear, and quantum phenomena). Physics learners conduct investigations 40% of class time which can include experimentation in a simulated environment. Both process skills and content standards apply to all physics learners in Texas (TAC, §112.39).

Education assessment. Education assessments provide the method for determining learner mastery of instructional content. In Texas, the assessment for physics learners is the State of Texas Assessment of Academic Readiness (STAAR) standardized test administered to Learners. The STAAR assesses learner mastery of the three process skills and five content standards provided in the TEKS. The STAAR is a required assessment for all physics learners regardless of demographic background, just as with the educational standards.

Learner demographics. Physics learners in Texas constitute a large and diverse population. Table 1.1 provides data describing the size of the physics learners' population in Texas for the 5 years beginning in 2007 and ending in 2012. According to the data in this table, during the 2007-08 school year there were 120,286 physics learners in Texas; however, by the year 2011-12 the number of physics learners in Texas increased to 266,522. Over the 5-year period from 2007 to 2012, the size of the physics student population increased by 146,236 physics learners (122%).

Many categories have been used to describe the diversity of physics learners in Texas. Table 1.2 provides data describing the diversity of the physics learner population from 2007-08. According to the data in this table, slightly more than half of all physics learners in Texas are categorized as Non-white. For example, in the 2007-

08 school year there were 63,600 physics learners (53%) not categorized as White; as opposed to 56,686 physics learners (47%) categorized as White. However, by the 2011-2012 school year the physics learners in Texas not categorized as White increased to 170,011 (167 %), whereas the physics learners categorized as White increased from 56,686 to 96,511—an increase of only 39,825 (70%). During the 5-year period, from the 2007-08 school year to the 2011-12 school year, physics learners in Texas categorized as minorities have increased by more than twice the number of physics learners categorized as White.

Table 1.1

Number of Physics Learners in Texas for the Past 5 Years

Year	Total number of physics learners	Percent increase per year
2007-2008	120,286	
2008-2009	135,578	10.1%
2009-2010	181,340	33.8%
2010-2011	248,854	37.2%
2011-2012	266,522	7.1%

A closer look at Table 1.2 reveals both changes in how learner diversity is categorized and changes in the diversity of the Texas population. Between the school years of 2007-08 and 2008-09, the following categories were used for demographics of learners: African American, Asian, Hispanic, Native Indian, and White. The categories collected by the Texas Education Agency (TEA) were changed for the 2009-10 school year. New categories for the 2009-10 school year and following years are: American Indian or Alaskan Native, Asian, Black or African American, Hispanic/Latino, Native Hawaiian/Other Pacific, Two or More Races, and White.

The demographics of learners taking physics have changed over the last 5 years. Regardless of how diversity is described, in the 2007-08 school year the majority of learners enrolled in physics were categorized as White; however, by the 2011-12 school year the number of minorities had increased. General trends observed in Table 1.2 are that (a) the Hispanic population of learners almost tripled in size, with the largest increase between the 2009-10 and the 2010-11 school year; and (b) in 2009-2010, the physics learners categorized as Hispanic became the largest subpopulation in Texas enrolled in physics starting in 2010-2011 school year.

Table 1.2

Number of Physics Learners in Texas Categorized by Minority Group for the Past 5 Years

	Category							
Year	American Indian or Alaskan Native or Native American	Asian	Black or African American	Hispanic/ Latino	Native Hawaiian/ Other Pacific	Two or More Races	White	Total
2007-2008	454	8,301	13,568	41,277			56,686	120,286
2008-2009	478	8,957	15,305	49,949			60,889	135,578
2009-2010	910	10,032	19,485	75,898	222	2,818	71,975	181,340
2010-2011	1,203	11,807	29,615	110,170	361	4,088	91,610	248,854
2011-2012	1,289	12,747	29,880	121,180	333	4,582	96,511	266,522

Physics Learners in Texas with Limited English Skills

In Texas, the SBOE and TEC also have an extended history of involvement in science literacy for K-12 learners with limited English skills. The TEKS standards, created by the SBOE and a part of the TEC, stress the importance of physics knowledge. Furthermore, the SBOE recommends all learners in the state enroll in physics as one of the four science courses required for graduation. In this section I discuss three areas related to physics learners with limited English skills in Texas: education standards, education assessment, and learner demographics.

Education standards. Education standards provide the blueprint for instructional content in K-12 classrooms. As previously mentioned, in Texas the standards for physics are found in the TEKS. Also previously mentioned, all learners should take physics between the ninth and twelfth grades (SBOE §74.63.b.3). Physics learners with limited English skills have additional standards as outlined in the English Language Proficiency Standards (ELPS). The ELPS consist of five categories for cross curricular second language acquisition of essential knowledge and skills (i.e., cross curricular second language acquisition/learning strategies, cross curricular second language acquisition/listening, cross curricular second language acquisition/speaking, cross curricular second language acquisition/reading, and cross curricular second language acquisition/writing) and four proficiency level descriptors (i.e., beginning, intermediate, advanced, and advanced high). These standards include both second language acquisition and proficiency level descriptors apply to all learners with limited English skills.

Education assessment. Mastery of instructional content is a concern for both policymakers and educators. Education assessment provides the method for determining learner mastery of content. As previously mentioned, in Texas, the assessment for all physics learners is the STAAR. Physics learners with limited English skills, however, have the Texas English Language Proficiency Assessment System (TELPAS) as an additional assessment. The TELPAS assesses learner mastery of the five cross curricular second language acquisition essential knowledge and skills and the four proficiency level descriptors provided in the ELPS. The TELPAS is a required assessment for all physics learners with limited English skills regardless of demographic background, just as with the education standards.

Learner demographics. Physics learners with limited English skills in Texas constitute a large and diverse population. Table 1.3 provides data describing the size of the population for the 5 years beginning in 2007 and ending in 2012. According to the data in this table, during the 2007-08 school year there were 5,751 physics learners in Texas categorized as Limited English Proficient (LEP) or English as a Second language (ESL); however, by the year 2011-12 the number of physics learners categorized as LEP or ESL in Texas had increased to 18,974. This shows that over the 5-year period the number of physics learners categorized as LEP or ESL increased by 13,223 learners (230%). In terms of describing the diversity of physics learners categorized as LEP or ESL in Texas, many categories have been used. According to the data in the 2011-12 school year, populations for LEP or ESL physics learners categorized as either White or Non-white increased by approximately 230%.

As with changes revealed in Table 1.2, a closer look at Table 1.3 reveals both changes in how learner diversity is described and the diversity of the population. In this paragraph, I discuss the changing enrollment of physics learners categorized as LEP or ESL. Between the school years of 2007-08 and 2008-09 the following categories were used to classify the demographics of learners: African American, Asian, Hispanic, Native Indian, and White. The categories were changed by TEA for the 2009-10 school year. New categories for the 2009-10 school year and following years are: American Indian or Alaskan Native, Asian, Black or African American, Hispanic/Latino, Native

Hawaiian/Other Pacific, Two or more races, and White. The demographics of learners taking physics have changed over the last 5 years. For the last few years from the 2007-08 school year to the 2011-12 school year, the number of physics learners categorized as LEP or ESL have shown an increase.

Table 1.3

Number of Physics Learners in Texas Categorized as LEP or ESL for the Past 5 Years.

	Category							
Year	American Indian or Alaskan Native or Native American	Asian	Black or African American	Hispanic/ Latino	Native Hawaiian/ Other Pacific	Two or More Races	White	Total
2007-2008		769	113	4,739			130	5,751
2008-2009		858	152	5,859			151	7,020
2009-2010	68	1,041	204	10,509		29	249	12,100
2010-20011	58	1,436	316	16,612	39	54	299	18,814
2011-2012	74	1,462	336	16,590	20	66	426	18,974

In this paragraph, I discuss educational policy governing learners with limited English skills, which are categorized as ESL or LEP. Federally funded schools offer accommodations to learners with limited English skills. Learners who choose to receive accommodations in schools are categorized as ESL. Learners who choose not to receive accommodations in school are categorized as LEP. For the purpose of this research I have placed the two groups into one category, English language learners (ELLs). During the 2011-12 school year, 18,846 physics learners enrolled in the State of Texas were categorized as either LEP or ESL. Table 1.3 shows the increase in numbers of learners categorized as LEP or ESL learners enrolled in physics over the last 5 years. According to Table 1.2, the population of total physics learners in Texas increased from 248,854 to 266,522 learners (7%) from the 2010-11 to 2011-12 school years. However, the numbers of learners categorized as LEP and ESL did not increase at an equivalent rate over the same time (Table 1.4). The number of learners categorized as LEP and ESL increased by 167 learners. The total population of LEP and ESL learners increased from 18,679 to 18,846 learners (1%). The learners categorized as LEP decreased from 8,707 to 8,669 in the 2010-11 and 2011-12 school years.

Table 1.4

Number of LEP and ESL Learners Enrolled in Physics

Year	LEP learners	ESL Learners	Total LEP and ESL Learners	Percent Increase
2007-08	3,025	2,689	5,724	
2008-09	3,729	3,253	6982	22%
2009-10	6,274	5,745	12,019	72%
2010-11	8,707	9,972	18,679	55%
2011-12	8,669	10,177	18,846	1%

Education Policy Pertaining to Physics Learners with Limited English Skills

Federal policy has a history of being involved in the development of science literacy for K-12 learners with limited English skills. In 1974, the United States Supreme Court made a decision stating that publicly funded schools must provide an equal education for all learners. More specifically, in Lau v. Nichols (1974, 414 U.S. 563), the court ruled all schools must provide special assistance for minority learners with limited English speaking skills (Baker & de Kanter, 1983). Learners with limitations affecting their acquisition of a meaningful education require accommodations through additional instructional interventions. In 2001, Congress introduced the No Child Left Behind Act of 2001 (NCLB, 2001). This act intended for schools to improve the academic achievement of all children, in particular groups identified as “historically underrepresented.” Learners with limited English skills are one of these underrepresented groups. The majority of learners with limited English skills (Table 1.4) are categorized as minorities. Ethnic minority learners have also been identified as less successful in science than their peers (Barton, 1998; Fradd & Lee, 2001; Lee, 2005; Lee et al., 2008; NRC, 2008; NRC, 2007). In the past 40 years, the federal government has tried to equalize education for underrepresented groups (NCLB, §1032). In addition to the federal government, many states have taken an active role in addressing education for underrepresented groups.

Texas state policy in the TEC (§28.005) states that English is the basic language of instruction in public schools. Learners with no English skills to limited English skills are placed in academic content classes taught in English. TEC states that if a district has more than 20 learners in the same grade with limited English skills, special instruction shall be provided (TEC §89.1205). Compliance with TEC is not required by law, but compliance is required for public funding and public accreditation. Therefore, the TEC carries the effect and intent of a law.

This section has dealt with policy actions pertaining to K-12 learners with limited English skills, physics learners in Texas, physics learners in Texas with limited English skills, and educational policy pertaining to physics learners and limited English skills. The next section includes four research concepts: problem, significance of the study, purpose of the study, and research questions.

Statement of the Problem

Science literacy includes the ability to solve problems, formulate conclusions, and engage in science-intensive employment. Preparation for science literacy is a major concern for education actors (Barton, 1998; Fradd & Lee, 2001; Lee, 2005; Lee et al., 2008; NRC, 2008; NRC, 2007). As previously stated, this concern was identified in the nineteenth century and has brought about changes in legislation over time. However, a problem still exists: not all physics learners have equivalent English skills. In this section, I discuss the two major problems associated with teaching learners with limited English skills. The first problem addressed is the language barrier and the second problem is the abstract nature of the content of physics.

Texas requires that classes be taught in English (TEC §28.005). Language is the primary issue of comprehending content in the classroom, and when the mode of instruction is English learners with limited English skills can suffer. When learners with limited English skills are not familiar with the language, they are simultaneously learning science and a new language (Lee, 2004; Lee & Fradd, 1998; Lee et al., 2005; Lee et al., 2006). Science requires learners to communicate their results, negotiate understanding with their peers, and formulate conclusions through discussions. Because learners with limited English skills have not yet mastered conversational English, these learners may not be able to engage in the discourse necessary to grasp the nature of science and science content.

A second difficulty is found when science teachers attempt to create connections between real world situations or past experiences of the learners with new science content knowledge, especially abstract content. When real world connections stem from the experiences most familiar to their teachers, learners with limited English often do not have a similar context with which to make those connections due to different backgrounds and culture (Lee, 2005). Because of life contrasts, a conflict can exist between the ideals of equal education for all learners and the reality of education in schools today (Barton, 1998; Fradd & Lee, 2001; Lee, 2005; Lee et al., 2008; NRC, 2008; NRC, 2007). As stated earlier, English is the language of instruction in Texas. Consequently, the difficulty learners with limited English skills have in grasping abstract concepts potentially increases the learners' difficulty levels compared to their English-speaking peers. Additionally, in Texas physics standards involve scientific process skills and the understanding of abstract concepts. The summative assessment known as STAAR requires that all physics learners pass the assessment at the end of the school year.

Every day ELLs face an instructional environment in which they do not necessarily comprehend simple English instructions. Teachers of learners with limited English skills face the issues of trying to teach abstract concepts with real world examples from a different perspective, background, or culture, and to students who use a foreign language. From the instructors' perspectives, they are charged with teaching complex abstract concepts in English, while the learners in their classrooms have limited abilities to grasp physics concepts due to the language barrier.

Significance of the Study

One of the physics standards listed under the topic of laws governing motion in a variety of situations is Newton's Third Law. Here, the learner is expected to understand a pair of forces between two objects (TEKS §112.39 4D) as described in Newton's Third Law. This law of physics represents essential knowledge in understanding how the world works. While the law is an important concept for learners to understand (Heller & Stewart, 2010), research conducted with high school and college learners has revealed difficulties in learners' acquisition of a deep understanding related to concepts covered by the law. Consider an example of Newton's Third Law where a large truck collides with a smaller car, producing a large amount of damage to the smaller car with little damage to the truck. Learners make these observations and yet struggle to understand that forces are really equal between the car and truck but are in the opposite direction (Bao, Hogg, & Zollman, 2002; Dancy, Christian, & Belloni, 2002; Knight, 2004; Maloney, 1984; Redish, 2003a; Redish, 2003b; Smith & Wittman, 2007). The cause of the damage is due to other related principles in physics with explanations of additional concepts.

The significance of this study is to identify an alternative approach for teaching physics concepts to all learners. Not all learners have equivalent English skills, whether in underrepresented populations or not. Specific research on secondary education physics learners with limited English skills is not available, so this study will add to the field of knowledge in this area, and may prove to be applicable to broader populations as well.

Purpose Statement

The purpose of this study was to investigate the relationship between an instructional approach of using computer simulations and English language learners' conceptual understanding of Newton's Third Law. The underlying assumption is that Computer simulations, which provide visual representations of Newton's Third Law, will be advantageous to all limited English learners, regardless of their level of proficiency in listening, speaking, reading, or writing. The participants in this study are learners with limited English skills, from a school in the southwestern part of the United States. The English language skills for the participants range from beginner to advanced high, according to the Texas English Language Proficiency Assessment System. The English language proficiency levels of beginning, intermediate, advanced, and advanced High are not grade-specific (see Figure 1.2).

Learners with limited English skills may exhibit different proficiency levels within the language domains of listening, speaking, reading, and writing. Table 1.5

excerpts TELPAS ratings for learners with limited English skills in four language domains (see http://www.elltx.org/docs/English_Language_Proficiency_Standards.pdf for the full text).

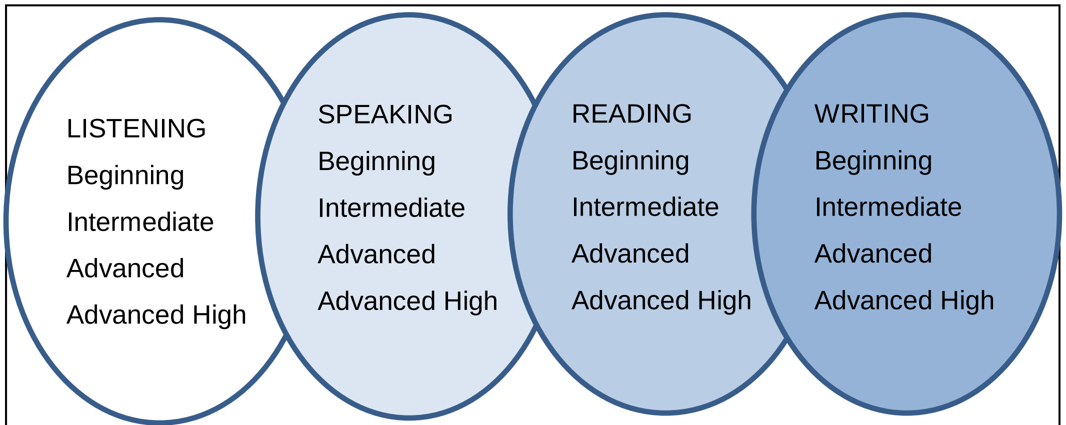

Figure 1.2. Language proficiency levels. English learners with limited English skills may have skills in more than one rating category. For example, a learner may have a listening rating of advanced, speaking rating of intermediate, reading rating of beginner, and writing rating of beginner. See TELPAS grades K-12 revised September 2011, TEA. n.d. http://www.tea.state.tx.us/student.assessment/ell/telpas 12-30-12.

In this study, responses of learners receiving instruction through traditional hands-on laboratory investigations were compared to the responses of learners receiving instruction through the use of computer simulations. Learners in the computer simulations group of learners were able to manipulate variables while interacting with computer simulations. These learners were able to observe results from manipulating variables online (Christian & Belloni, 2004). Learners in the hands-on laboratory investigations group were able to manipulate variables using equipment such as spring scales. I theorized that the computer simulations learners would be able to successfully adjust their conceptual understanding as they made predictions, recorded observations, and formulated conclusions from manipulating variables while interacting with the computer simulations.

Previous physics education research has shown that conceptual understanding can increase as learners interact with physics computer simulations in the following topics: electricity and magnetism (Dancy et al., 2002), electric circuits (Finkelstein, Adams, Keller, Perkins, & Wieman, 2006), the photoelectric effect (McKagan, Handley, Perkins, & Wieman, 2009, quantum mechanics (McKagan, Perkins, Dubson, Malley, Reid, LeMaster, & Wieman, 2008), as well as other more general physics concepts (Adams, Reid, LeMaster, McKagan, Perkins, Dubson, & Wieman, 2008; Perkins, Adams, Dubson, Finkelstein, Reid, & Wieman, 2006). Wu, Krajcik, & Soloway (2001) reported that sensory information can aid learner understanding. Furthermore, the ability to visualize phenomena can assist learners in developing mental models (Ardac & Akaygun, 2004; Wu et al., 2001). Through the construction of mental models, learners are able to examine the viability of their prior conceptions by manipulating variables in a computer simulations and observing the results (Dancy et al., 2002).

Table 1.5

TELPAS Ratings for Proficiency Levels

	Speaking	Reading	Writing
Beginning ELLs	little or no ability to speak English in academic settings; mainly using single words and short phrases; may be hesitant to speak; may give up in their attempts to communicate.	little or no ability to read and understand English used in academic contexts; understanding very limited	little or no ability to use the English language to express ideas in writing and engage meaningfully in grade-appropriate writing assignments in content area instruction
Intermediate ELLs	speak in a simple manner using English commonly heard in academic settings; participate in short conversations; may hesitate frequently to think before speaking	read and understand simple, frequent English words used in routine academic contexts; read and understand on a somewhat wider range of topics and with increased depth	limited ability to use the English language to express ideas in writing
Advanced ELLs	use grade-appropriate English, with second language acquisition support; participate comfortably in most academic discussions on familiar topics, with some pauses	read and understand, with second language acquisition support; a variety of grade-appropriate English vocabulary words used in academic contexts	English vocabulary and language structures to address grade-appropriate writing tasks; second language acquisition support needed; express ideas in meaningful grade-appropriate writing
Advanced High ELLs	ability to speak using grade-appropriate English, with minimal second language acquisition support, in academic settings; participate in extended discussions on grade-appropriate academic topics; occasional hesitations or pauses.	ability to read and understand, with minimal second language acquisition support, grade-appropriate English in academic contexts; read and understand vocabulary at a level nearly comparable to native English-speaking peers	have acquired English vocabulary and command of English language structures necessary to address grade-appropriate writing tasks with minimal second language acquisition support

Research Questions

The following research questions are posed:

1. What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?
2. What are the differences in conceptual conversations between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?
3. What are the differences in conceptual conversations in relationship to their conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?

Definition of Terms

Seven definitions used throughout this dissertation include the following:

English Language Learner (ELL) – refers to an individual who is learning English as a second language (ESL) or has limited English proficiency (LEP). English is not the individual's native language. Therefore these learners have difficulty performing ordinary classwork in English. They often have a different cultural background than their peers. Other terms associated with these learners are language minority learners or culturally and linguistically diverse (CLD) learners (Texas Education Agency http://www.elltx.org/, 1-10-13).

English as a Second Language (ESL) – refers to the condition of a learner whose primary language is other than English who chooses to participate in a bilingual school program. These learners receive accommodations to assist in their English language skills (TEC, §29.052).

Hispanic or Latino – refers to a person with a heritage of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin regardless of race (State and County QuickFacts, 2011, http://www.census.gov/prod/cen2010/briefs/c2010br-04.pdf).

Instructional Effectiveness – means value is added or there is a gain in the learner's conceptual knowledge.

Limited English Proficient (LEP) – describes a learner with limited English proficiency who is eligible for assistance in the bilingual program at school but refuses to participate (TEC, §29.052).

Other Central City – refers to the classification of a high school where data are collected because it is located in a county with a population of between 100,000 and 774,999 (TEA, http://www.tea.state.tx.us/acctres/analyze/1011/district1011.html#L).

Texas English Language Proficiency Assessment System (TELPAS) – an instrument designed to assess the progress of learners with limited English skills. There are two components of the test. Reading Proficiency Tests (RPTE) in English and Texas Observation Protocols (TOP). The previous assessment has been recently replaced with the Oral Language Proficiency Test (OLPT). The first year of enrollment the Linguistically Accommodated Testing (LAT) is utilized.

Limitations

This research has several limitations related to learners with limited English skills. The three main testing limitations are: (a) specific instructional strategy, (b) specific physics concept, and (c) specific population of learners.

First, this study is limited to a specific instructional strategy, computer simulations. Computer simulations are a form of visual representation designed to teach or reinforce a scientific concept. Learners are able to manipulate variables and observe the results of those changes. Computer simulations have the advantage of using visual representations to teach scientific content with limited written instructions. Therefore learners are able to focus on scientific content. As previously mentioned, research has shown through the manipulations of variables learners are able to change their conceptual understanding (Dancy et al., 2002; Finkelstein et al., 2006; McKagan et al., 2009; McKagan et al., 2008; Adams et al., 2008).

Second, this study is limited to a specific physics concept, Newton’s Third Law. This is a difficult concept for physics learners to comprehend from high school to college ages (Smith & Wittman, 2007; Bao et al., 2002; Maloney, 1984).

Third, this study is limited to a specific population of high school ELLs attending one school situated in one geographic location.

Assumptions

Three basic categories of assumptions were made in the design of this study. The first assumption is that all learners were equally engaged in one of the two experimental conditions, computer simulations or hands-on laboratory investigations.

Furthermore, I assumed that all learners were equally engaged in answering both the pretest and posttest. The second assumption is that language is an impediment to understanding scientific concepts. As previously mentioned, TEC mandated English as the language of instruction. As ELLs have limited English skills, English-only instruction can increase the learners' difficulty in grasping science content, confirmed by Lee (1997) and Lee et al. (2005). Some words may have different meanings due to different backgrounds and cultures, and this can add to the learners' difficulties (Lee, 1997; Lee et al., 2005).

Implications

Computer simulations in teaching abstract science concepts such as Newton's Third Law are implicated as holding promise in providing a key for learners who may not yet possess the language skills necessary to understand listening to a teacher or reading. The results of this study have implications for transforming aspects of science teaching requiring mastery of abstract concepts, such as Newton's Third Law, in order to embrace "science for all," including learners with limited English language. Results favoring computer simulations would imply that learners with limited English skills can grasp abstract science concepts along with their English speaking peers.

Conclusion

While limitations exist in this exploratory study, it is the first of its kind in investigating the efficacy of computer simulations in teaching abstract science concepts to secondary learners without prerequisite English language skills. I proposed to investigate ELLs' understanding derived from two different experimental conditions, both of which enable ELLs to manipulate variables and observe the results of their manipulations. Different, however, are the language requirements for successful completion of activities related to manipulating the variables. Hands-on laboratory investigations traditionally require students to set up equipment, collect and manage data, and employ calculations and/or graphing to see results. More time is required to collect multiple trials, and errors are possible in the set-up of equipment, collecting data, calculations, and graphing results. Computer simulations have the equipment already set up, data collection possibilities, and potential graph selections embedded within the program; therefore, the ELLs can focus on changing variables and immediately "seeing" the results, which occur without error.

CHAPTER II

LITERATURE REVIEW

In Chapter I, I discussed the federal and state governmental policies pertaining to education and more specifically, policies related to teaching physics to English language learners (ELLs). Furthermore, I reported increases in the number of ELLs enrolling in physics classes, thus emphasizing that physics teachers are experiencing new challenges related to teaching physics as they create science learning environments effectively serving classrooms of students speaking several languages other than English as their first language. ELLs in high school possess varying levels of English skills, often dependent on the number of years they have attended American schools, where English is the required language of instruction. Subsequently, most ELLs new to living in the U.S. struggle with understanding the subject matter in their classes, which become even more challenging when they must grasp understandings related to abstract science concepts (Lee, 2004; Lee et al., 2006; Lee et al., 2005; Lee & Fradd, 1998), many of which are contrary to the practical knowledge students have accumulated through experience that relates to how the world works.

As a physics teacher in a school district currently serving a diverse population of ELLs from many different countries, I have been concerned for a number of years about ways to help ELLs grasp abstract physics concepts. Above all other topics, Newton's Third Law remains to be one of the most difficult physics concepts for me to teach. Noted in the literature as a difficult concept for English-speaking learners, my experiences indicate that the concept is difficult for all learners, but especially difficult for ELLs.

In this chapter, I address two issues. The first issue relates to teaching Newton’s Third Law in high school physics classes, specifically: (a) the importance of Newton’s Third Law to developing an understanding of physics concepts, and (b) the challenges to high school physics teachers in relation to teaching ELLs. The second issue relates to doing research about successful strategies in teaching about Newton's Third Law to ELLs, including (a) specifying the design elements for a research design involving ELLs' learning of Newton's Third Law, and (b) developing research methods to evaluate ELLs’ conceptual understanding, mental models, and language associated with Newton’s Third Law.

Conceptual Framework

The conceptual framework navigating the literature review for this chapter appearing as Figure 2.1 indicates my placement of these issues within a logical framework for reviewing the literature related to teaching and research issues involving ELLs' learning of Newton's Third Law. Subheadings in this chapter correlate with concepts appearing in the conceptual framework.

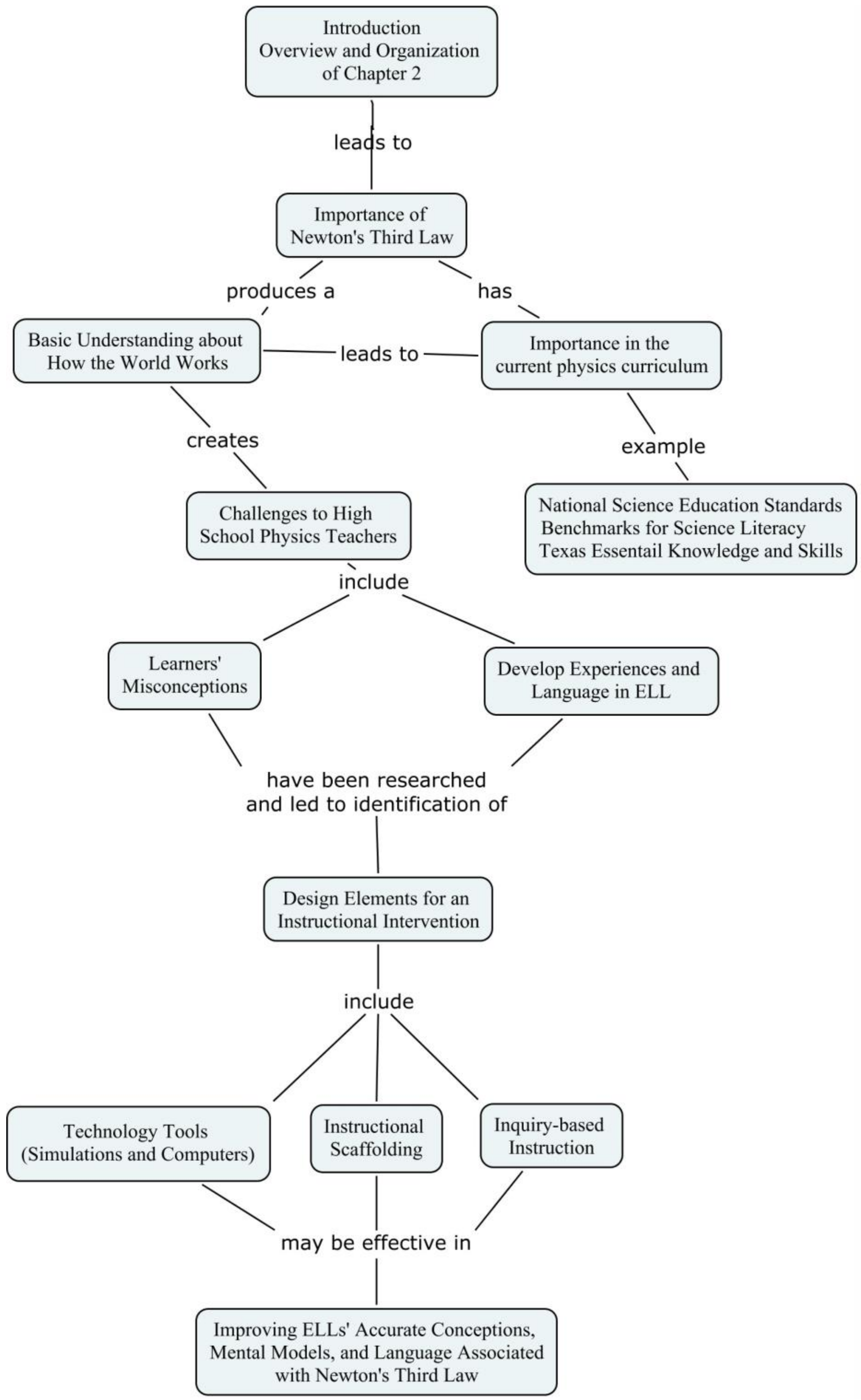

Figure 2.1. Outline of the literature review.

Importance of Newton’s Third Law

A conceptual understanding of physics requires an understanding of Newton’s Third Law, which provides basic knowledge of the constructs for how the world works. For example, learners confuse “force” with how fast an object is moving or if the object is increasing or decreasing speed (Hestenes, Wells, & Swackhamer, 1992; Maloney, 1984; Smith & Wittman, 2007). Learners face challenges with application of the law to real world situations, primarily due to the fact that learners bring to the topic an array of misconceptions. These misconceptions are in opposition with the principles of Newton’s Third Law. In addition to the instructional challenges needed to overcome these misconceptions, teachers of physics learners who are ELLs encounter a unique set of additional challenges in teaching Newton’s Third Law to these learners.

The two instructional interventions chosen for this investigation allow for comparison in ELLs' learning outcomes in computer-assisted and hands-on instruction. The hands-on instruction intervention engages learners in traditional laboratory-based instruction with set-ups of equipment, measuring of variables, and examination of results. The computer-assisted intervention employs technology in the form of computer simulations designed for learners to develop a better understanding of Newton’s Third Law and to alter existing misconceptions. The computer simulations chosen for the intervention have instructional scaffolding assisting learners in developing a conceptual understanding of forces as the learners manipulate different variables utilizing the inquiry approach. As the variables are being manipulated, the learner is able to observe resulting changes. While research does exist on teaching the concept of Newton’s Third

Law to physics learners, especially to college students, research involving teaching Newton’s Third Law to high school learners who have limited English skills is nonexistent, nor do any studies compare two different modes of learning about Newton's Third Law.

In the eyes of Albert Einstein, Isaac Newton’s understanding of the how the world works embodied the greatest of all minds (Krull, 2006), and Newton’s work has affected generations of physicists and their concepts of physics. As an example, before rockets went into space many physicists thought that resistive mass was required for acceleration of motion. Space has little or no mass. Consequently, many physicists thought rockets once in space could not alter movements. The assumption that external mass is required for motion proved false since the propulsion force is acting on the internal spacecraft and therefore produces motion. But, as modern space travel is now possible, the assumption that space is a complete vacuum is also false.

Newton’s Third Law states, “Force of one object on a second is the same size (magnitude) as that on the first by the second, but in the opposite direction” (Smith & Wittman, 2007, p. 1). Newton’s Third Law explains interaction of surrounding forces (Hewitt, 1997). Without a full understanding of Newton’s Third Law, learners are unable to grasp a basic understanding of physics. A learner then easily develops misconceptions and faulty mental models.

Texas mandates the *Texas Essential Knowledge and Skills* standards for physics. Section 4C of TEKS requires that students know the laws governing motion, and expects students to demonstrate the effects of forces on the motion of objects. For example, in high school physics students should develop a conceptual framework of forces as exhibited in the following TEKS statement:

> (4) Science concepts. The student knows and applies the laws governing motion in a variety of situations. The student is expected to: (D) calculate the effect of forces on objects, including the law of inertia, the relationship between force and acceleration, and the nature of force pairs between objects; (http://ritter.tea.state.tx.us/rules/tac/chapter112/ch112c.html#112.39 retrieved 3-19-2011).

In addition to state mandates, the *National Science Education Standards* as set forth by the NRC (1996) state, "Whenever one object exerts a force on another object, a force equal in magnitude and opposite in direction is exerted on the first object" (p. 180). The *Benchmarks for Science Literacy* (1993) under the subtitle Motions and Forces states, "Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object" (p. 179).

Challenges to High School Physics Teachers

Challenges of learners' misconceptions. Christian and Belloni (2004) investigated the efficacy of changing learners' misconceptions and beliefs through interactions with computer simulations. These researchers substantiated that the use of visual representations during lessons on electricity could produce a change in learners' mental models (Christian & Belloni, 2004). Others have noted the importance of learners' being actively involved in constructing conceptual knowledge (e.g., Leonard, Dufresne, & Mestre, 1996). Learners need to be able to manipulate variables while interacting with computer simulations in order to develop conceptual understanding. A learner's ability to actively work and assimilate material in order to make sense of it is consistent with research findings (Leonard et al., 1996). A computer simulations enhance a learner's understanding when it contains animation, engages learners, controls access to variables, and limits time and number of variables (de Jong, Martin, Zamarro, Esquembre, Swaak, & van Joolingne, 1999). Computer simulations with these qualities result in increased intuitive knowledge of the learner.

The NRC (2000a) defines a misconception as an incorrect thought that has part or all of the ideas associated with a concept. Other words associated with the concept of misconceptions have been used (see Table 2.1). These include alternate or common naïve conceptions and common-sense beliefs. Obstacles to learning physics are often entangled in personal common-sense misconceptions that learners hold about the way the world works. Derived from the learners' observations of the world around them, these misconceptions become the learners' explanations (Dykstra, Boyle, & Monarch, 1992; Hudson, 1984; Maloney, O'Kuma, Hieggelke, & Van Heuvelen, 2001), developed over time by interacting with the environment (Maloney, 1984). Since misconceptions are often deeply rooted and difficult to change, learners who tightly adhere to them are not able to fully benefit from instruction (Dykstra et al., 1992).

Table 2.1

Words and Phrases Associated with the Identification of Incorrect Conceptual Understanding

Words and phrases	References
Alternate conceptions	Maloney, 1984; Redish, 2003b
Aristotelian	Halloun & Hestenes, 1985a
Common naïve conception	Redish, 2003b
Common sense beliefs	Halloun & Hestenes, 1985a
Facets	Minstrell, 2008
Initial conceptions	Maloney, 1984
Mental models – can contain misconceptions, part or whole	Bao, Hogg, & Zollman, 2002; Redish, 2003b
Misconceptions	Minstrell, 1982; Hammer, 1996; Redish, 2003b
Preconceptions	National Research Council, 2000b; Redish, 2003b
Student views	Thornton, 1997

An example of a misconception in physics when learning Newton's Third Law can be found in a student's attempts to describe an interaction between a larger object and a smaller object. Learners incorrectly think that the larger object exerts a greater force on the smaller object. In reality, the amount of force exerted by the larger object is the same as the force exerted by the smaller object. The direction of the forces is opposite. As Newton's law states, the forces are equal in magnitude but in the opposite direction. Another example of a common misconception is the thought that a moving object exerts a larger force when it collides with a stationary object (Maloney, 1984).

Misconceptions are one source of learners' struggles when trying to understand Newton's Third Law (Bao et al., 2002).

Challenges of accurate mental models. Craik (1943) first used the term mental models. Later, Gentner and Stevens (1983) used the term to describe beliefs developed through observing the real world, a prior knowledge used to form understanding of the world. Cognitive scientists have studied mental models, and many cognitive scientists are utilizing prior knowledge and perceptions to explain new situations. One or many misconceptions can be included in a mental model, or misconceptions can be included along with many truths to combine to form a mental model (Davidson, Dove, & Weltz, 1999).

Some commonly held beliefs are that only living objects can exert forces, nonliving objects impede or stop motion, and a greater force is needed for objects to move than for objects to remain stationary. The use of force in everyday language and nomenclature such as: "the force be with you"; "police force"; or the "force of the conversation" leads learners to develop misunderstandings of force as it is used in physics (Halloun & Hestenes, 1985a). Maloney (1984) found learners' beliefs to be inconsistent with Newton's Third Law. Other researchers have concluded that preexisting beliefs have a detrimental effect on the learners' performance in physics (Halloun & Hestenes, 1987).

Smith and Wittman (2007) analyzed scenarios in which objects were pushed and in which objects collided (see Table 2.2). In the first scenario, pushing involved the interaction of two objects for an extended period of time. During the pushing, objects of differing masses remained at a constant speed, sped up, or slowed down. Many learners thought that the object with the larger mass had the larger force. Some learners thought that the first object exerted force and the second object only felt force. If the larger mass was moving and the smaller mass was stationary, learners thought that the force was largely due to motion. Many learners believed that the forces were equal if the objects moved at constant speeds. In the collision scenario, learners observed collisions between cars and trucks, which led to the misconception that the larger truck had a greater force because the smaller car received the most damage (Smith & Wittman, 2007).

Learners can apply correct conceptual understanding in a particular situation, while in different scenarios learners often revert back to old misconceptions. Learners' previous educational instruction, everyday experiences, and thoughts influence their conceptual understanding of physics instruction (Bao & Redish, 2006). Minstrell (2008) coded the following facets held by learners:

- Stronger exerts more force.
- One with more motion exerts more force.
- More active/energetic exerts more force.
- Bigger/heavier exerts more force.

Another example of a misconception is when learners believe the reason a horse can pull a cart is because the horse pulls harder on the cart than the cart pulls on the horse (Olenick, 2000). In one study, Maloney found that learners believe in the "dominant principle." That is, learners thought that a larger force is produced when an object has a greater mass (Maloney, 1984). Learners believed that the object with the larger mass, the greater velocity, or the object doing the pushing, is the dominating object with the greater force (Bao et al., 2002; Maloney, 1984).

Table 2.2

Words and Phrases Associated with Learners' Common Misconceptions Pertaining to Newton's Third Law

Words and phrases	Misconceptions
Objects being pushed	Larger mass objects exert greater force
Objects being pushed	Pushing objects exert force, objects being pushed only feel the force
Objects moving	Moving objects have more force
Objects move at constant velocity	Forces are equal
Objects colliding	Larger mass objects exert greater force
Objects colliding	Smaller object displays more damage, therefore less force

Learning Newton's Third Law and its many facets poses a difficult problem for learners because of their preconceived ideas, which can also affect instruction (Bao et al., 2002). These authors further explain that mental models are constructed by learners in association with specific topics during instruction. Often common misconceptions are integrated by learners into their mental models. These mental models are constructed by learners throughout daily lessons, teacher-directed instruction, and laboratory activities. Learners refer to their mental models during problem solving and consistently retreat to their misconceptions when answering questions about new material. Sometimes, however, they may use diverse mental models on different questions.

In a study by Bao et al. (2002), questions were developed to assess only one feature of a concept at a time. The authors found that seven out of nine undergraduate learners at Kansas State University consistently applied one dominant misconception dealing with Newton's laws when answering questions concerning force. The rest of the learners applied a mixed or confused state, containing some correct and some incorrect mental models. They also found that some learners applied conceptual understanding one way with one question and when asked a different question, used a different conceptual misunderstanding.   Bao & Redish (2006) reported five years later that learners' applications of mental models concerning Newton's Third Law varied with the situation.

Other researchers have investigated learners' thinking about Newton's laws. Traditional teaching methods do not always change a learner's understanding of Newton's laws. Thornton and Sokoloff (1998) tested learners' knowledge regarding Newton's laws before and after instruction. They concluded that learners' understandings of the laws were not changed through traditional teaching methods. Their study demonstrated that conceptual understanding was gained through active application and hands-on laboratory activities.

One of the most important things a teacher can do is find out what a learner already knows (Ausubel, 1960; Novak & Gowin, 1984; NRC, 2000a). Previous knowledge will alter how learners add new knowledge to already held common-sense beliefs (NRC, 2000a). Certain common beliefs should be considered when teaching Newtonian physics. Learners develop their beliefs through experiencing the world over years. As mentioned, some publications label these beliefs as misconceptions (Halloun & Hestenes, 1985a; Halloun & Hestenes, 1985b). Minstrell (2008) labels such beliefs as facets (http://depts.washington.edu/huntlab/diagnoser/facetcode. html#400). Many of the learners' common misconceptions or misbeliefs are labeled by some as Aristotelian due to the fact that Aristotle held some of these same ideas himself (Halloun & Hestenes, 1985a).

Learners need opportunities to assess and revise their conceptual understanding (Barron, 1998). With computer simulations, learners can change the amount of force and the direction of the force, which provides visual feedback. Learners are able to self-assess as they work through answering questions (Dancy et al., 2002). Utilizing computer simulations allows learners to test their answers and adjust their conceptual understanding (Christian & Belloni, 2004). Application of what they have learned offers learners a chance to demonstrate their conceptual understanding (Barron, 1998). Animations contain embedded scaffolding. Learners can alter their mental models as new observations are made (Leonard et al., 1996). Published research states that conceptual understanding does increase with the use of Physlet® simulations in physics (Dancy et al., 2002). Physlets® are computer simulations developed by Davidson College to assist students in developing conceptual understanding. Wolfgang Christian and Mario Belloni construct computer simulations for their physics courses named Physlets. The students interact with the computer simulations to reinforce a lecture, small group inquiry activities, visualization of mathematical homework problems or hands-on laboratory investigations. The word Physlets® was derived from physics applets. University of Colorado has developed computer simulations which they call PhETs which stands for physics education technology. PhETs are created and tested for accurate visual presentation of a physics concept in computer simulation form (Adams, et al., 2008; Finkelstein et al., 2006; McKagan et al., 2009; McKagan et al., 2008; Perkins, et al., 2006).

Learners learn through active participation (Driver, 1989). By being actively involved with multiple representations, learners are better able to take abstract concepts and formulate concrete ideas regarding Newton's three laws. Research has shown an increase in retention of concepts when learners use multiple representations such as computer animations, computer simulations, and virtual laboratories (NRC, 2000b). Information presented in these multiple formats is readily transferred to other situations, including assessments (Jacobson & Kozma, 2000; Monaghan & Clement, 1999).

Challenges with English language learners. One problem faced when attempting to teach learners in a native language other than English is the number of native languages learners bring to a classroom. In California, more than 90 different languages are spoken (Becker, 1993). As many as ten different languages can exist in one school. Teachers and school districts are overwhelmed by trying to meet the many different language needs of their learners. Arizona categorizes native languages, such as American Indians dialects, as languages originating outside the United States (Barclay, 1983).

ESL programs place learners in regular content classrooms with instruction in English. Extra instruction is presented utilizing curriculum designed to teach non-native English speakers. The learner's native language does not need to be available in using an English as a second language approach (Baker & de Kanter, 1983). Learners with limited English language skills are often placed in science classrooms where English is the language of instruction. Academic difficulties are encountered by these learners. New content is presented to ELLs with limited everyday experiences in their backgrounds (Lee, 2005; Lee et al., 2006).

School districts place English learners in English-speaking content classes as soon as they can speak conversational English (Willig, 1985). According to some researchers this is not an acceptable learning environment. Cummins (1981) states children need to be instructed in their native language. Fillmore (1992) states that when content is abstract it is even more significant that it be taught in the learner's native language. Fradd (1987) concludes that learners acquiring language learn best when manipulatives are used. Learning increases when past experiences supply the context for learning.

According to a study Lai, Lucas, and Burke conducted in 1995, learners learning science in their second language experience enhanced difficulties. ELLs have backgrounds and past experiences that differ from their native English-speaking peers. English learners struggle with learning the language and scientific content while having different past experiences. The learners' English-speaking peers usually share common backgrounds and common experiences with the teacher (Lai et al., 1995).

Learners who come to a school district with a first language other than English have unique problems when learning physics. Evans (1978) implied that learners may understand a specific term, but cannot relate the term to the concept due to their limited language skills. Everyday language, and the meanings associated with the language, can be disconnected from the same or similar scientific term (Evans, 1978). In many school districts, the ideology is to mainstream or place ELLs into content classes believing content-rich meaning, material learned simultaneously with science vocabulary, aids student learning. Due to limited English proficiency, learners may not be able to express their scientific knowledge verbally. In these cases; concepts should be introduced first in the learner's native language. Using the learner's first language enables the learner to use previous information to aid in developing an English knowledge base (Lai et al., 1995).

Recommendations for types of common instructional strategies used to teach content-rich subjects to ELLs vary among experts. However, some strategies are more prevalent as educational approaches to teaching English language learners. Even though the approaches sound similar, often being confused for each other, they are distinct instructional strategies, see Table 2.3. Beginning English learners often have a bilingual teacher presenting the information in both languages simultaneously. Learners are learning English while in an environment with access to their native languages. The teacher is able to interject the learner's native language to assist in instruction (Baker & de Kanter, 1983).

Table 2.3

Characteristics of Different Types of Instructional Strategies Used with English Language Learners

Instructional Strategies	Characteristics	Information
Traditional Bilingual Education (TBE)	Concepts first taught in native language; taught in both native language and English	Language and content learned simultaneously
Immersion	Non-native English speakers in an English-only classroom	
Structured English Immersion (SEI)	Concepts taught only in English	Use instructional strategies to increase language acquisition; appropriate level of English
Sheltered English Immersion	Concepts taught only in English	Curriculum modifications for language learners
Submersion	Concepts taught only in English	No extra assistance; no extra instructional support
Dual Language	Native and non-native language taught simultaneously	

Traditional bilingual educational (TBE) programs involve separating children who do not speak English into classrooms with other minority language learners. TBE topics are taught both in the learner's native, or home, language and in English. Content or subject-specific information is taught first in the native language (Baker & de Kanter, 1983). This approach allows for academic advancement while learning English. The TBE approach teaches content knowledge in English utilizing instructional support with native language materials and culture (Adams & Jones, 2006). The amount of native language used slowly phases out while the amount of instruction in English slowly increases. Educators follow this approach until the learner is able to be placed in an English-only classroom (Baker & de Kanter, 1983).

One advantage of the TBE approach is that the teacher understands the learner's language that is spoken at home. Learners are able to express themselves in their native language while responding to instruction. The teacher may respond in the learner's native language but usually the instruction is in English. Presenting content without requiring prior background education is another advantage of this method of instruction. Learners learn both content and English at the same time (Baker & de Kanter, 1983).

Immersion is placing non-native English speaking learners in a classroom where English is the language of instruction. Usually the teacher speaks only English, and learners are "immersed" in English as a second language. The English language learners are expected to learn the English language and subject content simultaneously (Baker & de Kanter, 1983). Immersion is conducted using varying methods, such as Structured English Immersion and Sheltered English Immersion.

Presentation in English by an English-speaking teacher is a feature of Structured English Immersion (SEI). The teacher uses instructional strategies which increase language acquisition along with developing content material (Adams & Jones, 2006; Baker & de Kanter, 1983). Content and English acquisition occurs at the same time (Baker & de Kanter, 1983). A variety of strategies are used to assist in teaching content. English is taught at appropriate levels according to the learners' abilities (Ramirez, Yuen, & Ramey, 1991). Learners are grouped by language ability for English instruction. In this approach learners obtain another language, content knowledge, and skills at the same time (Echeverria, Vogt, & Short, 2000).

One of the problems with implementation of SEI is that the class moves along with content material at a pace designed for native English speakers. The pace is set forth by state or district lesson plans (Adams & Jones, 2006). ELLs might learn only part of the material required by the state standards (Hayes & Salazar, 2001). Under SEI programs, English language learners placed in content classrooms have intermediate English skills (Adams & Jones, 2006). Since formal instruction presentation is not made in the native language, SEI therefore differs from transitional bilingual instruction (Baker & de Kanter, 1983).

In Sheltered English Immersion the presentation of content material is also in English. Curriculum modifications are designed for learners learning the language, and English language learners experience modified classroom presentations to assist in learning the content material along with learning the language (Wright, 2005). Sheltered English Instruction simultaneously teaches content knowledge and the English language. The English used to teach academic content is specially designed for ELLs. Scientific vocabulary is taught in context with scientific instruction (Adams & Jones, 2006). Sheltered instruction differs from structured immersion in the instructional approach used.

Schools that use the submersion or total immersion method place non-English speakers in regular English speaking classrooms. Learners do not experience the support of instructional strategies that assist them in acquiring English. Learners are expected to learn content-specific knowledge without the assistance of modifications in classroom content and language mechanics (Baker & de Kanter, 1983). The Supreme Court ruled that the submersion approach violated a learner's civil rights (Lau v. Nichols, 1974, 414 U.S. 563,572). Assisting learners in overcoming problems due to language difficulties is a requirement of schools (Lau v. Nichols, 1974, 414 U.S. 563,572).

While learners need to learn English as soon as possible, learners taught in their native language demonstrate greater gains in cognitive and language development than those in either a bilingual classroom or an English-only classroom. An additional obstacle to teaching non-native speakers in their own language is the cost, which is very expensive. In Arizona all classes are taught in English (Barclay, 1983).

Texas Education Code defines Dual Language Immersion as students who are offered an instructional setting in which students are expected to learn in two languages. The Dual Language class is composed of students with limited English proficiency and native English speakers. Students start the program in prekindergarten and can continue through the elementary grades (TEC §89.1203). Dual Language can exist in two forms; Two Way Immersion, and One Way Immersion. In Two Way Immersion academic content is taught in both English and the other native language. Two languages are learned simultaneously. Native English speakers learn the other language while native other language speakers learn English. One Way Immersion differs in that only limited English proficient students are in the program. These students are eventually transferred to traditional English only instruction (TEC §89.1210). The rationale behind Dual Language according to Collier (1989) is that while acquiring language and skills in one language, those skills assists the learner when exposed to another language. The anticipated outcome is developing a proficiency in another language while learning academic content.

Design of the Instructional Interventions

Technology tools (simulations and computers). Technology fosters education (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004), and a mandate used by school districts today is to "teach utilizing technology." The problem is teachers often under-interpret this phrase; they have added Power Point® presentations to their technological repertoire but are still lecturing. A better technology tool is the use of interactive instructional computer simulations such as an accepted instructional program called Physlets®, developed by Christian and Belloni (2004).

Physlets® were designed to increase learning through learner interactions with computer simulations relating to physics concepts and the visualization of these concepts (Christian & Belloni, 2004). Learners are able to interact with the computer simulations and observe the results of manipulating variables. To solve Physlets® problems, learners must have some conceptual understanding. Learners may discover misconceptions through observations, collecting, and analyzing data utilizing computer simulations (Dancy et al., 2002). Christian and Belloni (2004) present an approach for learners to self-assess their conceptual understanding while observing and collecting data.

Chi, Slotta, & de Leeuw (1994) define conceptual change as "learning that changes some existing conception." Their study developed tutorials that use computer simulations to change conceptual understanding through guided questions. Learners make predictions and interact with computer animations and computer simulations to observe physics phenomena. Learners manipulate variables that address their misconceptions and construct knowledge through the utilization of tutorials at a self-pace (Finkelstein & Pollock, 2005).

Computer simulations of Newton's Third Law in the treatment involved the use of learners manipulating variables and observing arrows indicating magnitude and direction of forces. The first computer simulation was a Physlet® (Java applet) from the Davidson College website. The simulation demonstrated two spheres colliding. The forces were displayed by arrows of the same length, but the arrows pointed in opposite directions. The second computer simulation was from the University of Colorado. PhETs® (Physics Education Technology) are computer simulations developed to assist learners in developing correct conceptual understanding. Two PhETs® were used in this treatment to show that the magnitude of the forces displayed by arrow length is the same but the arrows pointed in opposite directions. The last simulation was developed to show Newton's Third Law with a smaller car pushing a larger truck. Arrows were used to show that the forces are equal where the car and truck touch but in opposite directions. Action and reaction statements were placed throughout the computer simulations to assist learners in focusing on two objects, two forces of equal magnitude but opposite in direction. Learners were asked in the student journal to apply their understanding to different situations by making predictions.

Newton's Third Law states, "Force of one object on a second is the same size (magnitude) as that on the first by the second, but in the opposite direction" (Smith & Wittman, 2007, p. 1). Newton's Third Law explains interaction of surrounding forces (Hewitt, 1997). Physlets® and PhETs® were chosen for two reasons. The first reason was these simulations demonstrated Newton's Third Law in the manner which was tested on the Force Concept Inventory (FCI). Secondly, research is available on computer simulations developed specifically for students as created by Davidson College and the University of Colorado at Boulder (Adams, et al., 2008; Christian, & Belloni, 2001; Christian, & Belloni, 2004; Christian, & Esquembre, 2007; Cox, et al. , 2011; Dancy et al., 2002; Finkelstein et al., 2006; McKagan et al., 2009; McKagan et al., 2008; Perkins, et al., 2006).

Hands-on laboratory investigations. Hands-on laboratory investigations foster education. Learners are able to formulate conclusions through manipulating science equipment. Hands-on laboratory investigations assist learners in science discourse as they develop written and oral communication (Lee, Deaktor, Hart, Cuevas, & Enders, 2005).

Thornton and Sokoloff (1998) demonstrated that conceptual understanding was gained through active application and hands-on laboratory investigations. Learners are able to observe and record results from manipulating variables in a hands-on laboratory investigations. Learners may discover misconceptions through observations, collecting, and analyzing data. Learners can investigate through interacting with an experiment that can address their misconceptions and construct new knowledge. Activities providing guidance as learners perform the hands-on laboratory investigations can prompt learners to observe and reflect on a key concept (NRC, 2007). Conceptual understanding can be developed through repeating a hands-on laboratory investigation. Learners can reflect on patterns in the data assist learners in formulating conclusions through hands-on laboratory investigations (NRC, 2000b).

The hands-on laboratory investigations were constructed to be as closely aligned as possible to the learning experience of the computer simulations. Hands-on laboratory investigations treatment involved the use of rubber bands and spring scales. Learners were able to feel and record the magnitude of the forces while participating in the direction of the forces. First, the learners felt the force by pulling a rubber band. Secondly, a spring scale is attached to each end of a rope. Learners pulled on the spring scale located on the ends of the rope and recorded the scale reading. The forces recorded from the strength of the pull were changed by pulling harder. A third spring scale is added in the middle, now there are three spring scales. Learners record the readings on the three scales. The strength of the pull was increased and the readings were recorded. Learners were asked to apply their understanding to other situations by making predictions. Action and reaction statements were placed throughout the hands-on laboratory investigations.

Instructional scaffolding. Many times learners miss important ideas or concepts or the patterns in data during an investigation. Providing guidance as the learners perform an investigation supports learners' performance. A framework that guides learners through a series of steps or questions, prompts learners to observe or reflect on a particular key concept, and assists learners in accomplishing a task is called scaffolding (NRC, 2007). Scaffolding assists learners in learning through activity (Tabak, 2004). The support can be placed inside the investigation. Learners may be directed to make certain observations, become aware of important points, or collect specific data. Learners navigate through the simulation being guided by scaffolding questions or statements, which increases learning of concepts (Hogan, Natasi, & Pressley, 2000).

Computer simulations and animations are visual representations of a scientific concept. These visual representations contain buttons or sliders which learners can manipulate and thereby observe results. Computer simulations and animations are effective teaching strategies in classes with English language learners because they enable learners to interact with visual representations. Variables can be altered or manipulated repeatedly until a learner can predict the result from a particular scenario or has developed a conceptual understanding as demonstrated by sketching a physics situation, drawing a graph, or constructing a motion or free body diagram (Dufresne, Gerace, & Leonard, 1997). Tutorials alone do not improve success for physics learners. Increasing the conceptual understanding of learners is an outcome of visual representations (Finkelstein & Pollock, 2005).

Research conducted in developing effective teaching strategies rarely takes into account the limited English skills and limited background knowledge of learners. By allowing manipulation of variables through inquiry, the strategy used in this study can provide an instructional environment that fosters learning. The instructional environment does not necessitate language mastery so that communication problems in the environment decrease. As learners discuss computer simulations and animations, language is practiced while concurrently acquiring content knowledge from the scientific setting. Learners communicate their conceptual understanding through visual means, so language is less of a deterrent or obstacle (Lee et al., 2006).

Many cultures do not teach children the questioning method or inquiry skills in traditional instructional settings.   Children are taught not to question their elders. Utilizing computer simulations presents the learners with a non-threatening learning environment (Lee et al., 2006). Computer simulations can take the child who is taught not to question into a question-friendly environment. Fradd and Lee have researched culture clashes between science inquiry and a learner's home culture and found some home cultures lead learners to have a greater difficulty with science classrooms (Fradd & Lee, 1999; Lee, 2002).

According to Heller, Keith, and Anderson (1992), cooperative problem solving enables learners to share knowledge both conceptually and procedurally. Incidentally, learners gain understanding through discussions, and discussions may lead to clarification and elaboration of explanations. It is known that cooperative problem solving produces higher outcomes than individual problem solving. Peers address difficulties as they arise and learners deepen their conceptual understanding due to the discourse (Heller, Keith, & Anderson, 1992). Linguistically and culturally diverse learners have the need to develop a knowledge base just as other learners do to succeed in their futures. Utilizing scaffolding as an approach with these learners increases the success of students with diverse learner backgrounds. Additionally, utilizing guidance with the intervention also increases success of diverse learners (Lee et al., 2006).

Instructional scaffolding assists learners in completing a learning objective or investigation beyond their independent skills (Reiser, 2004; Tabak, 2004). Learners are able to develop skills necessary to accomplish the investigation when scaffolding is embedded in the investigation or activity (Tabak, 2004). Scaffolding assists learners in performing tasks at a higher level (NRC, 2004; Reiser, 2004).

Research indicates that placing support or scaffolding in strategic locations increases performance of learners to a higher level. Scaffolding asks learners to formulate conclusions during particular tasks. Sometimes scaffolding assists learners in utilizing prior knowledge at an increased level of sophistication. Another aspect gives the learners facts, or prompts a learner to make discoveries. Scaffolding enables learners to focus on a main concept because the scaffolding can keep the learner concentrated on the main idea through asking the learner to reflect, formulate conclusions, and interpret data in relationship to a particular pattern or patterns. Crucial information is embedded into the investigation, making the process easier to accomplish along with prompting the learners to stay focused on the main concepts. A graphical organizer is an excellent way to assist learners in finding patterns within their data. Learners can benefit from the instructional framework, which can result in the performance of the task in a more complex way due to the embedding of the scaffolding (Hogan, Natasi, & Pressley, 2000; NRC, 2007; NRC, 2004; Reiser, 2004, Tabak, 2004).

Instructional scaffolding can be slowly decreased or even eventually removed. This process is called “fading.” McNeill, Lizotte, Krajcik, and Marx, (2006) discovered that gradually removing or fading scaffolding from learners during the treatment period enhances performance compared to learners who received scaffolding during the entire time. The learners who received scaffolding that was decreased during the investigations had a better understanding of the concepts investigated. The increased understanding was demonstrated on the posttest.

Computer simulations can have scaffolding embedded into their programming, leading learners into observation of relationships in the data and prompting the formulation of conclusions. Key concepts can be highlighted. Learners can be led down a path without their awareness of the predetermined path. The learners can then build on the background knowledge they acquire along the journey. Scaffolding can provide assistance for learners in formulating an association of related concepts. Through computer simulations visualization assists learners in developing patterns between key concepts, which increases understanding. Guiding learners through a task can also be a form of scaffolding. All of these assist learners in performing at a higher level. Thinkertools®, a computer software program, facilitates learner experimentation through scaffolding of many physics concepts including Newtonian physics (White & Fredericksen, 1998). Visualizations through computer simulations can aid learners in discovering relationships, which guides the learners to an increased understanding of major concepts (NRC, 2004; White, 1993).

Interactive computer simulations have the ability to call attention to important points or concepts, assisting the learners in developing relationships between key concepts. The scaffolding can be placed so learners are prompted to manipulate specific variables or to observe certain patterns (NRC, 2004).

Inquiry-based instruction. Inquiry-based instruction is described by the National Research Council as engaging learners in scientific discovery of data, answering questions through collecting data, formulating explanations from the data collected, and communicating those conclusions (NRC, 2000a, p. 25). Inquiry according to the NRC standard is defined as: Inquiry is a multifaceted activity that involves making observations; posing questions, examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations (NRC, 2000a, pp. 13-14).

Computers can be a good tool for teaching physics. Computer programs have been developed to aid learners in physics understanding. Computer simulations, as discussed here, are interactive programs performed on typical individual computers. Learners are able to predict and then run a simulation. The learners then explain the differences between their prediction and observations. Learners usually believe observations made when viewing computer simulations. Instructional activities present an arrangement that gives the learner a chance to make predictions contradictory to their observations. Learners, who proceed through the computer simulations when presented as tutorial instruction, resolve their conflicts and are likely to change strongly held common-sense beliefs. This procedure assists learners in changing their beliefs. The process, however, cannot guarantee that change in the learner's attitude will occur or that if change does occur that it will be long-lasting (Grayson & McDermott, 1996). Many learners resort back to their strongly held beliefs after many months in the classroom (Maloney, 1984).

There are different levels of inquiry depending on the amount of teacher direction. Inquiry can vary from teacher-directed to learner-directed. Types of inquiry range from open to guided to structured, if the three primary categories are used (see Table 2.4). When inquiry is broken into four categories, coupled inquiry is included (NRC, 2000b; Gengarelly & Abrams, 2009; Hume & Coll, 2010).

Table 2.4

Different Types of Inquiry

Type of inquiry	Teacher	Learner
Structured inquiry	Chooses the topic, the question to investigate, the procedure or series of steps for the learners to follow	Performs the investigation determined by the teacher; formulates a conclusion
Guided inquiry	Chooses the topic, the question to investigate	Designs the procedure; chooses materials to use; displays results
Open inquiry	Chooses the topic	Chooses question(s) related to the teacher's topic; designs the procedure; displays results
Coupled inquiry	Chooses the topic, the question to investigate	May investigate a question that arises during the guided inquiry investigation

In open inquiry, the teacher decides the topic and the learners select the questions to investigate. The learners construct the procedural steps for the investigation and decide how the results will be communicated. In guided inquiry, learners choose the laboratory equipment and may assist in the formation of the procedure for the investigation. The learners formulate a conclusion from the data recorded. In structured inquiry, learners create a conclusion from the data collected by moving through a series of steps in the investigation provided by the teacher. A combination of open and guided inquiry is called coupled inquiry. Learners receive a question to investigate and, as learners' progress through the investigation; they may choose to develop a procedure to investigate a question that arises during the initial investigation (Clough & Clark, 1994).

During an investigation it is important for learners to manipulate one variable at a time. The other factors involved in the investigation are controlled. Through the process of inquiry learners are able to investigate, collect, and record data, then formulate conclusions based on their data and communicate their conclusions (NRC, 2000b).

In this investigation of Newton's Third Law, learners are given questions to answer and are directed in making certain observations that lead to the collection of specific data. The learners are guided through a series of questions in formulating a conceptual understanding of Newton's Third Law. Throughout this process learners are discussing their ideas and observations with their lab partners. Through a series of computer simulations learners will have formulated a conceptual understanding of Newton's Third Law. The computer simulations contain events that challenge common misconceptions.

Learners manipulate variables, making observations which lead to the construction of knowledge. As knowledge level increases, the learners' mental models of concepts are altered. Computer simulations place learners in different situations where the previous knowledge can be applied to a new situation. The questions remain the same for each simulation; therefore learners are manipulating variables, recording their observations, and collecting data that generates new situations (White & Frederiksen, 1998).

Computer simulations with scaffolding built into the investigation and that incorporate inquiry methods of instruction increase learners' conceptual understanding of physics (White & Frederiksen, 1998). Bell, Urhahne, Schanze, & Ploetzner (2010) stated that inquiry practiced in the science classroom is collaborative inquiry learning. Collaborative inquiry learning can have computer support embedded in the inquiry process.

Through the process of inquiry-based questions learners can acquire scientific content and conceptual understanding. When inquiry-based learning occurs in conjunction with manipulating computer simulations, learners gain an increased conceptual understanding through the process of discovery-based learning (NRC, 2000b).

Investigations utilizing inquiry-based questions assist learners in applying their knowledge to other situations. Learners manipulate variables utilizing inquiry-based investigations while visualizing or observing the results. Computer simulations assist learners in formulating patterns and trends from observing the results of manipulating variables (NRC, 2000b).

The constructions of activities intend to engage the learners and so start with no required background knowledge. The learners, working through a series of investigations, self-improve their conceptual understanding (Edelson, Gordon, & Pea, 2004). Each segment of the inquiry learning process builds on information previously learned or revisits the information. The learners are able to make similar observations with the same results. The intent of the procedure is to aid the learners in altering pre-existing misconceptions. Scaffolding placed in significant locations reinforces and assists learners in the construction of correct conceptual understanding (Tuan, Chin, Tsai, & Cheng, 2005; Edelson et al., 2004).

Science inquiry enables learners from diverse backgrounds to engage in science learning (Cuevas, Lee, Hart, & Deaktor, 2005). The definition for inquiry instruction bases itself upon the National Research Council's (2000b) definition of a specific subject matter. The National Research Council (2000b) states that inquiry is where learners are able to apply scientific skills such as observing, predicting, collecting, and assessing data to a particular situation.

The inquiry method incorporates new knowledge into learners' previous knowledge. Using their previous knowledge and incorporating evidence from current observations, the inquiry method enables learners to formulate a conclusion or an explanation. As learners conduct an investigation they collect data, record observations, and manipulate variables. A greater understanding of scientific knowledge develops through the use of making observations and formulating conclusions, along with development of a greater reasoning ability and critical thinking skills. Learners are able to reflect on their observations and patterns in their data to formulate conclusions (NRC, 2000b).

Inquiry requires learners to interconnect scientific knowledge with process skills as they develop their scientific understanding. Learners use critical thinking and reasoning ability to incorporate the new knowledge with their previous understanding. Learners are able to participate in development of their own scientific knowledge and use their observations or evidence to justify their formulated conclusions. Conclusions should include weaknesses and strengths. By reflecting on their conclusions, learners should be able to construct more investigations to support or defend their conclusions or investigate their weaknesses (NRC, 2000b).

Working together as colleagues within and across disciplines and grade levels, educators who use the inquiry method will find it can be used to solve new problems. Scaffolding placed to assist the learners focuses their attention on important information. The learners' progress through the different computer simulations uses fading scaffolding. In fading scaffolding, the scaffolding is slowly removed from the investigation and focusing questions are slowly removed. The learners should be able to make observations and formulate conclusions backed by their observed evidence. Reflecting on their observations and conclusions, learners' understanding of scientific concepts should deepen. As learners develop inquiry skills they should be able to apply the inquiry method to resolve different situations (NRC, 2000b).

Conclusion

The teaching of Newton's Third Law has been previously researched using native English speakers. Corresponding research on English language learners, however, is limited. ELLs face a different set of problems than native English speakers, learning the language along with learning science content. Not only do ELLs have to struggle with conceptual understanding of Newton's Third Law, they struggle with the language barrier. The gap in the research surrounding this population and their encounter with learning Newton's Third Law should be addressed.

An understanding of Newton's laws is fundamental to understanding physics. National and state standards require an understanding of Newton's laws. Newton's Third Law explains the interrelation of forces. Newton's laws are core concepts in science curriculum (NRC, 2008).

All learners naturally face challenges as they attempt to learn Newton's Third Law. Misconceptions have been developed over years of observing real-world situations and attempting to make sense of their observations. Their misconceptions can be partially or completely incorrect. For learners who are not native English speakers or who have experienced varying cultural interpretations, the challenges increase. Not only do these learners need to learn complex scientific concepts but also the language. Conceptual change is difficult for native English speakers, and the difficulty increases for non-native speakers (NRC, 2008). Beyond that, state assessments are given in English.

A suggested instructional intervention design is the use of computer simulations. Computer simulations contain scaffolding which assists learners in focusing their attention on certain variables. The variables are manipulated by the learners themselves. Learners are able to observe patterns and develop a conceptual understanding through the manipulation of the variables. The simulation is able to focus the learners' attention on specific observations and outcomes of their data. This approach assists learners in observing certain patterns in the data. Scaffolding helps learners formulate concepts. Therefore learners are guided down a path in the development of conceptual understanding (NRC, 2008).

An understanding of fundamental physics principles is required of all high school learners in Texas. The state of Texas has stated all high school learners will take physics and pass a state-mandated examination. And yet, previous research is missing in the area of high school English language learners and Newton's Third Law.

A conceptual understanding of introductory physics, at its most basic and more advanced conceptualizations, requires an understanding of Newton's Third Law. This law provides a basic understanding of the constructs of how the world works. For example, in order for a learner to understand the physics of forces a student needs an understanding of Newton's Third Law. All learners face challenges with the application of the law to real-world situations, primarily due to the fact that learners prepossess an array of misconceptions, which often contradict the principles of the law. In addition to the instructional challenges needed to overcome these misconceptions, educators of physics learners who are simultaneously English language learners encounter a unique set of additional challenges in teaching Newton's Third law to these special learners.

In the first section, I discussed two issues: (a) the importance of Newton's Third Law to an understanding of physics concepts, and (b) the policy influencing learners grasping the conceptual understanding of Newton's Third law. Next, I discussed the challenges for all learners and, more specifically, challenges for ELLs. I discussed the use of computer simulations in teaching Newton's Third Law and the literature informing my instructional intervention. In the last section of chapter II is the design element for this instructional intervention.

CHAPTER III

METHODS

In Chapter I, I provided information about the growing population of English language learners (ELLs) in Texas schools today. Chapter II contained a review of research concerning science instruction in American high school and college classrooms, particularly in relation to teaching physics. The literature shows that Newton's Third Law is one of the most difficult concepts for all physics students (Hestenes et al., 1992; Maloney, 1984; Smith & Wittman, 2007). The literature survey also revealed that students' misconceptions derived from their real world observations are in opposition with Newton's Third Law. ELLs in particular struggle with learning abstract concepts in physics while also working with limited English skills.

Critical in the review of research were findings indicating the potential of using computer simulations as an instructional approach for teaching ELLs complex physics concepts. Researchers did express that computer simulations held promise in allowing students to manipulate variables on the computer and develop an understanding of how physical systems work without requiring students to have a mastery of the English language. Currently, however, no studies reported the results of investigations involving the use of computer simulations with ELL physics learners. The results of the literature review grounded my final decisions for the current study investigating the results of two different instructional approaches in developing ELL students' conceptual understanding about Newton's Third Law. Due to the exploratory nature of the research, I chose a quasi-experimental research design using a mixed methods approach to collect and analyze data comparing gains in ELL students' conceptual understanding resulting from their engagement in one of two instructional approaches: traditional instructional hands-on laboratory investigations approach in physics versus the more visual approach of using computer simulations to teach Newton's Third Law. A flow chart displaying the contents of this chapter appears as Figure 3.1.

Rationale

Quasi-Experimental Research Design

This study used a quasi-experimental design, as complete randomization was not feasible. The selected population was all English language learners (ELLs) from a single Texas high school, further reduced due to parental consent. After permission slips were received, each of 44 ELL participants was randomly assigned to one of two experimental treatments. Participants were assigned to learn Newton’s Third Law either by computer simulations or by hands-on laboratory investigations (Campbell & Stanley, 1963).

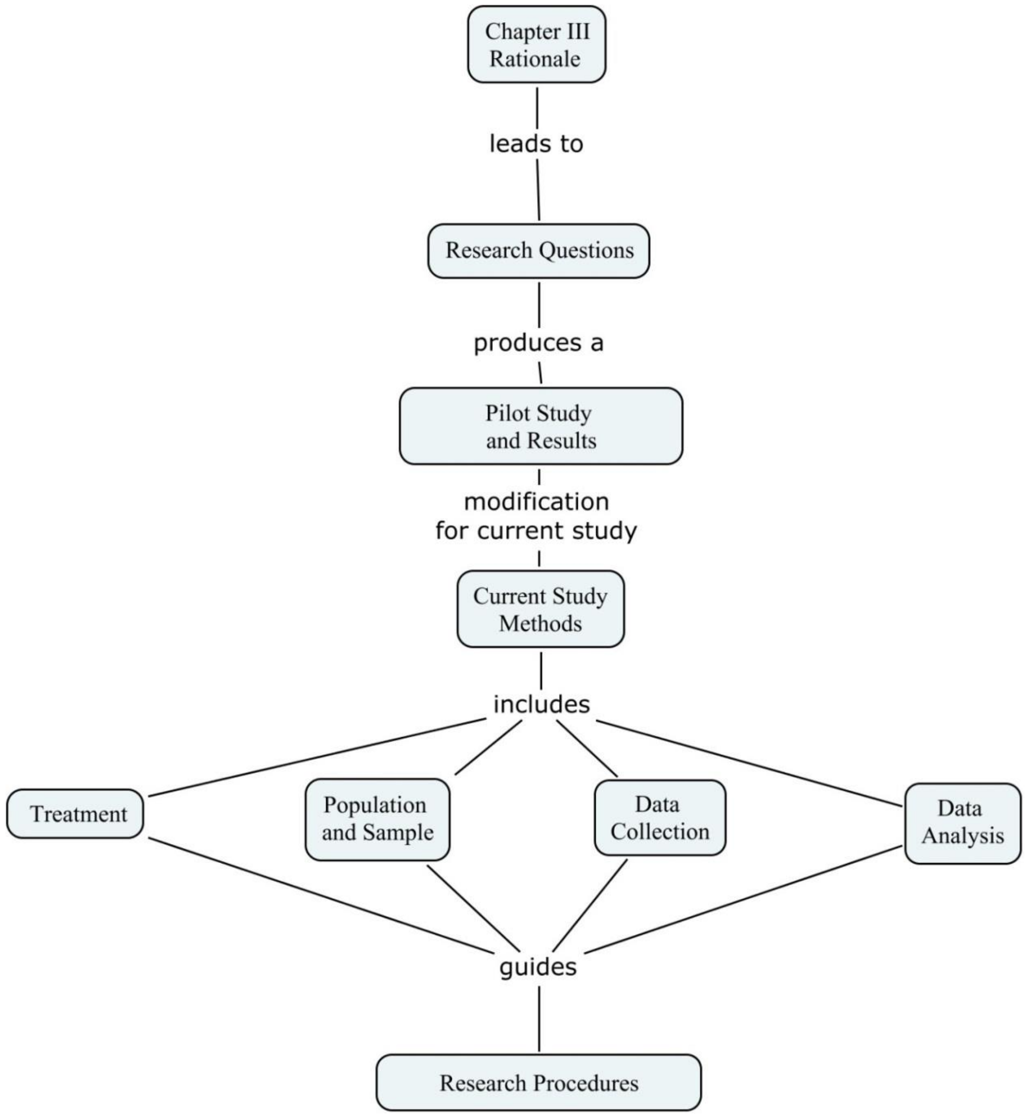

Figure 3.1. Outline for the contents of chapter III, which embeds the discussion of an intensive pilot study and resulting modifications for the current study.

Campbell and Stanley (1966) used a uniform system of notation in representing the design for Alternative Treatment Comparison research studies. See Figure 3.2 for a visual representation of the Alternative Treatment Comparison Design.

Group A (Computer Simulations)	O_1____	X_1____	O_2/O_3 / O_4
Group B (Hands-on Laboratory Investigations)	O_1____	X_2____	O_2/O_3/ O_4

Figure 3.2. Visual representation of the experimental design for this study, resembling Campbell and Stanley's (1966) Alternative Treatment Comparison Design (Quantitative Pre- and Posttest with Qualitative Post-treatment Measures of Conceptual Speech and Writing). The diagram uses the conventional classic notation system after Campbell and Stanley so that $X_{1\ \text{and}}$/ X_2 = exposure of a group to an experimental event or treatment (subscripts represent type of treatment, with; X_1 = computer simulations treatment; X_2 = hands-on laboratory investigations treatment. O_1 / O_2 / O_3 / O_4 = observations or measurements; with O_1 = conceptual understanding pretest; O_2 = conceptual understanding posttest; O_3 = videotapes of conceptual communications during treatment; and/ O_4 = scientific journal entries measuring conceptual understanding.

Mixed Methods Approach

The research design employed a mixed methods approach to collect and analyze the data for the study. Both quantitative and qualitative data were collected and analyzed to answer research questions related to ELL students' conceptual understanding of Newton's Third Law resulting from the two different experimental treatments. As both forms of data were used, the approach qualified as a mixed method study. Data were analyzed within the context of a triangulation mixed methods design (Creswell & Plano-Clark, 1997), as quantitative and qualitative data were complementary to each other and therefore used to assess the degree to which the analyses of data sources "agreed" with each other.

Qualitative data. Two forms of qualitative data were collected for the study: (1) student groups' science journals used to record aspects of their participation in their assigned treatment, and (2) videotaped conversations of students while they were engaged in their assigned treatment. Videotaped conversations were transcribed and analyzed to reveal learners' conceptual understanding while performing either the computer simulations or the hands-on laboratory investigations treatment. Another analysis of the videotapes allowed the calculation of learners' time on task. Student journals, the second form of qualitative data, were analyzed for evidence of students' conceptual understanding.

Quantitative data. Quantitative data were obtained from each student's responses to the same four questions on a pretest and posttest designed to measure students' conceptual understanding of Newton's Third Law. Questions were extracted from the Force Concept Inventory (Hestenes et al., 1992), a well-known physics test measuring conceptual understanding of basic physics concepts.

Merging of data. One strength and benefit of utilizing both qualitative and quantitative data is that one can corroborate the results from one source of data with the results of another form of data (Creswell, 2003; Creswell & Plano Clark, 2007). The merging of qualitative and quantitative data sets occurred to triangulate findings from the analysis and make overall conclusions about changes in conceptual understanding as a result of their participation in one of the two treatments. Qualitative data from the transcriptions of the videotapes and the written records in the learners' student journals were converted to numerical scores, which were then merged with quantitative data gathered from students' pretest and posttest scores on the FCI.

Expectations

My choices of data sources followed the chain of reasoning used in forming expectations for the investigation. In regard to the relationship between ELLs' conceptual conversation and conceptual understanding, I reasoned that ELLs' conceptual understanding (which is usually measured quantitatively) would be enhanced by relevant conceptual conversation (which must be derived from a qualitative data source). As either treatment engaged learners in hands-on laboratory investigations or interacting with computer simulations, I expected that conversations would occur among the group members about Newton's Third Law. Relevant, enriched conversation among group members should increase conceptual understanding.

Figure 3.3 follows this line of reasoning, indicating that the quality of the students' Conceptual Conversation (as captured through video recordings) would enhance ELLs' Conceptual Understanding (as measured by both the FCI and student groups' written records in student journals). In regard to the treatment, I also reasoned that learners' Conceptual Understanding would be greater for those groups engaged in computer simulations than for those groups engaged in the hands-on laboratory investigations.

Research Questions

Three research questions were posed for the research:

1. What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?
2. What are the differences in conceptual conversations between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?
3. What are the differences in conceptual conversations in relationship to their conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?

These research questions guided the choice of instruments and treatments used to answer them, which are summarized in Table 3.1. Questions, instruments, and treatments guided the implementation of a pilot test conducted in the spring of 2011 before the final study in the fall of the same learning?

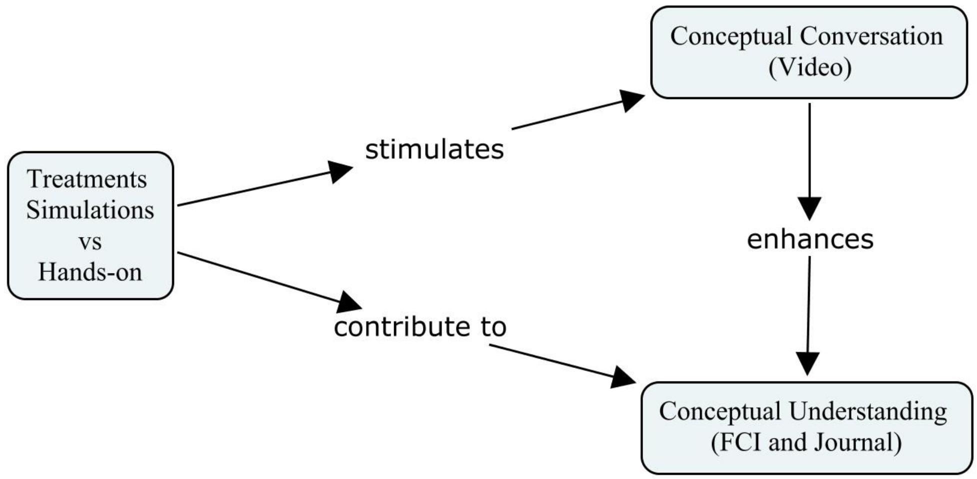

Figure 3.3. Diagram indicating expected results regarding the direct and indirect contributions of Treatment (Computer Simulations vs. Hands-on Laboratory Investigations) to ELLs' Conceptual Conversations and Conceptual Understanding of Newton's Third Law. I expected that groups of ELL students engaged in the Computer Simulations treatment would outperform students engaged in the Hands-on Laboratory Investigations treatment in both Conceptual Conversation and Conceptual Understanding. I further expected that the quality of groups' Conceptual Conversations would contribute to students' overall Conceptual Understanding, with higher levels of students' engagement in Conceptual Conversation showing more improvement in their Conceptual Understanding than students engaged in lower levels of Conceptual Conversation.

Table 3.1

Research Questions with Procedures and Measurement Instrument

Research Questions	Variable & Data Source(s)	Analysis
1. What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?	*Conceptual Understanding* (two measures) (1) Pretest, posttest (Force Concept Inventory, questions 4,15,16,28); and (2) Student Journal (written responses to questions)	(1) (a) Frequency analysis of FCI responses and calculation of score (b) Calculation of % gain in score between pre- and posttest; (2) Content analysis of journal entries to yield a single journal "score"
2. What are the differences in conceptual conversations between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?	*Conceptual Conversation* Video Transcriptions, yielding (1) Keywords, Key Concepts; and (2) Time on Task	(1) Content analysis to yield a single "conversation score;"(2) Count of minutes in conceptual conversation
3. What are the differences in conceptual conversations in relationship to their conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?	*Conceptual Understanding Gain* (1) measured by FCI + Journal Score; and (2) compared with Conversation Score	Results compared and merged to seek patterns in the relationship between Conceptual Understanding and Conversation Score

Data Sources, Methods for Collection and Analysis

Force Concept Inventory

Four FCI questions were used to evaluate learners' preconceptions concerning Newton's Third Law. The FCI questions that pertain to Newton's Third Law are 15, 16, 28 and 4 (see Appendix A). Identical questions were used in the pretest and posttest. Questions 15 and 16 concentrated on the thought that the most active object produces the greatest force. Questions 4 and 28 were concerned with the concept of greater mass means a greater force. Hestenes et al. (1992) labeled each of the FCI answer choices with the applicable misconception commonly held by learners. I used the misconceptions associated with the FCI questions to classify learners' probable misconceptions when examining their test results.

Student Journals

Student journals contained questions for both treatment groups of learners, which were similar, and focused the learners on the basic concepts of the material as it relates to Newton's Third Law. While each student in the pilot study was assigned a journal in which to record findings during the treatment, the protocol was changed for the final investigation to a group journal with a rotating learner-scribe recording the group's observations, data, and answers to discussion questions. Each participant scribed for approximately one-third of the student journal. The student journals contained questions focusing the learners' attention on the magnitude or amount of forces and the direction of the forces. Student journals were labeled by the learners' birthdays and initials.

While student journals were similar for the both treatment groups, some differences also existed. These differences were related to the specific treatment. For example, student journals for the computer simulations groups contained questions pertaining to the manipulation of variables while interacting with computer simulations (see Appendix B). Student journals for the hands-on laboratory investigations groups contained common experiments performed in a physics classroom (see Appendix C).

I used qualitative analysis for data collected in student journals. I designed a rubric to quantify the learners' recordings in the student journals (Lewin & Shoemaker, 1998). As a scoring guideline used to assess learners' work, the rubric was designed to assess students’ understanding that “one object touches another object; the second object touches the first object back with the same amount of force but in the opposite direction” being the ideal. Point values were assigned for correct and complete answers to questions within the journal on a three-point scale. A bottom score of zero was awarded for missed answers. The learners’ recordings in the student journals were coded and analyzed for conceptual understanding. The expectation was that the learners would be able to answer the questions in the student journals correctly after completing either the hands-on laboratory investigations or the computer simulations. Both types of investigations were designed to produce enduring conceptual understanding of Newton’s Third Law.

Videotaped Interactions of Students During Engagement in the Treatment

Videotape transcriptions of learners’ discussions of conceptual understandings were analyzed qualitatively for student groups in both treatments. The videotapes were analyzed for time on task and evidence of conceptual conversation about aspects of Newton's Third Law.

Overall Results and Integration (i.e., Merging Data Sources)

Data sources of students' individual FCI Gain Scores and group Student Journal scores were merged to assess individual students' and treatment groups' overall Conceptual Understanding of Newton's Third Law. The resulting Conceptual Understanding scores for each small group with the two treatments were then compared with the small groups’ Conceptual Conversation score to assess the role of Conceptual Conversation in student groups' overall Conceptual Understanding. By group, the role of treatment in students' Conceptual Understanding was also assessed. Figure 3.4 summarizes both quantitative and qualitative data collection and analysis methods.

Pilot Test Design and Results

I performed a pilot study to inform the final design of the investigation and to perform an initial assessment of the appropriateness of computer simulations as a teaching approach for science learners with limited English language skills. The pilot study focused on times allotted for various research activities, the appropriateness in the design of data collection strategies, and the location in which the investigations would occur. The learners in the pilot study were chosen from classes where teachers spoke only English.

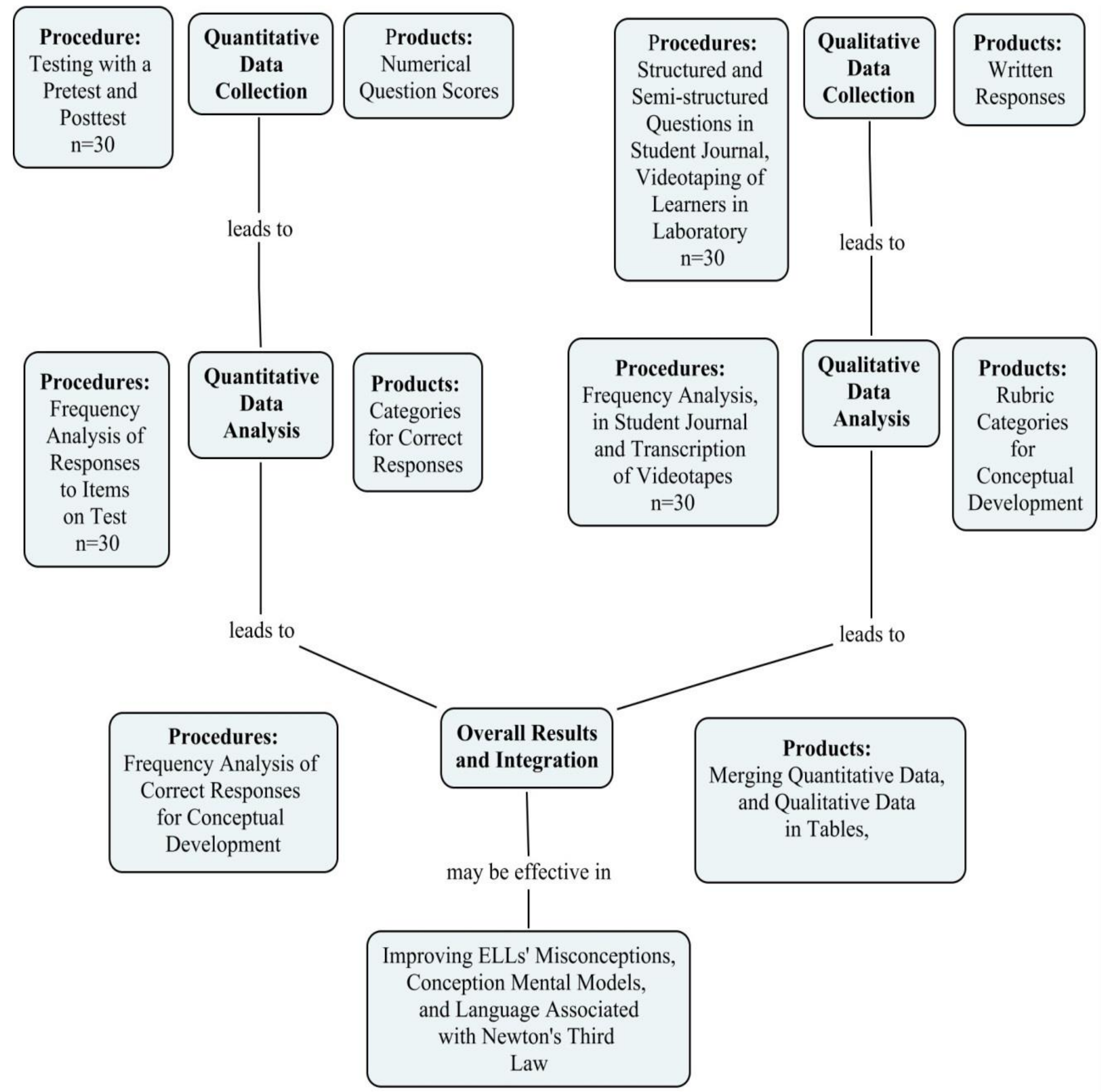

Figure 3.4. Summary of mixed methods data collection and analysis procedures (after Creswell & Clark, 2007) used in the final investigation.

Pilot Participants

Pilot participants were from diverse socioeconomic backgrounds. I received formal approval for students to participate in the pilot project from parents, learners, the high school, the school district, and the Institutional Review Board at Texas A&M University. At the time I conducted the pilot study, 54 ELLs were enrolled in the ESL program in a single school identified as “other central city high school” (neither "urban" nor "rural") by the Texas Education Agency (TEA, retrieved April 19, 2012). The demographics for the learners selected in the project were 86% Hispanic (n=47), 6% Vietnamese (n=3), 4% French (n=2), 2% Thai (n=1), and 2% Mandarin (n=1). Only 22 of the 54 limited-English learners returned the signed parental consent. The demographics for the 22 learners were 82% Hispanic (n=18), 10% Vietnamese (n=2), 5% Thai (n=1), and 5% Mandarin (n=1).

Groups of participants were assigned to one of two treatments. The treatment groups were either computer simulations or hands-on laboratory investigations demonstrating Newton’s Third Law. In the pilot test, students' engagement in the treatment occurred over a period of 3 hours.

Treatments

Both treatment groups were administered pre-tests measuring their conceptual understanding of Newton's Third Law before the assigned treatment began. Students were provided with the option of taking the pretest in their native language or in English. After the pretest, the proctor-teacher began each learning sequence with a discussion of the physics concept of "force." During both treatments, individual students were required to follow procedures and write answers to questions appearing in a "student journal." The journal was designed for two purposes: (1) to be used as a guide to the treatment procedures and (2) to serve as one of the qualitative data sources to assess students' conceptual understanding. At the end of the treatment, students were required to turn in their journals to the proctor-teacher and take a posttest on Newton's Third Law. The posttest contained the same questions as the pretest, and students had the same option of taking the test in their native language or in English.

Findings of the Pilot Study

Force Concept Inventory (FCI). On the FCI, the computer simulations groups outperformed the hands-on laboratory investigations groups on the posttest. Students' scores on each of the four FCI questions appear in Table 3.2. Note, in particular question 28, computer simulations participants chose the wrong answer 100% on the pretest to 55% correct on the posttest whereas the hands-on laboratory investigations participants chose the wrong answer on the pretest 100% and only 36% chose the correct answer on the posttest.

Table 3.2

Pilot Test Results on ELLs' Pre- and Posttest Scores on Four FCI Questions for Computer Simulations Groups and Hands-on Laboratory Investigations Groups

	Computer Simulations (n=11)		
FCI Question	Pretest (%)	Posttest (%)	Total Difference (%)
15	0%	27%	27%
16	10%	27%	17%
28	0%	55%	55%
4	27%	64%	37%
	Hands-on Laboratory Investigations (n=11)		
FCI Question	Pretest (%)	Posttest (%)	Total Difference (%)
15	19%	19%	0%
16	19%	46%	27%
28	0%	36%	36%
4	0%	46%	46%

Of concern to me in the results were that students scored the lowest when answering question 15 and 16. Both computer simulations and hands-on laboratory investigations were designed to correct this misconception. Learners did not finish the packet therefore did not spent an equal amount of time on computer simulations or hands-on laboratory investigations designed to correct misconceptions. Learners also may have been focused on finishing the packet and not on the content. Therefore the learners did not gain the conceptual understanding pertaining to those questions.

Other Pilot Study Findings and Subsequent Modifications for the Research Study

The purpose of performing an extensive pilot study was to strengthen the investigation overall in as many ways as possible. Changes were made for the research study. Results from the pilot study led to the following changes.

Computer simulations groups did not finish the packet. The simulations and questions pertaining to questions 15 and 16 were in the back of the packet. Since it appeared that I presented too many simulations to finish in 3 hours, I decreased the number of simulations pertaining to questions 4 and 28. The participants also missed some variables to manipulate and questions to answer. I had wanted the participants to focus on specific questions and manipulate more variables pertaining to each simulation. The difference between the pretest and the posttest was smaller for questions 15 and 16.

Hands-on Laboratory Investigations groups did not proportionately spend the same amount of time on the hands-on laboratory investigations pertaining to questions 15 and 16 as on questions 4 and 28. To equal out the participants' time for each laboratory exercise, some elements of the hands-on laboratory investigations were deleted from the science journal. The difference between the pretest and posttest for questions 15 and 16 may have been lower due to the participants not finishing the packet.

Other findings from analyzing other data sources in the pilot study led to consequent adjustments of the research procedures and protocol, as summarized below:

1. Learners in the hands-on laboratory investigations treatment did not finish the packet. I therefore reduced the number of laboratory investigations in the laboratory investigations treatment.
2. Learners in the computer simulations treatment did not complete the entire sequence of simulations. I therefore reduced the number of computer simulations in the treatment.
3. Learners in the computer simulations treatment moved to the next computer simulation without manipulating all of the variables or grasping an adequate understanding of the concepts. I therefore increased the amount of time for learners to be engaged in each computer simulation, by pointing out specific variables or asking specific questions with the reasoning that more time should enable learners to manipulate all of the computer simulation variables and formulate better conclusions.
4. Analysis of the transcription of the videotapes revealed that learners' discussions in both treatment groups were limited. I therefore added questions in the student journals in specific areas to increase conceptual discussions.
5. Also as a result of observing that discussions were limited, I decided to allow more time for students to interact with the materials in both treatments to increase conceptual conversation.

6. Analysis of videotapes revealed that both groups were overly focused on writing in their individual student journals. I therefore assigned one student journal to a group of three learners to focus students on the treatment.
7. I also decided to direct learners within a group to rotate the task of recording data in the group's journal in order to increase discussion of group members (Appendices B and C).
8. Learners in both groups participated in their treatments in the school library, where they were easily distracted and did not stay engaged in their treatment groups. I therefore changed rooms from the library to a science classroom for the hands-on laboratory investigations and to a computer room for the computer simulations.

Methods for the Final Investigation

The same high school used in the pilot study was the site for the final investigation. However, none of the ELLs engaged in the pilot study were involved in the final investigation. Similar to the students in the pilot study, the diverse participants in the current study varied in English abilities and economic backgrounds. As in the pilot study, the ELLs were randomly assigned to either of two modalities, which were either computer simulations or hands-on laboratory investigations. The same proctor-teacher was used for each treatment. Similar to the pilot study, Campbell and Stanley's (1966) Alternative Treatment Comparison Design (Quantitative Pre- and Posttest with Qualitative Post-treatment Measures of Conceptual Speech and Writing) was used in the final investigation, and a mixed methods approach was employed to collect, analyze, and merge quantitative and qualitative data. Some procedures were altered as a result of the pilot study, as previously described above. The computer simulations groups were tested in the morning; and the hands-on laboratory investigations groups were tested in the afternoon. Both groups engaged in the treatment for 175 minutes, with quantitative and qualitative data collection and treatment occurring over a period of three days. Approval for the final investigation followed piloted procedures to include approval Institutional Review Board (IRB) of Texas A&M University, ELL learners' parents, the participating ELLs, the high school, and the school district.

Population and Sample

School demographics. The learners who participated in the investigation were from diverse backgrounds and socioeconomic backgrounds. A total of 69 ELLs were enrolled in a single school categorized as an "other central city high school." The breakdown of demographics for the population of ELLs available for the project were: 88% Hispanic (61), 4% Vietnamese (3), 3% French (2), 2% Dutch (1), 2% Russian (1), and 2% Thai (1).

Selection process. A letter of participation including a confidentiality statement for parental consent was sent home with each ELL. Out of the 69 possible participants, 44 returned a participation form signed by the parent. Only learners returning the signed form were selected for participation. Each of the 44 eligible participants also signed a student consent form.

Learners and Group Assignment

The groups were composed of learners which varied in English abilities as well as educational backgrounds. Within treatment groups, learners varied in English abilities as well as educational background. A total of 44 ELLs returned permission slips and were therefore eligible for participation in the study. The breakdowns of demographics for the 44 learners involved in the project were: 89% Hispanic (n=39), 2% Dutch (n= 1), 2% French (n=1), 2% Russian (n=1), 2% Thai (n=1), and 2% Vietnamese (n=1). See Appendix D for the individual TELPAS ratings of the 44 ELLs. See Appendix E and F for the TELPAS ratings of individual ELLs for the two experimental treatments, computer simulations and hands-on laboratory investigations respectfully.

Prior to assignment to groups, administration of the FCI pretest to all 44 ELL students occurred. Learners were then randomly placed into one of the two treatment groups using a random number generator. Within each of the two treatment groups, smaller groups of three students (and one group of four) were randomly selected and randomly assigned to work together.

Attrition of students occurred at various stages in the study, beginning with the first day of the treatment and ending on the third and last day. A total of 30 learners engaged in all aspects of the treatment, unequally distributed so that seven groups of learners engaged in the computer simulations treatment group, while only three groups of learners engaged in the hands-on laboratory investigations treatment group. Table 3.3 summarizes the composition of students in small groups associated with each of the two treatment groups.

Table 3.3

Demographics of Individual ELL Members within Small Groups of Treatment Groups

Groups	Member	Gender	Nationality/Cultural Background	Education Background	TELPAS Rating
		Computer Simulations Treatment (7 groups)			
CS-1	5/7/1994 CR	F	Spanish	12	AH-3.9
	5/23/1994 EH	F	Spanish	12	AH-3.8
	10/13/1994 MJM	F	Spanish	11	A-2.8
CS-2	5/2/1994 JC	M	Spanish	12	AH-3.6
	3/9/1996 AA	M	Spanish	R-9	AH-3.1
	3/5/1995 ML	M	Spanish	R-10	AH-3.6
CS-3	11/24/1995 MS	F	Spanish	10	AH-3.9
	5/30/1997 CH-C	M	Spanish	10	AH-3.6
	10/24/1997 JG	M	Spanish	10	A-2.9
CS-4	5/14/1996 AB	F	Spanish	11	A-2.9
	10/27/1996 AS	F	Spanish	9	AH
	12/30/1995 IR	M	Spanish	10	A-2.9
CS-5	5/20/1994 RR	M	Spanish	11	AH-3.9
	8/21/1994 JR	M	Spanish	10	AH
	12/30/1994 EM	M	Spanish	10	I-2.0
CS-6	4/26/1996 MM	F	Spanish	11	AH-3.9
	6/29/1997 SGR	F	Spanish	10	AH-3.9
	5/19/1994 NR	F	Spanish	12	AH-3.9
CS-7	7/27/1998 MCG	F	Spanish	9	AH
	3/13/1998 QN	F	Vietnamese	9	A

continue

Table 3.3

Continued

Groups	Member	Gender	Nationality/Cultural Background	Education Background	TELPAS Rating
Hands-on Laboratory Investigations Treatment (3 groups)					
H-1	7/23/1996 JC	M	Spanish	11	AH-3.9
	10/5/1995 FZ	F	Spanish	12	B-1.2
	4/12/1997 JH	M	Spanish	10	A-3.0
H-2	12/11/1993 WM	M	Spanish	11	A-2.8
	6/3/1994 AV	M	Spanish	12	AH
	9/16/1996 LZ	M	Spanish	10	A-3.1
H-3	12/19/1995 JD	M	Dutch	11	I
	10/1/1996 AG	F	Russian	11	I
	10/2/1994 IRA	F	Spanish	11	A-3.7
	12/16/1997 MM	M	Spanish	9	I

Procedures

Timeline

Table 3.4 summarizes the research events occurring over the total investigation period of three days. Treatments for the computer simulations small groups occurred in the morning, while treatments for the hands-on laboratory investigations groups occurred in the afternoon of the same day. The first day the pretest was scheduled for a period of 20 minutes, but all learners finished the pretest before the allotted period of time. The treatment was administered to the learners on the second day for a total of 175 minutes, which consisted of an initial discussion of forces by the proctor-teacher for approximately 15 minutes for both treatment groups, with the remainder of the time spent in treatment groups working with either computer simulators or hands-on laboratory investigations equipment. The post test was administered on the third day, which was completed by all students in less than the 20 minutes allotted.

Table 3.4

Plan for Research Events During the Three-Day Investigation Period

		Research Events	
Day	Allotted Period of Time (min.)	Hands-on Laboratory Investigations	Computer Simulations
1	20	Pretest - FCI Demographic Survey	Pretest - FCI Demographic Survey
2	175	Introductory Discussion Treatment Use of Student Journals Videotaped Conversations	Introductory Discussion Treatment Use of Student Journals Videotaped Conversations
3	20	Posttest - FCI	Posttest - FCI

Assurances of Confidentiality

Participants were identified by their birthday and initials for all data collected. The participants wrote their birthdays and initials on their pretest and their posttest. The participants recorded their birthdays and initials on the student journals with identifiable colors of clothing for the transcriptions of the videotapes. The names of the participants are located in a sealed file container.

Establishment of Validity and Reliability of Measures

Random selection increases the internal validity of the experiment by equalizing the participant's differences. Any differences found in the data between the groups should therefore be due to either the participants' interaction with computer simulations or with the hands-on laboratory investigations. The random generator is located at the following website http://randomizer.org/form.htm and was used to place learners in one of the two groups. The FCI assessment was tested for reliability and validity by Hestenes et al., (1992), who cited a reliability estimate greater than 90%.

Summary of Methods

This chapter provides details of the methods employed to compare the conceptual understanding of ELLs engaged in two different instructional treatments. I explain how the results of an extensive pilot study informed the design of the final investigation, which involved the collection, analysis, and merging of both quantitative and qualitative sources of data in an Alternative Treatment Comparison Design (Quantitative Pre- and Posttest with Qualitative Post-treatment Measures of Conceptual Speech and Writing; Campbell & Stanley, 1966). A mixed methods approach triangulating quantitative with qualitative data was employed to strengthen the findings of the research.

CHAPTER IV

DATA ANALYSIS

In the previous chapters, I have written about the increasing number of English language learners in Texas public school systems. In Texas, English is the required language of instruction. Consequently, ELLs often struggle in Texas classrooms. Their difficulties intensify when learners attempt to master complex abstract science concepts. Another problem exists when learners have common misconceptions concerning science concepts. ELLs struggle with learning content and changing misconceptions (Hestenes et al., 1992; Lee, 2005; Maloney, 1984; Smith & Wittman, 2007). I have elected to use a mixed methods approach to investigate the effectiveness of computer simulations in educating ELLs in mastering the abstract science concept of Newton's Third Law. A mixed methods approach uses qualitative and quantitative data to compare learners' use of computer simulations in mastering abstract science concepts against learner's exposure to hands-on laboratory investigations of the same concept.

Research Question 1: What Are the Differences in Conceptual Understanding between Groups of ELLs Who Learn Newton's Third Law by Computer Simulations as Compared with Hands-On Laboratory Learning?

Total Pre- and Posttest Results

Quantitative data analysis describes results in numerical values. In my research I used frequency analysis to describe results from the pretests and posttests for the participants. Participants were randomly divided into small groups. The group interacting with computer simulations answered questions 15, 16, 28, and 4 on both the pretest and posttest from the Force Concept Inventory (FCI). According to the data in Table 4.1, 13 out of 20 computer simulations participants (65%) failed to answer a single pretest question correctly. Conversely, only 5 out of 20 of the same participants (25%) failed to answer a single posttest question correctly. Over half of these participants answered at least one posttest question correctly after having failed to answer at least one pretest question correctly. When looking at the difference column in Table 4.1, 15 out of 20 (75 %) participants answered at least one more question correctly on the posttest than on the pretest. Finally, the percent of correctly answered questions on the pretest was 11% whereas the percent correct on the posttest was 40%, reflecting a difference gain of 29%.

Table 4.2 describes research results from the pretests and posttests for the hands-on laboratory investigations' participants. According to the data in Table 4.2, 7 out of 10 participants (70%) failed to answer a single pretest question correctly. Conversely, only 1 out of 10 of the same participants (10%) failed to answer a single posttest question correctly. This suggests that over half of the participants answered at least one posttest question correctly after having failed to answer at least one pretest question correctly. When looking at the test difference column, Table 4.2, 7 out of 10 participants (70 %) answered at least one more question correctly on the posttest than on the pretest. Finally, the percent of correctly answered questions on the pretest was 10% whereas the percent correct on the posttest was 38% reflecting a difference gain of 28%.

Table 4.1

Number of Correct Answers for the Pretest and Posttest Data Describing Differences in the FCI Scores for 20 ELLs Using Computer Simulations

Groups	Participant	Pretest	Posttest	Difference
CS-1	5/7/1994 CR	0	1	1
	5/23/1994 EH	0	1	1
	10/13/1994 MJM	1	0	-1
CS-2	5/2/1994 JC	2	3	1
	3/9/1996 AA	2	0	-2
	3/5/1995 ML	0	1	1
CS-3	11/24/1995 MS	0	0	0
	5/30/1997 CH-C	0	1	1
	10/24/1997 JG	0	4	4
CS-4	5/14/1996 AB	0	1	1
	10/27/1996 AS	1	0	-1
	12/30/1995 IR	0	0	0
CS-5	5/20/1994 RR	0	2	2
	8/21/1994 JR	1	2	1
	12/30/1994 EM	0	2	2
CS-6	4/26/1996 MM	1	2	1
	6/29/1997 SGR	1	2	1
	5/19/1994 NR	0	2	2
CS-7	7/27/1998 MCG	0	4	4
	3/13/1998 QN	0	4	4
Total (out of 80)		9	32	23
% Correct		11%	40%	29%

Table 4.2

Number of Correct Answers for the Pretest and Posttest Data Describing Differences in the FCI Scores for 10 ELLs Using Hands-on Laboratory Investigations

Groups	Participant	Pretest	Posttest	Difference
H-1	7/23/1996 JC	0	2	2
	10/5/1995 FZ	0	2	2
	4/12/1997 JH	2	1	-1
H-2	12/11/1993 WM	0	1	1
	6/3/1994 AV	1	2	1
	9/16/1996 LZ	0	3	3
H-3	12/19/1995 JD	0	1	1
	10/1/1996 AG	1	1	0
	10/2/1994 IRA	0	2	2
	12/16/1997 MM	0	0	0
Total (out of 40)		4	15	11
% correct		10%	40%	30%

Research Question 1 was "What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" A comparison of Tables 4.1 and 4.2 reveals that the within the computer simulations treatment, Group CS-7 outperformed the other groups. Furthermore, computer simulations Group CS-7 and one participant from computer simulations Group CS-3 moved from choosing misconceptions on the pretest to 100% correct answers on the posttest. Computer simulations Group CS-5 had two participants move from choosing misconceptions on the pretest to choosing 50% correct answers on the posttest. Computer simulations Group CS-6 had one participant move from choosing misconceptions on the pretest and 50% correct answers on the posttest. In contrast, the best performing hands-on laboratory investigations group was Group H-2. In Group H-2, one participant moved from choosing misconceptions on the pretest to 75% correct answers on the posttest. Hands-on laboratory investigations Group H-1 had two participants move from choosing misconceptions on the pretest to 50% correct on the posttest. Hands-on laboratory investigations Group H-3 also had one learner that moved from choosing misconceptions on the pretest and choosing two correct answers (50%) on the posttest. The FCI questions used were number 15, 16, 28 and 4 (Hestenes et al., 1992). The pretest and posttest results for each question are discussed below.

FCI Question 15 Results

Tables 4.3 and 4.4 present the data from question 15 on the FCI. Question 15 (see Appendix A) refers to a large truck that was broken down on the road (see Figure 4.1). The truck was pushed back to town by a compact car, which increased its speed during the trip. The question asks students to select a correct response indicating that the forces are equal and opposite in direction when the car pushed on the truck with the same amount of forces as the truck pushed back on the car. The possible misconceptions for Question 15 were:

- A is the correct answer of the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car
- B is an incorrect answer of a greater mass implies greater force
- C is an incorrect answer of the most active agent produces the greatest force
- D is an incorrect answer of only active agents exert force

- E is an incorrect answer of obstacles exert no force

Figure 4.1. Diagram from question 15 (FCI, 1995).

Table 4.3 summarizes changes in individual learners' responses (misconceptions) on question 15 for computer simulations. A positive change was for learners' responses that were incorrect on the pretest and correct on the posttest. A positive change was displayed by 3 out of the 20 (15%) computer simulations participants. Table 4.3 indicates a negative change for responses that were correct on the pretest and incorrect on the posttest. A negative change was displayed by 2 out of the 20 participants (10%). Finally, Table 4.3 indicates a neutral change for incorrect yet different responses on both the pretest and posttest. The data exhibits that 10 out of the 20 participants (50%) demonstrated a neutral change. One other condition existed. A learner may have chosen the same answer on both the pretest and posttest; such a response was considered no change. Results show 5 learners out of 20 participants (25%) had no change. Only a single computer simulations learner chose the correct answer both on the pretest and the posttest.

Table 4.3

Computer Simulations Participants' Responses for Question 15 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

Groups	Participants	Pretest Responses					Posttest Responses					Change			
		A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
CS-1	5/7/1994 CR		B						C					X	
	5/23/1994 EH			C					C						X
	10/13/1994 MJM		B						C					X	
CS-2	5/2/1994 JC	A					A								X
	3/9/1996 AA	A							C				X		
	3/5/1995 ML			C					C						X
CS-3	11/24/1995 MS		B					B							X
	5/30/1997 CH-C				D				C					X	
	10/24/1997 JG		B				A					X			
CS-4	5/14/1996 AB		B						C					X	
	10/27/1996 AS				D			B						X	
	12/30/1995 IR				D			B						X	
CS-5	5/20/1994 RR			C					C						X
	8/21/1994 JR	A							C				X		
	12/30/1994 EM				D				C					X	

Table 4.3

Continued

Groups	Participants	Pretest Responses					Posttest Responses					Change			
		A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
CS-6	4/26/1996 MM			C				B						X	
	6/29/1997 SGR			C				B						X	
	5/19/1994 NR			C				B						X	
CS-7	7/27/1998 MCG		B				A					X			
	3/13/1998 QN			C			A					X			
Total (out of 20)		3	6	7	4	0	4	6	10	0	0	3	2	10	5
% correct												15%	10%	50%	25%

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

Table 4.4 summarizes changes in individual learners' responses (misconceptions) for the hands-on laboratory investigations participants for question 15. The possible misconceptions for Question 15 were:

- A is the correct answer of the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car
- B is an incorrect answer of a greater mass implies greater force
- C is an incorrect answer of the most active agent produces the greatest force
- D is an incorrect answer of only active agents exert force
- E is an incorrect answer of obstacles exert no force

According to the data in Table 4.4, 9 out of 10 participants (90%) failed to answer a single pretest question correctly. A positive change was displayed by 6 out of 10 participants (60%) on the posttest. A negative change was displayed by 1 out of 10 participants (10%) on the posttest because the participant chose the correct answer on the pretest and a misconception on the posttest. No change was displayed by 3 out of 10 participants (30%).

Comparing differences in treatment groups' responses for Question 15 with regard to Research Question 1, "What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" revealed the hands-on laboratory investigations groups outperformed the computer simulations groups. On the posttest the hands-on laboratory investigations participants corrected their misconceptions and chose the correct answer, i.e., that the force of the car pushing the truck is equal to the force of the truck pushing back on the car. The hands-on laboratory investigations Group H-2 all chose the correct answer on the posttest without choosing the correct answer on the pretest, and two participants from Group H-3 moved from choosing a misconception on the pretest to the correct answer on the posttest.

Table 4.4

Hands-on Laboratory Investigations Participants' Responses for Question 15 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

		Pretest Responses					Posttest Responses					Change			
Groups	Participants	A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	**Neutral	****No
H-1	7/23/1996 JC			C					C						X
	10/5/1995 FZ		B				A					X			
	4/12/1997 JH	A							C				X		
H-2	12/11/1993 WM				D		A					X			
	6/3/1994 AV			C			A					X			
	9/16/1996 LZ			C			A					X			
H-3	12/19/1995 JD		B				A					X			
	10/1/1996 AG			C			A					X			
	10/2/1994 IRA			C					C						X
	12/16/1997 MM				D					D					X
Total (out of 10)		2	2	5	1	0	6	0	3	1	0	6	1	0	3
% Correct												60%	10%	0%	30%

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

The majority of the participants in the hands-on investigations groups chose the "greater mass implies greater force" and "the most active agent exerts the greater force" while one learner chose "only active agents exert force" on the pretest. Computer simulations Group CS-7 corrected their misconceptions and chose the correct answer on the posttest. The learners in computer simulations Group CS-7 chose the misconception of “the greater mass implies greater force” and “the most active agent produces the greatest force” on the pretest. One learner in computer simulations Group CS-3 chose the misconception of “the greater mass implies greater force” on the pretest but corrected his misconception to the forces is equal on the posttest.

FCI Question 16 Results

Tables 4.5 and 4.6 presents the data from Question 16 on the FCI (see Figure 4.2). Question 16 (see Appendix A) presents the scenario of a smaller compact car pushing a larger truck, which had broken down. The difference from question 15 is that the car pushed the truck with a constant cruising speed instead of speeding up (see Figure 4.2). The correct answer was the car pushed on the truck with the same amount of force that the truck pushed on the car.

The possible misconceptions for Question 16 were:

- A is the correct answer of the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car
- B is an incorrect answer of a greater mass implies greater force
- C is an incorrect answer of the most active agent produces the greatest force
- D is an incorrect answer of only active agents exert force
- E is an incorrect answer of obstacles exert no force

Figure 4.2. Diagram from question 16 (FCI, 1995).

According to the data in Table 4.5, 17 out of 20 participants (85%) failed to answer a single pretest question correctly. A positive change was displayed by 14 out of 20 participants (70%) on the posttest, participants choosing a misconception on the pretest to the correct answer on the posttest. A negative change was displayed by 3 out of 20 participants (15%) on the posttest because the participants chose the correct answer on the pretest and a misconception on the posttest. A neutral change was displayed by 2 out of 20 participants (10%) on the pretest and posttest by choosing misconceptions. No change was displayed by 1 out of 20 participants (5%), who chose the same misconceptions on the pretests and posttests.

Table 4.5

Computer Simulations Participants' Responses for Question 16 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

		Pretest Responses					Posttest Responses					Change			
Groups	Participants	A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	**** No
CS-1	5/7/1994 CR			C			A					X			
	5/23/1994 EH		B				A					X			
	10/13/1994 MJM	A								D			X		
CS-2	5/2/1994 JC			C			A					X			
	3/9/1996 AA	A							C				X		
	3/5/1995 ML			C						D				X	
CS-3	11/24/1995 MS			C					C						X
	5/30/1997 CH-C			C			A					X			
	10/24/1997 JG			C			A					X			
CS-4	5/14/1996 AB				D		A					X			
	10/27/1996 AS	A						B					X		
	12/30/1995 IR			C						D				X	
CS-5	5/20/1994 RR		B				A					X			
	8/21/1994 JR				D		A					X			

Table 4.5

Continued

Groups	Participants	Pretest Responses					Posttest Responses					Change			
		A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	**** No
	12/30/1994 EM		B				A					X			
CS-6	4/26/1996 MM		B				A					X			
	6/29/1997 SGR		B				A					X			
	5/19/1994 NR		B				A					X			
CS-7	7/27/1998 MCG		B				A					X			
	3/13/1998 QN			C			A					X			
Total (out of 20)		3	7	8	2	0	14	1	2	3	0	14	3	2	1
% Correct												0.7	0.2	0.1	0.1

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

According to the data in Table 4.6, 7 of 10 participants (70%) failed to answer a single pretest question correctly. The possible misconceptions for Question 16 were:

- A is the correct answer of the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car
- B is an incorrect answer of a greater mass implies greater force
- C is an incorrect answer of the most active agent produces the greatest force
- D is an incorrect answer of only active agents exert force
- E is an incorrect answer of obstacles exert no force

A positive change was displayed by 4 out of 10 participants (40%) on the posttest. A negative change was displayed by 2 out of 10 participants (20%) on the posttest because the participant chose the correct answer on the pretest and a misconception on the posttest. A neutral change was displayed by 2 out of 10 participants (20%) on the pretest and posttest, 1 of those participants chose the correct answer for both of the pretest and posttest. The other participant chose the same misconception. No change was displayed by 2 out of 10 participants (20%).

Comparing differences in treatment groups' responses for Question 16 with regard to Research Question 1, "What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" revealed the computer simulations groups outperformed hands-on laboratory investigations groups. Computer simulations Groups CS-5, CS-6, and CS-7 moved from choosing one of the following misconceptions:
(a) greater mass exerts a greater force, (b) most active agent produces the greater force and (c) only active agents can exert a force on the pretest to choosing the correct answer on the posttest that the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car. Computer simulations Groups CS-1 and CS-3 had two learners move from choosing the misconception "of the most active agent exerts the greatest force" on the pretest to the correct answer of the forces are equal on the posttest out of a group of three participants. Computer simulations Groups CS-2 and CS-4 had only one learner in the group move from the misconceptions of "the

most active agent produces the greatest force” or “only active agents exert forces” to a correct answer on the posttest.

Table 4.6

Hands-on Laboratory Investigations Participants' Responses for Question 16 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

Groups	Participants	Pretest Responses					Posttest Responses					Change			
		A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
H-1	7/23/1996 JC		B				A					X			
	10/5/1995 FZ		B				A					X			
	4/12/1997 JH			C			A					X			
H-2	12/11/1993 WM		B						C					X	
	6/3/1994 AV	A					A								X
	9/16/1996 LZ			C			A					X			
H-3	12/19/1995 JD	A						B					X		
	10/1/1996 AG	A						B					X		
	10/2/1994 IRA				D				C					X	
	12/16/1997 MM				D					D					X
Total (out of 10)		3	3	2	2	0	5	2	2	1	0	4	2	2	2
% Correct												40%	20%	20%	20%

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

All the learners in the hands-on laboratory investigations Group H-1 chose either the misconception of “the greater the mass the greater the force” or “the most active agent produces the greatest force” on the pretest to a correct answer on the posttest, whereas only one learner from the hands-on laboratory investigations Group H-2 moved from the misconception of “the most active agent produces the greatest force” on the pretest to a correct answer on the posttest.

FCI Question 28 Results

Tables 4.7 and 4.8 display the data from Question 28 on the FCI. Question 28 (see Appendix A) presents the scenario of student “a” is sitting in an identical office chair as student “b.” Student “a” is a larger person than student “b.” Student “a” has his knees bent with the bottom of his bare feet placed on the knees of student “b” (see Figure 4.3). Student “a” suddenly pushes with his feet against the knees of student “b” causing both office chairs to move. The correct answer is each student exerts the same amount of force on the other while the feet of student “a” are in contact with the knees of student “b.” The possible misconceptions for Question 28 were:

- A is an incorrect answer of only active agents exert force
- B is an incorrect answer of only active agents exert force
- C is an incorrect answer opposite of D
- D is an incorrect answer of a greater mass implies greater force and the most active agent produces the greatest force
- E is the correct answer of each student exerts the same amount of force on the other.

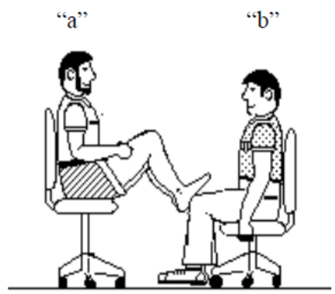

Figure 4.3. Diagram from question 28 (FCI, 1995).

According to the data in Table 4.7, 18 out of 20 participants (90%) failed to answer a single pretest question correctly. A positive change was displayed by 8 out of 20 participants (40%) on the posttest, participants choosing a misconception on the pretest to the correct answer on the posttest. A neutral change was displayed by 7 out of 20 participants (35%) by choosing misconceptions on both the pretest and posttest. No change was displayed by 5 out of 20 participants (25%), 2 of those participants chose the correct answer on both the pretest and posttest. The other three chose the same misconception on the pretest and posttest.

Table 4.7

Computer Simulations Participants' Responses for Question 28 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

	Participants	Pretest Responses					Posttest Responses					Change			
Groups		A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
CS-1	5/7/1994 CR		B							D				X	
	5/23/1994 EH		B							D				X	
	10/13/1994 MJM		B						C					X	
CS-2	5/2/1994 JC					E					E				X
	3/9/1996 AA		B						C					X	
	3/5/1995 ML				D					D					X
CS-3	11/24/1995 MS			C					C						X
	5/30/1997 CH-C		B							D				X	
	10/24/1997 JG	A									E	X			
CS-4	5/14/1996 AB		B							D				X	
	X10/27/1996 AS			C					C						X
	12/30/1995 IR		B						C					X	
CS-5	5/20/1994 RR				D						E	X			
	8/21/1994 JR	A									E	X			
	12/30/1994 EM			C							E	X			
CS-6	4/26/1996 MM		B								E	X			
	6/29/1997 SGR					E					E				X

Table 4.7

Continued

Groups	Participants	Pretest Responses A	B	C	D	E	Posttest Responses A	B	C	D	E	Change *Positive	**Negative	***Neutral	****No
	5/19/1994 NR		B								E	X			
CS-7	7/27/1998 MCG				D						E	X			
	3/13/1998 QN		B								E	X			
Total (out of 20)		2	10	3	3	2	0	0	5	5	10	8	0	7	5
% Correct												40%	0	35%	25%

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

According to the data in Table 4.8, 10 out of 10 participants (100%) failed to answer a single pretest question correctly. The possible misconceptions for Question 28 were:

- A is an incorrect answer of only active agents exert force
- B is an incorrect answer of only active agents exert force
- C is an incorrect answer opposite of D
- D is an incorrect answer of a greater mass implies greater force and the most active agent produces the greatest force
- E is the correct answer of each student exerts the same amount of force on the other.

A positive change was displayed by 3 out of 10 participants (30%) on the posttest. A neutral change was displayed by 6 out of 10 participants (60%) on the posttest. No change was displayed by 1 out of 10 participants (10%).

Table 4.8

Hands-on Laboratory Investigations Participants' Responses for Question 28 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

		Pretest Responses					Posttest Responses					Change			
Groups	Partici-pants	A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
H-1	7/23/1996 JC				D						E	X			
	10/5/1995 FZ		B							D				X	
	4/12/1997 JH				D						E	X			
H-2	12/11/1993 WM	A								D				X	
	6/3/1994 AV				D					D					X
	9/16/1996 LZ		B							D				X	
H-3	12/19/1995 JD				D			B						X	
	10/1/1996 AG				D			B						X	
	10/2/1994 IRA		B								E	X			
	12/16/1997 MM				D				C					X	
Total (out of 10)		1	3	0	6	0	0	2	1	4	3	3	0	6	1
% Correct												30%	0%	60 %	10 %

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

Research Question 1 was, “What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?” Tables 4.7 and 4.8 indicate that computer simulations groups outperformed the hands-on laboratory groups. Computer simulations Groups CS-5 and CS-7 moved from choosing the following misconceptions “only active agents exert a force”, or “the greater the mass implies a greater force” and “the most active agent produces the greatest force” on the pretest to a correct answer of each student exerts the same amount of force on the posttest whereas in the hands-on laboratory investigations three participants moved from the misconceptions of only active agents exert force or the greater mass implies greater force and the most active agent produces the greatest force to the correct answer on the posttest.

FCI Question 4 Results

Tables 4.9 and 4.10 summarizes the data from question 4 on the FCI. Question 4 (see Appendix A) involves a larger truck colliding with a compact car (no information offered on whether or not the compact car was moving). The correct answer is during the collision the truck exerts the same amount of force on the car as the car exerts on the truck. The possible misconceptions for Question 4 were:

- A is an incorrect answer of greater mass implies greater force
- B is an incorrect answer opposite of answer A
- C is an incorrect answer of a greater mass implies greater force and the most active agent produces the greatest force
- D is an incorrect answer of a greater mass implies greater force
- E is the correct answer of the truck exerts the same amount of force on the car as the car exerts on the truck.

According to the data in Table 4.9, 18 out of 20 participants (90%) failed to answer a single pretest question correctly. A positive change was displayed by 4 out of 20 participants (20%) on the posttest. A negative change was exhibited by 1 out of 20 learners (5%). A neutral change was displayed by 11 out of 20 participants (55%) on the pretest and posttest. No change was displayed by 4 out of 20 participants (20%), 1 of those participants chose the correct answer for both of the pretest and posttest. The other three chose the same misconception on both the pretest and posttest.

According to the data in Table 4.10, 9 out of 10 participants (90%) failed to answer a single pretest question correctly. The possible misconceptions for Question 4 were:

- A is an incorrect answer of greater mass implies greater force
- B is an incorrect answer opposite of answer A
- C is an incorrect answer of a greater mass implies greater force and the most active agent produces the greatest force
- D is an incorrect answer of a greater mass implies greater force
- E is the correct answer of the truck exerts the same amount of force on the car as the car exerts on the truck.

Table 4.9

Computer Simulations Participants' Responses for Question 4 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

		Pretest Responses					Posttest Responses					Change			
Groups	Participants	A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
1	5/7/1994 CR	A						B						X	
	5/23/1994 EH	A						B						X	
	10/13/1994 MJM	A								D				X	
2	5/2/1994 JC		B				A							X	
	3/9/1996 AA	A						B						X	
	3/5/1995 ML	A									E	X			
3	11/24/1995 MS			C						D				X	
	5/30/1997 CH-C	A					A								X
	10/24/1997 JG				D						E	X			
4	5/14/1996 AB		B						C					X	
	10/27/1996 AS			C				B						X	
	12/30/1995 IR					E		B					X		
5	5/20/1994 RR		B						C					X	
	8/21/1994 JR				D		A							X	
	12/30/1994 EM		B							D				X	
6	4/26/1996 MM					E					E				X
	6/29/1997 SGR	A					A								X
	5/19/1994 NR	A					A								X

Table 4.9

Continued

Groups	Participants	Pretest Responses A	B	C	D	E	Posttest Responses A	B	C	D	E	Change *Positive	**Negative	***Neutral	****No
7	7/27/1998 MCG			C							E	X			
	3/13/1998 QN			C							E	X			
Total (out of 20)		8	4	4	2	2	5	5	2	3	5	4	1	11	4
% Correct												20%	5%	55%	20%

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

A positive change was displayed by 2 out of 10 participants (20%) on the posttest. A negative change was exhibited by 1 out of 10 learners (10%). A neutral change was displayed by 4 out of 10 participants (40%) on the pretest and posttest. No change was displayed by 3 out of 10 participants (30%).

Research Question 1 was, "What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" Tables 4.9 and 4.10 indicate that computer simulations groups outperformed the hands-on laboratory groups. The misconceptions chosen by the computer simulations learners were that the greater the mass implies greater force and the most active agent produces the greatest force. One learner in Group CS-2, one learner in Group CS-3 and all the learners in Group CS-7 of the computer simulations participants moved from misconceptions to the correct answer. Hands-on laboratory investigations groups H-2 and H-3 each had one learner move from the misconceptions of the greater the mass implies the greater force and the most active agent produces the greater force on the pretest to the correct answer on the posttest.

Table 4.10

Hands-on Laboratory Investigations Participants' Responses for Question 4 Describing Differences in the Misconception Scores for the Pretest and Posttest Data

Groups	Participants	Pretest Responses					Posttest Responses					Change			
		A	B	C	D	E	A	B	C	D	E	*Positive	**Negative	***Neutral	****No
H-1	7/23/1996 JC	A					A								X
	10/5/1995 FZ				D		A							X	
	4/12/1997 JH					E	A						X		
H-2	12/11/1993 WM			C					C						X
	6/3/1994 AV		B				A							X	
	9/16/1996 LZ			C							E	X			
H-3	12/19/1995 JD		B				A							X	
	10/1/1996 AG	A					A								X
	10/2/1994 IRA	A									E	X			
	12/16/1997 MM			C						D				X	
Total (out of 10)		3	2	3	1	1	6	0	1	1	2	2	1	4	3
% Correct												20%	10%	40%	30%

*Positive = wrong answer to right answer; **Negative = right answer to wrong answer; ***Neutral = misconception to misconception; ****No Change = same answer on both pre- and posttest

Conclusion

Table 4.11 Summarizes noteworthy findings regarding Question 1.

Table 4.11

Summary Table: Noteworthy Findings

Research Question	Criteria	Computer Simulations	Hands-on Laboratory Investigations	Comparison
What are the differences in conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?	Pretest Posttest Difference	CS-7 – increase of 100% on posttest; CS-3 and CS-5 – increase of 42% on posttest	H-2 – increase of 42% on posttest; H-1 increase of 33% on posttest	Computer simulations – 3 participants moved from 0% on pretest to 100% correct answers on posttest Hands-on Laboratory Investigations – 1 participant moved from 0% on pretest to 75% correct answers on posttest

In conclusion, 3 of the 20 participants (15%) interacting with computer simulations improved by choosing the correct answer on all four FCI questions; whereas none of the participants interacting with the hands-on laboratory investigations chose all four correct answers on the posttest. The participants interacting with the hands-on laboratory investigations only had one participant chose three out of the four questions correctly. The participants interacting with computer simulations and the participants interacting with hands-on laboratory investigations both had three participants chose two correct answers on the posttest.

Research Question 2: What Are the Differences in Conceptual Conversations between Groups of ELLs Who Learn Newton's Third Law by Computer Simulations as Compared with Hands-On Laboratory Learning?

Total Student Journals and Videotaped Recordings Results

Qualitative data are measures of descriptions or categories, or data which can be captured through observation (Creswell & Plano Clark, 2007). The qualitative data in this study were (a) student journals where one participant in each group recorded their observations during the manipulation of variables while interacting with the computer simulations or the hands-on laboratory investigations, and (b) videotaped recordings of activities and conversations while participants interacted with the computer simulations or the hands-on laboratory investigations.

In the journals, the learners also answered specific questions. These questions were designed to assist the learners in focusing on particular observations (see Appendices B and C). One form of qualitative data in this study comes from the investigator observing videotapes which contain discussions of the participants in their experimental groups for either the computer simulations or hands-on laboratory investigations. Appendix G displays the rubric used to quantify the data from the student journals and from observation of the videotapes for the participants manipulating variables while interacting with computer simulations. Appendix H shows the rubric used to quantify the data from the student journals and from observation of the videotapes for the participants interacting with hands-on laboratory investigations.

Table 4.12 displays the quantified data from the student journals concerning the participants' conceptual understanding and the transcriptions from the videotapes concerning the participants' conceptual conversation. Groups CS-4, CS-5, and CS-7 did not complete their student journals; therefore their total accumulated scores are low. Groups CS-4, CS-5, and CS-7 earned less than one-third of the total 99 points available. Group CS-5 is the lowest with 18 points out of 99 (18%). Groups CS-2 and CS-3 have the greatest number of points earned at 79 (80%) and 71 (72%), respectively. The points were earned from recording data and answering questions in their student journals along with their conceptual conversation during the interactions with computer simulations.

The participants in the hands-on laboratory investigations were placed in groups of three with one group of four. Each group had one student journal to record their observations and answer questions pertaining to Newton's Third Law. Table 4.13 displays the quantified data from observing the videotapes and the learners' entries in their student journals. All three hands-on laboratory investigations groups recorded over 80% of the possible questions. Group H-1 earned the least points with 79 out of 99 (80%). Group H-2 earned 87 points out of 99 (88%) points available. Group H-3 earned 93 points out of 99 (94%) available. One learner in the group did the majority of the discussion and recording entries into the student journal concerning the hands-on laboratory investigations. The hands-on laboratory investigations groups outperformed the computer simulations groups.

Table 4.12

Computer Simulations Qualitative Data Quantified from Student Journals and Dialogue from Videotapes Used to Describe Learners' Conceptual Development of Newton's Third Law for the ELLs

		Groups						
Computer Simulations		CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7
Fireman and Door								
a.	Answered all the questions	2	3	2	2	1	3	1
b.	Magnitude of forces	1	3	3	1	1	3	1
c.	Direction of forces	1	3	3	1	1	3	1
d.	Action reaction statements	0	3	3	0	0	3	0
e.	Discussed concepts	1	2	2	0	0	1	0
Impulse and Newton's Third Law								
a.	Answered all the questions	3	2	3	2	2	3	2
b.	Magnitude of forces	3	3	3	3	3	3	3
c.	Direction of forces	3	3	3	3	3	3	3
d.	Action reaction statements	3	3	3	1	3	3	1
e.	Discussed concepts	0	2	2	1	2	2	1
Man Pushing a Filing Cabinet								
	Answered all the questions	2	2	2	1	1	3	1
	Magnitude of forces	3	3	3	0	0	2	0
	Direction of forces	3	3	3	3	0	3	3
	Forces cancel	0	3	0	0	0	3	0
	Action reaction statements	3	3	3	0	1	3	0
	Discussed concepts	0	2	2	0	0	1	0
Predictions								
a.	Discussed concepts	0	0	0	0	0	0	0

Table 4.12

Continued

Computer Simulations		Groups CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7
Gravity Force Lab								
a.	Answered all the questions	3	3	2	0	0	2	0
b.	Magnitude of forces	3	2	3	0	0	1	0
c.	Direction of forces	3	3	3	0	0	3	0
d.	Action reaction statements	3	3	3	0	0	3	0
e.	Discussed concepts	0	2	1	0	0	1	0
Prediction - Soccer								
a.	Discussed concepts	0	0	0	0	0	0	0
Prediction - Collisions								
a.	Action reaction statements	1	3	3	0	0	3	0
b.	Discussed concepts	0	0	0	0	0	0	0
Prediction - Man Pushing a Filing cabinet								
a.	Prediction answered correctly	1	3	3	0	0	0	0
b.	Action reaction statements	3	3	3	3	0	3	0
c.	Discussed concepts	0	0	0	0	0	0	0
Car and Truck								
a.	Answered all the questions	3	3	3	0	0	1	0
b.	Magnitude of forces	2	3	1	0	0	3	0
c.	Direction of forces	3	3	2	0	0	0	0
d.	Action reaction statements	3	3	3	0	0	0	0
e.	Discussed concepts	0	2	1	0	0	0	0
Total		56	79	71	21	18	62	17

Table 4.13

Hands-on Laboratory Investigations Qualitative Data Quantified from Student Journals and Dialogue from Videotapes Used to Describe Learner's Conceptual Development of Newton's Third Law for ELLs

Hands-on Laboratory Investigations	Groups H-1	H-2	H-3
Rubber Bands			
a. Answered all the questions	3	3	3
b. Magnitude of forces	3	3	3
c. Direction of forces	3	3	3
d. Action reaction statements	3	3	3
e. Discussed concepts	2	2	3
Rubber Band and Spring Scale			
a. Answered all the questions	3	3	3
b. Magnitude of forces	3	3	3
c. Direction of forces	3	3	3
d. Action reaction statements	3	3	3
e. Discussed concepts	1	2	3
Predictions			
a. Discussed concepts	2	2	2
Spring Scales			
a. Answered all the questions	3	3	3
b. Magnitude of forces	3	3	3
c. Direction of forces	3	3	3
d. Forces Canceling	3	3	0
e. Action reaction statements	3	3	3
f. Discussed concepts	2	2	3

Table 4.13

Continued

Hands-on Laboratory Investigations		Groups		
		H-1	H-2	H-3
Spring Scales and Rope				
a.	Answered all the questions	3	3	3
b.	Magnitude of forces	3	3	3
c.	Direction of forces	3	3	3
d.	Action reaction statements	3	3	3
e.	Discussed concepts	1	1	3
Predictions – Add Third Spring				
a.	Discussed concepts	2	2	1
Predictions – Spring Scale and Table				
a.	Prediction answered correctly	0	2	3
b.	Discussed concepts	2	2	3
Predictions – Soccer				
a.	Prediction answered correctly	3	3	3
b.	Action reaction statements	3	3	3
c.	Discussed concepts	0	1	3
Balloon Laboratory Activity				
a.	Answered all the questions	2	3	3
b.	Magnitude of forces	1	3	3
c.	Direction of forces	3	3	3
d.	Action reaction statements	3	3	3
e.	Discussed concepts	1	2	3
Total		79	87	93

Table 4.14 displays the data from the entries in the student journals from the computer simulations groups. The points were earned from recording data and answering questions. The student journals were designed to focus participants' attention on specific observations and to assist the learners in gaining conceptual understanding. Three of the computer simulations groups choose to leave the majority of possible entries blank, earning 16 points (22%), 16 points (22%), and 20 points (28%). The other four groups' scores ranged from 55 points (76%) to 69 points (89%) out of a possible 72 points.

Table 4.14

Computer Simulations Qualitative Data Quantified from Student Journals Used to Describe Learner's Conceptual Development of Newton's Third Law for ELLs

	Groups						
Computer Simulations	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7
Fireman and Door							
a. Answered all the questions	2	3	2	2	1	3	1
b. Magnitude of forces	1	3	3	1	1	3	1
c. Direction of forces	1	3	3	1	1	3	1
d. Action reaction statements	0	3	3	0	0	3	0
Impulse and Newton's Third Law							
a. Answered all the questions	3	2	3	2	2	3	2
b. Magnitude of forces	3	3	3	3	3	3	3
c. Direction of forces	3	3	3	3	3	3	3
d. Action reaction statements	3	3	3	1	3	3	1

Table 4.14

Continued

Computer Simulations		Groups						
		CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7
Man Pushing a Filing Cabinet								
a.	Answered all the questions	2	2	2	1	1	3	1
b.	Magnitude of forces	3	3	3	0	0	2	0
Man Pushing a Filing Cabinet								
c.	Direction of forces	3	3	3	3	0	3	3
d.	Forces cancel	0	3	0	0	0	3	0
e.	Action reaction statement	3	3	3	0	1	3	0
Gravity Force Lab								
a.	Answered all the questions	3	3	2	0	0	2	0
b.	Magnitude of forces	3	2	3	0	0	1	0
c.	Direction of forces	3	3	3	0	0	3	0
d.	Action reaction statements	3	3	3	0	0	3	0
Predictions - Collisions								
a.	Action reaction statements	1	3	3	0	0	3	0
Predictions – Man Pushing a Filing Cabinet								
a.	Prediction answered correctly	1	3	3	0	0	0	0
b.	Action reaction statements	3	3	3	3	0	3	0
Car and Truck Computer Simulation								
a.	Answered all the questions	3	3	3	0	0	1	0
b.	Magnitude of forces	2	3	1	0	0	3	0
c.	Direction of forces	3	3	2	0	0	0	0
d.	Action reaction statements	3	3	3	0	0	0	0
Total		55	69	63	20	16	57	16

Table 4.15 displays the data from the entries in the student journals from the hands-on laboratory investigations groups. The points were earned from recording data and answering questions. The hands-on laboratory investigations groups outperformed the computer simulations groups. All three groups recorded over 90% of the possible entries. The three groups' scores were 66 points (92%), 71 points (99%), and 69 points (96%) respectively.

Table 4.15

Hands-on Laboratory Investigations Qualitative Data Quantified from Student Journals Used to Describe Learner's Conceptual Development of Newton's Third Law for ELLs

	Groups		
Hands-on Laboratory Investigations	H-1	H-2	H-3
Rubber Bands			
a. Answered all the questions	3	3	3
b. Direction of forces	3	3	3
c. Magnitude of forces	3	3	3
d. Action reaction statements	3	3	3
Rubber Band and Spring Scale			
a. Answered all the questions	3	3	3
b. Magnitude of forces	3	3	3
c. Direction of forces	3	3	3
d. Action reaction statement	3	3	3

Table 4.15

Continued

Hands-on Laboratory Investigations	Groups H-1	H-2	H-3
Spring Scales			
a. Answered all the questions	3	3	3
b. Magnitude of forces	3	3	3
c. Direction of forces	3	3	3
d. Forces canceling	3	3	0
e. Action reaction statement	3	3	3
Spring Scales and Rope			
a. Answered all the questions	3	3	3
b. Magnitude of forces	3	3	3
c. Direction of forces	3	3	3
d. Action reaction statement	3	3	3
Predictions – Spring Scale and Table			
a. Prediction answered correctly	0	2	3
Predictions - Soccer			
a. Prediction answered correctly	3	3	3
b. Action reaction statement	3	3	3
Balloon Laboratory Activity			
a. Answered all the questions	2	3	3
b. Magnitude of forces	1	3	3
c. Direction of forces	3	3	3
d. Action reaction statements	3	3	3
Total	66	71	69

Table 4.16 displays the quantified data from the transcriptions of the videotapes from the learners' dialogue while interacting with computer simulations. Groups CS-1, CS-4, and CS-7 did not communicate as an engaging body of learners trying to solve a problem. Group CS-3 discussed conceptual understanding of Newton's Third Law the most but still the discussion was only 8 out of a total of 27 points (30%). Group CS-2 earned the most points with 10 out of 27 points earned (37%). This was due to the group discussing Newton's Third Law only when the instructor was present.

Table 4.17 displays the quantified data from the transcriptions of the videotapes from the learners' dialogue while interacting with hands-on laboratory investigations. Groups H-1 and H-2 communicated as an engaging body of learners approximately 50% and 60% of the time, respectively. One learner in Group H-3 led the majority of the discussion.

Table 4.16

Computer Simulations Qualitative Data Quantified from the Dialogue from Transcriptions of Videotapes Used to Describe the Learner's Conceptual Development of Newton's Third Law for ELLs

	Groups						
Computer Simulations	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7
Fireman and Door							
Discussed concepts	1	2	2	0	0	1	0
Impulse and Newton's Third Law							
Discussed concepts	0	2	2	1	2	2	1
Man Pushing a Filing cabinet							
Discussed concepts	0	2	2	0	0	1	0
Predictions							
Discussed concepts	0	0	0	0	0	0	0
Gravity Force Lab							
Discussed concepts	0	2	1	0	0	1	0
Predictions - Soccer							
Discussed concepts	0	0	0	0	0	0	0
Predictions - Collisions							
Discussed concepts	0	0	0	0	0	0	0
Predictions – Man Pushing a Filing Cabinet							
Discussed concepts	0	0	0	0	0	0	0
Car and Truck							
Discussed concepts	0	2	1	0	0	0	0
Total	1	10	8	1	2	5	1

Table 4.17

Hands-on Laboratory Investigations Qualitative Data Quantified from the Dialogue from Transcriptions of Videotapes Used to Describe the Learner's Conceptual Development of Newton's Third Law for ELLs

	Groups		
Hands-on Laboratory Investigations	H-1	H-2	H-3
Rubber Bands			
Discussed concepts	2	2	3
Rubber Band and Spring Scale			
Discussed concepts	1	2	3
Predictions			
Discussed concepts	2	2	2
Spring Scales			
Discussed concepts	2	2	3
Spring Scales and Rope			
Discussed concepts	1	1	3
Predictions – Add Third Spring			
Discussed concepts	2	2	1
Predictions – Spring Scale and Table			
Discussed concepts	2	2	3
Predictions - Soccer			
Discussed concepts	0	1	3
Balloon Laboratory Activity			
Discussed concepts	1	2	3
Total	13	16	24

Research Question 2 is "What are the differences in conceptual conversations between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" Comparing Table 4.16 and Table 4.17 Group H-3 of the hands-on laboratory investigations outperformed the computer simulations groups. Group H-3 was engaged in discussing the hands-on laboratory investigations but did not discuss the questions pertaining to making predictions. The computer simulations groups did very little discussion while manipulating the variables of the computer simulations. The computer simulations groups also did not discuss the prediction questions.

Summary

Research Question 2 is "What are the differences in conceptual conversations between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" Table 4.18 displays data comparing the computer simulations groups with the hands-on laboratory investigations groups in recording data and answering questions in the student journal along with the transcriptions of the videotapes containing the group's discussions. Computer simulations Group CS-2 and computer simulations Group CS-3 documented their student journals approximately 90% of the data observed and questions to answer, whereas their discussions while interacting with the computer simulations were 37% and 25%, respectively. All of the hands-on laboratory investigations groups documented in their student journals over 90%.

Table 4.18

Qualitative Data and the Quantitative Data by Percentage Comparing the Difference Between Student Journals, and Dialogue from Videotapes to Describe the Learner's Conceptual Development of Newton's Third Law for ELLs

		Computer Simulations Groups							Hands-on Laboratory Investigations Groups		
Category	Total points	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	H-1	H-2	H-3
Student Journal	72	76%	89%	88%	28%	22%	79%	22%	92%	99%	96%
Discussion	27	4%	37%	25%	4%	7%	19%	4%	48%	59%	89%
Engagement in Treatment via Video Observations		No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes

Some patterns are observed in the comparison of the two conditions. The hands-on laboratory investigations groups outperformed the computer simulations groups with journal entries and dialogue. Hands-on laboratory investigations groups' percent correct was 96% on journal entries compared to computer simulations groups' percent correct was 58%. Discussion for the hands-on laboratory investigations groups averaged 65% whereas computer simulations average was less than 20%.

Research Question 3. What Are the Differences in Conceptual Conversations in Relationship to Their Conceptual Understanding between Groups of ELLs Who Learn Newton's Third Law by Computer Simulations as Compared with Hands-On Laboratory Investigations Learning?

Total Results Merged

Figure 4.4 shows a diagram of the merged data sets. The quantitative data are represented as the differences between the number of correct answers chosen by the learner in the pretest compared to the number of correct answers chosen in the posttest. The qualitative data are displayed in the recordings of the learner's student journal and in the discussions between participants in the group.

The computer simulations groups' FCI scores ranged from 8% to 100%. Student journal recordings ranged from 22% to 89%, whereas the discussions ranged from 4% to 37%. Four groups discussed less than 10%. Group CS-1, CS-2, and CS-4 scores on the FCI were less than 35%. Group CS-5 was composed of one learner engaged in the computer simulations while two learners were conversing about life.

Hands-on laboratory investigations groups' FCI scores ranged from 25% to 50%. Student journal recordings ranged from 92% to 99%, whereas the discussions ranged from 48% to 89%. One learner in Group H-3 dominated the discussions. Hands-on laboratory investigations groups spent more time discussing equipment set-up, collecting data, and recording data than discussing predictions and summary types of questions. Engagement with laboratory equipment was a catalyst for more discussion.

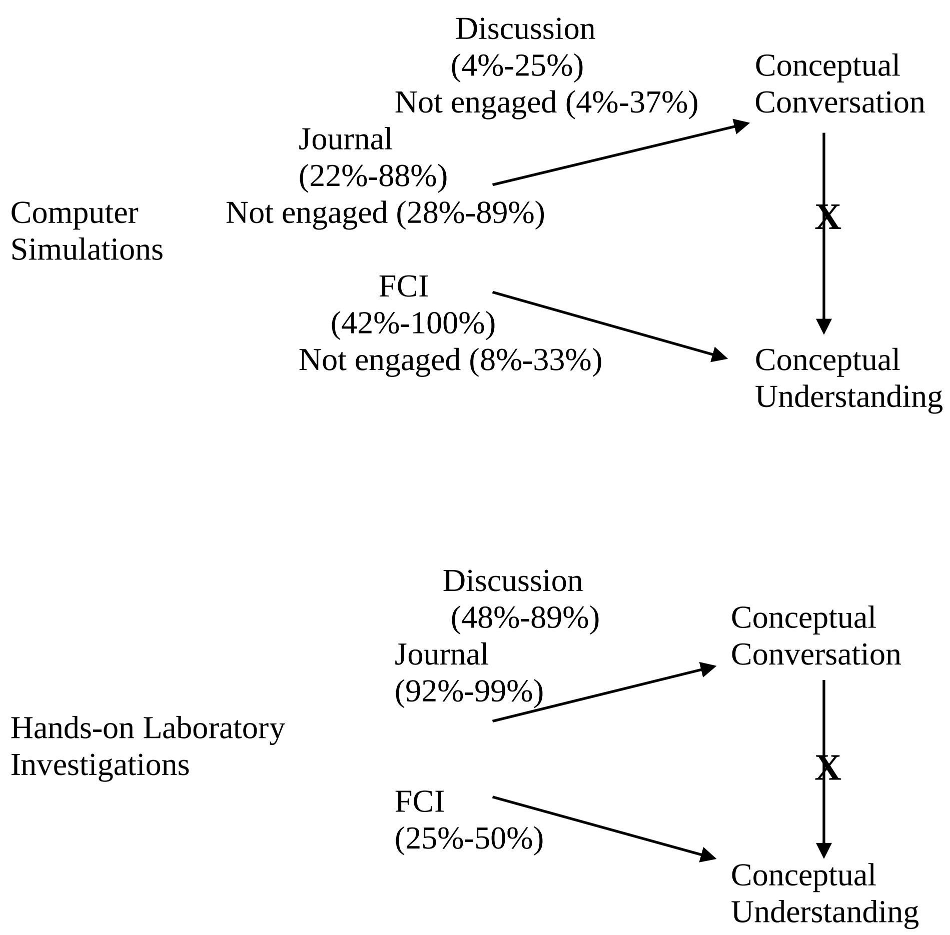

Figure 4.4. Summary of quantitative and qualitative data

Table 4.19

Qualitative Data and the Quantitative Data by Percentage Comparing the Difference Between the Pretest and the Posttest, Student Journals, and Dialogue from Videotapes To Describe the Learner's Conceptual Development of Newton's Third Law for ELLs

	Quantitative Data (FCI)	Qualitative Data	(Conceptual Conversation)
Groups	Gain Score (%)	Student Journal Entries Completed (%)	Discussion % Time Talking About Newton's Third Law
	Computer Simulations Groups		
*CS-1	17%	76%	4%
*CS-2	33%	89%	37%
CS-3	42%	88%	25%
*CS-4	8%	28%	4%
CS-5	50%	22%	7%
CS-6	50%	79%	19%
CS-7	100%	22%	4%
Range	8% to 100%	22% to 89%	4% to 37%
	Quantitative Data	Qualitative Data	
Groups	Gain Score (%)	Student Journal Entries Completed (%)	Discussion % Time Discussing Newton's Third Law
	Hands-on Laboratory Investigations Groups		
H-1	42%	92%	48%
H-2	50%	99%	59%
H-3	25%	96%	89%
Range	25% to 50%	92% to 99%	48% to 89%

* Not engaged

For example, some noteworthy group differences were observed in the data. Group CS-7 interacting with computer simulations outperformed all the other groups by answering all of the posttest questions correctly. In the videotape, Group CS-7 was engaged in manipulating the variables in the computer simulations, with very little discussion. They observed the results from actively manipulating variables in the simulations. In the journal, I observed very few answers were recorded in Group CS-7's student journal. However, computer simulations Group CS-7 moved from 0% on the pretest to 100% on the posttest. Table 4.19 displays merged data sets.

Summary

Research Question 3 is "What are the differences in conceptual conversations in relationship to their conceptual understanding between groups of ELLs who learn Newton's Third Law by computer simulations as compared with hands-on laboratory learning?" Table 4.19 displays data comparing the computer simulations groups with the hands-on laboratory investigations groups in the data from the posttest, the entries in the student journal, and the dialogue concerning Newton's Third Law. The computer simulations groups actively involved outperformed the hands-on laboratory investigations groups in the conceptual development displayed through the posttest answers. The hands-on laboratory investigation groups outperformed the computer simulations groups in entries in the student journal and dialogue concerning Newton's Third Law.

Three research questions guided data analysis for this investigation. Results of the analysis for Question 1 indicated that three learners in the computer simulations Groups CS-5 and CS-7 earned a 100% on the posttest. The highest hands-on laboratory investigations were one learner with 75%. Question 2 involved an analysis looking at conceptual conversation as reflected in videotapes and journal entries requiring conversation for agreement and responses to journal questions. Hands-on laboratory investigations groups outperformed the computer simulations groups in journal entries and conceptual conversation on videotapes. In response to Question 3, analysis revealed no patterns indicating that higher gains in FCI scores were associated with evidence of conceptual conversation. Figure 4.4 shows a comparison of the data. While patterns are not apparent, individual learners and group differences and levels of interactions with others and with the equipment can shed light on reasons for the lack of correspondence in posttest performance and conceptual conversation. These will be explained in Chapter V.

CHAPTER V

CONCLUSIONS, INTERPRETATIONS, AND RECOMMENDATIONS

Chapter I established the severity of the problem for learners and physics teachers as it relates to the highly abstract nature of Newton's Third Law. Chapter II contains the literature review which discussed the importance of Newton's Third Law in developing a conceptual understanding of physics. The literature review supports the effectiveness of computer simulations in teaching science content. Further, the review details the advantages of the guided inquiry approach for teaching science. Chapter III states the three research questions of this study, and the methods used to collect and analyze the data. Chapter IV presented the data acquired using both quantitative and qualitative approaches. The quantitative data were collected using questions from the Force Concept Inventory (Hestenes et al., 1992). The qualitative data were obtained from entries in the students' journals and videotapes of learner interactions. A mixed methods approach was used to integrate the results from both quantitative and qualitative data to compare and contrast computer simulations with traditional hands-on laboratory activities in mastering abstract science concepts.

This final chapter presents my interpretations and conclusions to the mixed methods study investigating the use of simulations to assist ELLs in grasping difficult concepts such as Newton's Third Law. Chapter V is composed of two sections (see Figure 5.1). In the first section, I present a summary of the problem and interpretation of the results pertaining to the three research questions. In the second section, I present applications of the results in three areas: (a) implications for further study, (b) implications for classroom practices, and (c) conclusions which may be effective in improving ELLs' accurate conceptions, mental models, and language associated with Newton's Third Law. All results and conclusions correspond to ELLs' mastering of the abstract science concept of Newton's Third Law.

Summary of the Problem

In this investigation, computer simulation technology was the tested intervention as compared with hands-on laboratory investigations. ELLs interacted with limited simulations under supervised classroom conditions. The study was designed to develop a conceptual understanding of Newton's Third Law, and alter existing misconceptions. Support from the literature included research by Christian and Belloni (2004), who found that simulations can change the misconceptions of English-speaking physics learners through interacting with simulations; Leonard, Dufresne, and Mestre (1996), who noted the importance of active involvement such as manipulating variables on computers when constructing conceptual knowledge; and de Jong et al. (1999), who found that simulations increase learning through engagement and manipulation of variables.

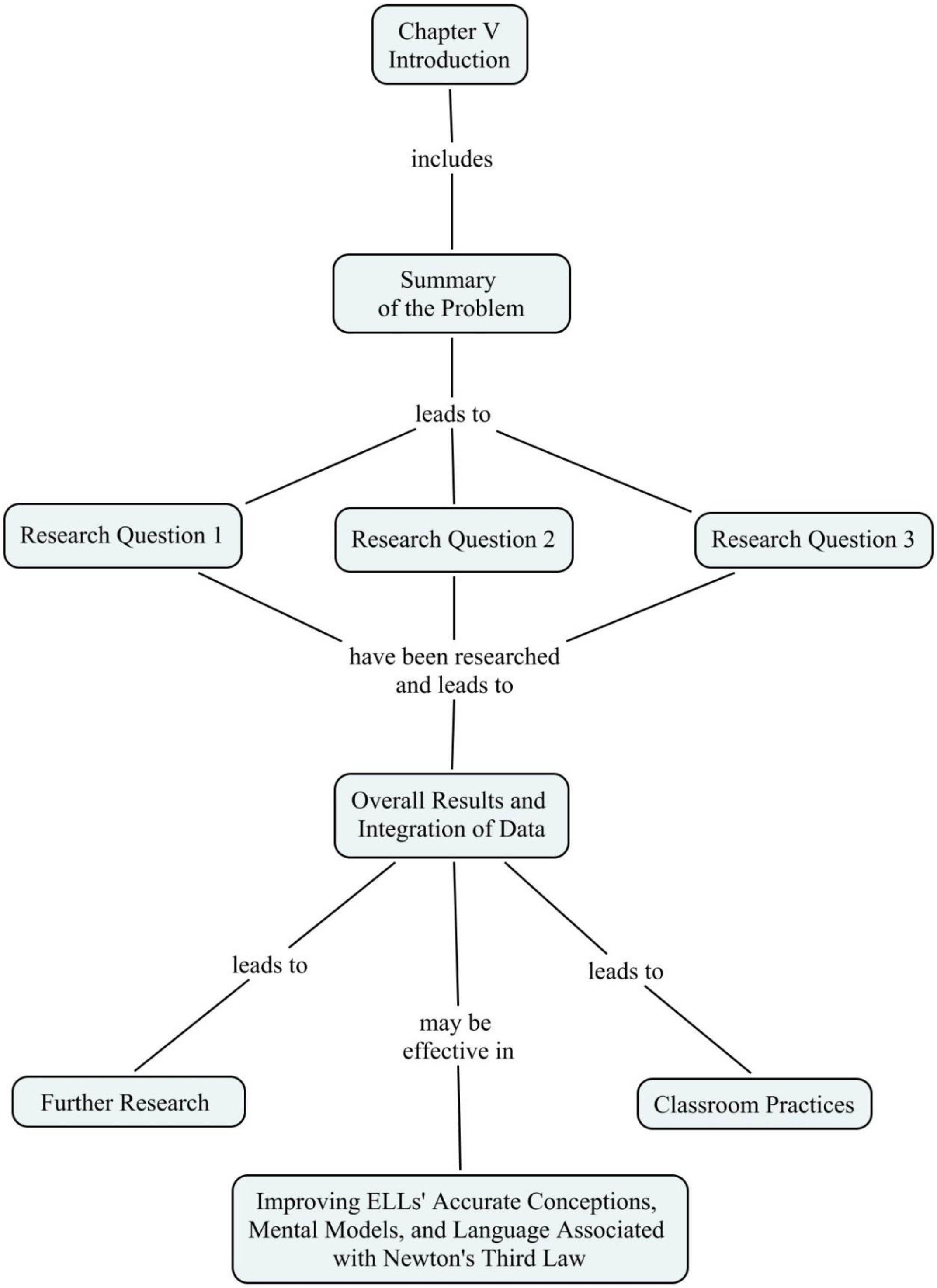

Figure 5.1. Outline for chapter V.

Furthermore, other researchers came to the same conclusion: learners interacting with multiple representations, such as those embedded within simulations, increase retention of physics content (Jacobson & Kozma, 2000; Monaghan & Clement, 1999; NRC, 2000a; NRC, 2000b). Simulations can also have instructional scaffolding embedded into the programs to assist ELLs in developing conceptual understanding as they manipulate variables; technology can be an enabling vehicle that fosters education through manipulation of variables and observation of results (Christian & Belloni, 2004; Fishman et al., 2004)

Previous research studies specifically addressed learning difficulties of ELLs. Lai, Lucas, and Burke (1995) found learners experience enhanced difficulties learning science in a second language. Evans (1978) found that abstract science concepts introduced to learners with limited language skills increases their learning difficulties. My findings from the review of the literature were that some research does exist on teaching physics to ELLs with traditional methods. However, research involving teaching complex concepts to ELLs including Newton's Third Law is practically nonexistent.

Research Question 1: What Are the Differences in Conceptual Understanding between Groups of ELLs Who Learn Newton's Third Law by Computer Simulations as Compared with Hands-On Laboratory Learning?

Analysis of learners' pretest and posttest scores on the FCI provided data that answers this question in several parts. A limitation to the interpreted results reported here resides in understanding a bit more about learners' overall participation in the two treatments (i.e., computer simulations, and the hands-on laboratory investigations) for this study. Some of the learners were actively engaged in the process, some learners were partially engaged, and a few learners were not engaged. Three of the seven computer simulations groups were observed in the videos as not participating or minimally participating, therefore, for use in comparisons, the three groups were interpreted as choosing nonengagement in the treatment. Table 5.1 indicates the gain in conceptual understanding between FCI pretest and posttest scores.

Table 5.1

Summary of the Quantitative Data by Percentage Comparing the Difference Between the FCI Pretests and the Posttests to Describe the Learner's Conceptual Development of Newton's Third Law for ELLs

	Computer Simulations Groups							Hands-on Laboratory Activities Groups		
Category	*CS-1	*CS-2	CS-3	*CS-4	CS-5	CS-6	CS-7	H-1	H-2	H-3
Correct - posttest	17%	33%	42%	8%	50%	50%	100%	42%	50%	25%

*Since these groups were observed not participating in the computer simulations, they were interpreted as choosing nonengagement in the treatment.

High-Scoring Groups with Perfect Scoring Individuals on the Posttest

Computer simulations Group CS-7 outperformed all other simulations groups and all hands-on laboratory investigations groups. Computer simulations Group CS-7 moved from choosing many misconceptions on the pretest (earning a 0%) to 100% accuracy on the posttest. One participant in computer simulations Group CS-3 also moved from choosing misconceptions on the pretest to earning a 100% on the posttest (see Table 5.1). Hands-on laboratory investigations groups did not have any participant earn a 100% on the posttest.

Moderate-Scoring Groups (75% to 50%) on the Posttest

Computer simulations groups had three participants in the moderate-scoring category. In computer simulations Group CS-5, two participants moved from choosing misconceptions on the pretest (earning a 0%) to earn a 50% on the posttest. One participant in computer simulations Group CS-6 also moved from choosing misconceptions on the pretest to earn a 50% on the posttest. Hands-on laboratory investigations groups had four participants in the moderate-scoring category. One participant in hands-on laboratory investigations Group H-2 outperformed all other participants in the hands-on laboratory investigations by choosing all misconceptions on the pretest (earning 0%) and choosing 3 correct answers on the posttest (earning a score of 75%). In hands-on laboratory investigations Group H-1, two participants moved from choosing misconceptions on the pretest (earning 0%) to earn a 50% on the posttest. One participant in hands-on laboratory investigations Group H-3 chose misconceptions on the pretest (earning a 0%) and chose two correct answers on the posttest to also earn a score of 50%.

Low-Scoring Groups (25% to 0%) on the Posttest

Computer simulations Groups CS-1, CS-2, and CS-4 performed at a very low level. This is not surprising, as these groups were not engaged in the treatment. An analysis of the videotaped records of students' activity within this group indicated that these groups did not manipulate variables or interact with the computer simulations. The proctor did not demand engagement from participating ELLs but answered student questions when approached without revealing an FCI response. Therefore, their scores on the pretests and posttests varied from choosing none to one correct answer on the posttest. Hands-on laboratory investigations groups were more engaged with manipulating laboratory equipment. Computer simulations Group CS-4 scored the lowest.

Summary

Computer simulations groups, when they were actively engaged in manipulating variables and observing the results on the computer, increased in conceptual understanding of Newton's Third Law as measured by the pre and post FCI answers (see Table 4.1). This substantiates previous research that computer simulations could improve understanding (e. g., Christian & Belloni, 2004; Dancy & Beichner, 2006; Dancy et al., 2002; de Jong et al., 1999; Leonard et al., 1996; Finkelstein & Pollock, 2005; Jacobson & Kozma, 2000). Hands-on laboratory investigations groups when they were actively engaged did not perform as well on the posttest. The percent correct for the hands-on laboratory investigations groups were lower (see Table 4.2). Results of this intervention are consistent with English based research that computer simulations should assist learners, in this case ELLs in grasping the abstract concept of Newton's Third Law.

An Explanation of Most Frequent Misconceptions

Misconceptions are difficult to change because they are developed over years of real world observations (Arons, 1990; Bao et al., 2002; Halloun & Hestenes, 1985a; Halloun & Hestenes, 1985b; Maloney, 1984). Misconceptions are incorrect thoughts or common sense beliefs associated with a concept (NRC, 2000a). Data related to Research Question 1 encouraged examination of some commonalities regarding learners' performance on misconceptions.

Not only do physics teachers deal with ELLs' limited English skills but also their misconceptions concerning their conceptual understanding of physics concepts. The main misconceptions for Newton's Third Law are: (a) only active agents exert forces, (b) greater mass implies greater force, (c) the most active agent produces the greatest force, and (d) obstacles exert no force (Hestenes et al., 1992).

The misconception of "greater mass implies greater force" was chosen most frequently both in the pretest and the posttest, 32 times and 24 times respectively (see Table 5.2). In real life, learners observe accidents where the smaller vehicle in a collision exhibits more damage. Real-life experiences therefore make this misconception a logical outcome. The second most chosen misconception on the pretest was "only active agents exert force." On the pretest 25 participants chose this misconception whereas on the posttest only 7 participants chose this misconception, a difference of 72%. In the posttests, learners corrected the misconception to the same amount of force.

Table 5.2

Number of Misconceptions for Both the Computer Simulations and the Hands-on Laboratory Investigations for Each Question on the FCI Pretest and Posttest

	FCI Questions										
	#15		#16		#28		#4		Total		
Misconceptions	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	% Change
Greater mass implies greater force	8	6	10	3			14	15	32	24	25%
Most active agent produces the greatest force	12	13	10	4					22	17	23%
Only active agents exert force	5	1	4	4	16	2			25	7	72%
Obstacles exert no force											
Each student exerts a force on each other but "b" exerts the larger force					3	6			3	6	-100%
Greater mass implies a greater force and the most active agent produces the greatest force					9	9	7	3	16	12	25%
Car exerts a greater amount of force on the truck than the truck exerts on the car							6	5	6	5	17%

Table 5.3 displays only computer simulations participants' misconceptions. Computer simulations participants displayed the greatest change between the pretest and the posttest in the misconception "only active agents exert force." On the pretest the 18 participants chose the misconceptions but on the posttest only 3 participants (83%) chose

this misconception. The second greatest change was displayed in the “greater mass implies greater force.” On the pretest 23 participants chose this misconception but on the posttest only 15 participants (35%) chose this misconception. Participants were able to manipulate variables and observe the results of those changes assisting the participant in developing conceptual understanding. Participants were able to observe arrows in the Computer simulations indicating same size arrows representing forces but pointing in opposite directions.

Table 5.3

Number of Misconceptions for Computer Simulations for Each Question on the FCI Pretest and Posttest

	FCI Questions										
	#15		#16		#28		#4		Total		
Misconceptions	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	% change
Greater mass implies greater force	6	6	7	1			10	8	23	15	35%
Most active agent produces the greatest force	7	10	8	2					15	12	20%
Only active agents exert force	4		2	3	12				18	3	83%
Obstacles exert no force											0%
Each student exerts a force on each other but “b” exerts the larger force					3	5			3	5	-67%
Greater mass implies a greater force and the most active agent produces the greatest force					3	5	4	2	7	7	0%
Car exerts a greater amount of force on the truck than the truck exerts on the car							4	5	4	5	-25%

Table 5.4 displays only hands-on laboratory investigations participants' misconceptions. Hands-on laboratory investigations participants displayed the greatest change between the pretest and the posttest in the misconception "greater mass implies a greater force and the most active agent produces the greatest force." On the pretest the 9 participants chose the misconceptions but on the posttest only 5 participants (44%) chose this misconception. The second greatest change was displayed in the "only active agents exert force." On the pretest 7 participants chose this misconception but on the posttest only 4 participants (43%) chose this misconception. Hands-on laboratory investigations participants were able to manipulate equipment and collect data but were not able to observe the length of arrows showing equal forces, and the directions of those arrows which would assist the participant in developing conceptual understanding. Computer simulations were able to demonstrate that forces were equal including forces from obstacles. Visualization assisted the learners in developing conceptual understanding of Newton's Third Law. Hands-on laboratory investigations groups were not able to visualize a force from an obstacle. Consequently, computer simulations that do display those arrows provide valuable visuals which assist learners in developing conceptual understanding.

Table 5.4

Number of Misconceptions for Hands-on Laboratory Investigations for Each Question on the FCI Pretest and Posttest

	FCI Questions										
	#15		#16		#28		#4		Total		
Misconceptions	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	% Change
Greater mass implies greater force	2		3	2			4	7	9	9	0%
Most active agent produces the greatest force	5	3	2	2					7	5	29%
Only active agents exert force	1	1	2	1	4	2			7	4	43%
Obstacles exert no force											0%
Each student exerts a force on each other but “b” exerts the larger force						1				1	0%
Greater mass implies a greater force and the most active agent produces the greatest force					6	4	3	1	9	5	44%
Car exerts a greater amount of force on the truck than the truck exerts on the car							2		2	0	-100%

Figure 5.2 combines Tables 5.3 and Table 5.4 in a bar graph. Table 5.3 exhibits the misconceptions displayed by the ELLs engaged in computer simulations. Table 5.4 exhibits the misconceptions displayed by the ELLs engaged in hands-on laboratory investigations.

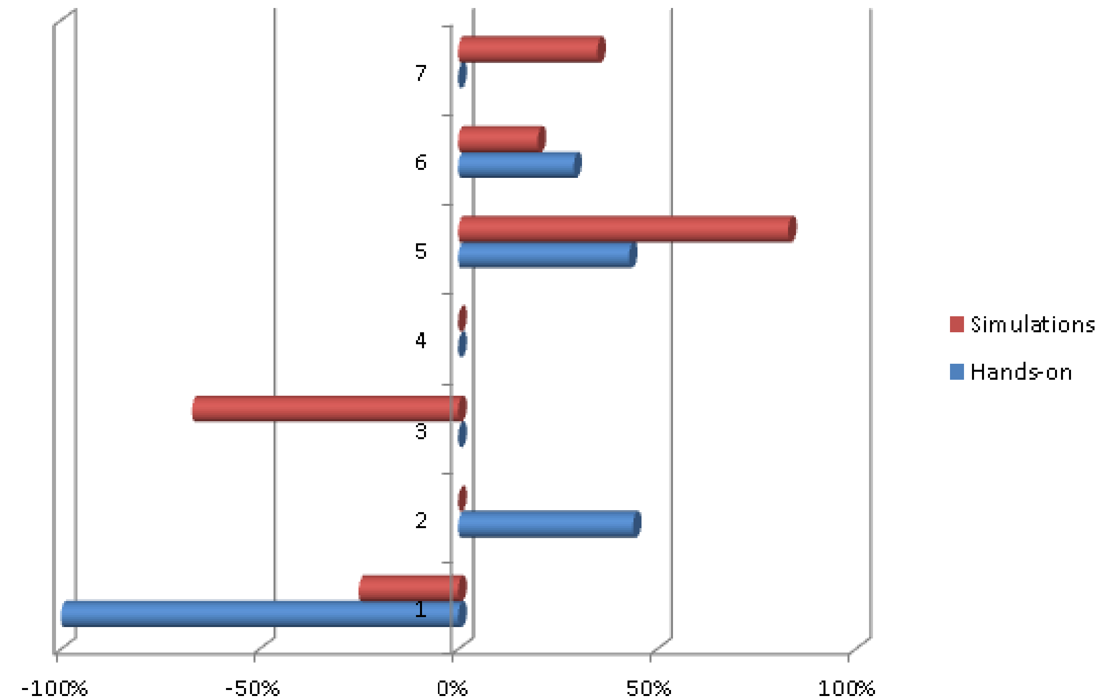

Figure 5.2. A graphical display of the percent difference between the pretest and posttest misconceptions for both the computer simulations and hands-on laboratory investigations for questions 15, 16, 28 and 4 from the FCI pretest and posttest.

Research Question 2: What Are the Differences in Conceptual Conversations between Groups of ELLs Who Learn Newton's Third Law by Computer Simulations as Compared with Hands-On Laboratory Learning?

Conversations were videotaped while the ELLs interacted with either computer simulations or hands-on laboratory investigations. Furthermore, all learner groups in both treatments were required to keep a journal providing directions and questions for each of the activities. I scored the transcriptions from the videotapes and students' journals as the data sources for "conversation," prompted by the requirement that learners within a group communicate with each other before making a journal entry. The plan was for each group to prepare a student journal in which the position of group recorder rotated periodically. Based on decades of classroom experience, I had anticipated that about one-third of the observations and data would be reported by each learner in the group. When approximately one-third of the computer simulations or hands-on laboratory investigations were completed, the learners were instructed in the student journal to switch the recorder responsibilities to another group member. Each recorder documented the reporting by initialing the applicable section. The student journal prompted learners to make specific observations and answer certain questions pertaining to the Newton's Third Law content that was presented.

Conversations in the videotapes were transcribed. Of particular interest is the hands-on laboratory investigations Group H-3, which outperformed computer simulations groups and the other hands-on laboratory investigations groups in discussions about Newton's Third Law. This group scored 89% out of the total conversation time spent on topics related to Newton's Third Law. No other group scored over 59% of the time. One member of Group H-3 dominated the entire conversation, contributing about 80% of the total group's conversation. The learner was a foreign exchange student, who seemed more outgoing than a typical ELL. All groups' conversations pertaining to Newton's Third Law ranged from 89% to 4%. Table 5.5 summarizes the data collected from these two sources.

Table 5.5

Summarizes the Analysis of Qualitative Data from Two Sources, Videotapes and Student Journals, by Percentage, Providing Evidence of Learners' Conceptual Conversations

	Computer Simulations Groups							Hands-on Laboratory Activities Groups		
Category	*CS-1	*CS-2	CS-3	*CS-4	CS-5	CS-6	CS-7	H-1	H-2	H-3
Student journals	76%	89%	88%	28%	22%	79%	22%	92%	99%	96%
Videotapes	4%	37%	25%	4%	7%	19%	4%	48%	59%	89%

*These groups were observed not participating in the computer simulations.

Conversations of the computer simulations groups, on the whole, indicated a wide range in percentages of time spent during the treatment in discussing Newton's Third Law. Percentages ranged from 37% to a low of 4%. Hands-on laboratory investigations groups, in contrast, ranged from 89% to 48%. Within the computer simulations groups, noteworthy is the low performance demonstrated by Groups CS-1, CS-4, and CS-5. These groups scored 4%, 4%, and 7% respectively. These groups spent the majority of class time discussing other topics not pertaining to Newton's Third Law. One learner in Group CS-5 interacted with computer simulations while the other two group members did not participate. Conversations among members of computer simulations Groups CS-1 and CS-4, which were females only, were primarily social. Members of Group CS-5, which were boys only, rarely communicated with each other. However, the other four Computer simulations groups ranked from 37% to 19%.

Three of four computer simulations groups (3, 5, and 6) spoke primarily in Spanish; Group CS-7, with a Vietnamese speaker and a Spanish speaker, rarely spoke at all. Members of computer simulations Group CS-7 did not discuss, I believe, due to the different languages of the members, Spanish and Vietnamese. When they did communicate, they spoke in English and only about Newton's Third Law. But also members of computer simulations Group CS-7 had lower TELPAS ratings which also could indicate a difficulty with communication or confidence in communication due to a lack of skills (see Appendix E). It is noteworthy that the material and methodology was of sufficient interest to Group CS-7 for the students to attempt very difficult communication.

These results for the computer simulations groups' levels of conversation about Newton's Third Law would be incomplete without discussion of the low-scoring groups' participation in the computer simulations. Members of computer simulations Groups Cs-1, CS-2, and CS-4 were minimally engaged in the computer simulations. During their computer simulations time, participants restricted their talk to topics other than Newton's Third Law. Conclusions presented here about the effectiveness of computer simulations, therefore, should necessarily be restricted to performance levels for Groups Cs-3, CS-5, CS-6, and CS-7. Furthermore, two of the computer simulations group members from Group CS-2 had repeated multiple grades, an indication of pre-existing learning problems.

High-Scoring Groups (Computer Simulations Groups CS-2, CS-3, and CS-6 and Hands-on Laboratory Investigations Group H-3)

Videotape analysis of computer simulations groups' discussions revealed that discussion about Newton's Third Law was not common. For example, in the high-scoring groups only one participant in computer simulations Group CS-3 was observed interacting with the computer simulations while the others were minimally engaged. Therefore 88% of the possible entries were recorded but only 25% discussion was recorded on the videotapes. Computer simulations Group CS-2 members were more concerned with filling in the student journal entries than interacting with each other or discussing the computer simulations. But Group CS-2 scored the highest in student journal entries and time discussing Newton's Third law. Ranges of discussion about the computer simulations indicate limited engagement with each other during the videotaped sequence of activities.

Videotapes of hands-on laboratory investigations groups revealed a high level (89%) of conversation about Newton's Third Law. One learner in particular in Group H-3 recorded the data and contributed most of the discussion for the group. The other learners in this group did not have an opportunity to make journal entries or discuss results. Scores on the student journal were high for hands-on laboratory investigations Group H-3. This was biased by the domination of one individual who was observed on tape to be highly engaged. Notable, however, are differences overall between videotaped conversation and journal completion. Computer simulations and hands-on laboratory investigations learners' attention was obviously more evident in student journal work than in conversation among group members.

Moderate-Scoring Groups (Computer Simulations Groups CS-1 and CS-6, and Hands-on Laboratory Investigations Groups H-1 and H-2)

Computer simulations Groups CS-1 and CS-6 filled in their student journals with partial observations and data pertaining to Newton's Third Law. The parts left blank in the student journal pertained to predictions and formulating conclusions. Discussions among members of computer simulations Groups CS-1 and CS-6 were less than 20%.

Hands-on laboratory investigations groups scored over 90% in the student journals. Discussions ranged from 89% to 48% of the time available. Hands-on laboratory investigations Group H-1 answered the least number of questions pertaining to predictions and formulating conclusions. Much of the discussion was equipment-related.

Low-Scoring Groups (Computer Simulations Groups CS-4, CS-5, and CS-7) with Group Members Discussing and Recording Observations and Data in the Student Journal

Computer simulations Groups CS-4, CS-5, and CS-7 made few journal entries. While computer simulations Group CS-7 was observed to be actively engaged in the simulations, members did not make many journal entries. Computer simulations Group CS-7, a group composed of two members, included native speaker of Spanish and of Vietnamese. Not sharing the same native language could have limited their discussions. Notable is that no hands-on laboratory investigations group placed in the low-scoring group. It is possible that the hands-on laboratory investigations learners had previous classroom laboratory investigations experience in recording data much like recording information or filling in worksheets. The low scoring computer simulations groups CS-4 and CS-5 were minimally engaged in the computer simulations and subsequently did not record their answers.

Discussion

Results did not support computer simulations as stimulating ELLs' conceptual conversation. However, the results for hands-on laboratory investigations groups indicated much higher scores on the journal entries and much higher percentages of time spent in conversation about Newton's Third Law. The explanation for these differences could be that the nature of hands-on laboratory investigations requires talking about setting up equipment and making observations. In contrast, learners engaged with computer simulations do not really need to talk with each other, since interaction is restricted to the computer. Classroom norms engaging learners to fill out their worksheets have been established long before this intervention. However, learners working with computer simulations had no instruction or requirement by the simulation itself to record anything since results were displayed on the screen without explanation or prompting. ELLs were asked questions in English in their journals. Establishing a mental link between the computer simulations experience in English and answering journal questions in English was beyond these students' apparent interest level and perhaps their language skill.

Hands-on laboratory investigations lend themselves to more discussion because group members are working together literally moving around the room while manipulating equipment, and interacting with other group members in making observations. For the three hands-on laboratory investigations groups, videotapes revealed significantly more conversation about Newton's Third Law, particularly in relationship to setting up the equipment to collect data and stay organized to observe the results. The experiment required members to participate in order to perform certain functions within the investigation such as two participants holding different ends of a string.

Research Question 3. What Are the Differences in Conceptual Conversations in Relationship to Their Conceptual Understanding between Groups of ELLs Who Learn Newton's Third Law by Computer Simulations as Compared with Hands-On Laboratory Investigations Learning?

Analysis of learners' FCI scores compared with learners' conversations pertaining to Newton's Third Law and student journal entries provided data to answer this research question, which has several parts. Table 5.6 compares the data from the pretest and posttest FCI scores with learners' entries in their student journals and their coded videotaped conversations. The table has a Y for yes and a N for no concerning conversation pertaining to Newton's Third Law during the intervention. If the groups conceptual conversation was limited to small percentage of time an N was placed in the column for little or no discussion pertaining to Newton's Third Law. A Y was placed in the column if discussion concerning Newton's Third Law was the majority of the group's discussion during the treatment. The student journal evidence is displayed by the rotation column and the amount of correct entries recorded. The science journals were divided into approximately three sections. Each participant in a group was to record approximately one-third of the observations or data. The rotation column was included to display if the group members shared in the recording of data and observations or did one group member record all or the majority. If the group members rotated so each member recorded approximately one-third of the data and observations a Y was placed in the rotation column otherwise an N was placed in the column. The amount of entries recorded ranged from no entries, to some entries, to the majority of the possible recordings were entered. The last three columns pertain to the differences between the numbers of correct answers on the pretest to the number of correct answers on the posttest. A gain per group of one to two more correct on the posttest was recorded in the medium column. A gain per group of three to four more correct on the posttest was recorded as high.

Table 5.6

Evidence of Connections from Comparing Merged Quantitative and Qualitative Data

		Videotape Recordings	Student Journal Evidence				Pretest to Posttest FCI Correct Answers		
Condition	Groups	Conversation Y or N	Rotation Y or N	No 0	Some 1, 2, 3	Lot of 4, 5	Low (0) 1	Med (1-2) 2	High (3-4) 3
Computer Simulations	CS-3	N	N			4		2	
Computer Simulations	CS-5	N	Y		2			2	
Computer Simulations	CS-6	N	N			4		2	
Computer Simulations	CS-7	N	N		2				4
Hands-on Lab	H-1	Y	N			5		2	
Hands-on Lab	H-2	Y	Y			5		2	
Hands-on Lab	H-3	Y	N			5	1		

A limitation to the results reported here resides in understanding a bit more about learners' overall participation in the two treatments (i.e., computer simulations, hands-on laboratory investigations) for this study. Noted earlier, not all of the learners were actively engaged. All of the participants were learners with limited English skills. Data recorded in Table 5.6 indicate the gain in conceptual understanding between conceptual conversation and the FCI pretest and posttest scores.

Computer simulations Groups CS-3, CS-5, CS-6, and CS-7 scored 3 or less on recording data and recording answers to prompted questions in the student journals. Conversations pertaining to Newton's Third Law while being engaged in manipulating variables were limited. Conceptual understanding scores from the difference between pretest scores and posttest scores were higher for computer simulations groups than the hands-on laboratory investigations groups.

Hands-on laboratory investigations Groups H-1, H-2, and H-3 outperformed the computer simulations groups in recording student journal entries. The hands-on laboratory investigations groups recorded answers to the majority of prompted questions and entered data from observations. But the recording of data and answering questions did not correspond to higher posttest scores on conceptual understanding, which are medium to low FCI posttest scores.

Summary

Computer simulations are reported to be effective when included with other teaching strategies in developing conceptual understanding, especially for teaching abstract physics concepts (Christian & Belloni, 2004; Dancy & Beichner, 2006; Dancy et al., 2002; Finkelstein & Pollock, 2005; Fishman et al., 2004). ELL students engaging in computer simulations did show improvement in their conceptual understanding. It has been well established that traditional hands-on laboratory investigations develop skills in manipulating equipment while using various instructional methods. Results of this research indicate a better conceptualization for learners would be obtained by including computer simulations with the use of hands-on laboratory equipment. The passive nature of some learners interacting with computer simulations in this research is similar to other classroom situations demonstrating the necessity of an instructor actively monitoring learners' progress.

Computer simulations could be attached as part of a homework assignment. One must consider, however, that some learners may not have the motivation to be engaged in a computer simulation at home. I would recommend an assessment at the end of the computer simulations homework be required for students to turn in and discuss in class. There are, however, several advantages to the use of computers that should be mentioned here.

Advantages of time, text, and equipment requirements. Computer simulations as applied in the intervention for this study can be an advantage for educating ELL learners due to the minimal amount of text and equipment needed. Computer simulations can allow learners to quickly make multiple trials to observe similar or exact same results as previously observed in earlier simulated experiments. The amount of time to learn a concept can be significantly shortened with a computer simulation compared to hands-on laboratory investigations, especially where completing multiple trails is needed to obtain better results. Hands-on laboratory investigations, in comparison, require set-up time by students and can consume extensive amounts of class instruction time. Total laboratory time also requires explanation by the teacher, which can be extensive when laboratory procedures involve multiple steps and reviews of laboratory safety. Considering the amount of curriculum required to cover in each school year, opportunities are restricted for students to engage fully in hands-on laboratory experiences that allow multiple trials for retrying and altering hands-on experiments.

Advantages of immediate feedback. Computer simulations can provide immediate feedback compared to hands-on laboratory investigations. Calculations, construction of data tables, graphs, or creation of other types of data display to develop and respond to a conclusion concerning a single experimental activity is usually time-consuming, especially restrictive in a typical 50-minute class period. When using computer simulations, learners have the ability to observe how their experimental manipulations can alter a graph in real time. Hands-on laboratory investigations learners have to take their data, which could have errors, and manually construct a graph to observe trends in the data. Computer simulations have the advantage of recreating an exact same situation with the exact same results for the learner who requires repetition in order to gain conceptual understanding of an abstract concept.

When I began this study, I knew the practice of using computer simulations in the classroom was an effective instructional strategy for science learners. I wanted to test how effective computer simulations would be for learners with limited English skills.

Since all high school learners are often engaged in computer games I thought learners would be more engaged in computer simulations. The lack of engagement overall was not expected. The treatment investigated the use of computer simulations in the classroom with an instructor actively monitoring learners. The student journal included probing questions which was to assist learners to stay on task. Students recording data is an effective instructional approach. While this research showed that computer simulations can be effective for learners with limited English skills, I was surprised to observe so many learners engaged in off-task behavior. Hands-on laboratory investigations groups were on task discussing Newton's Third Law more than computer simulations. Student journal recordings from the hands-on laboratory investigations groups were over 90%, whereas the computer simulations groups ranged from 22% to 88%.

Applications

In this section I discuss the applications of the results in three areas: (a) further research, (b) classroom practices, and (c) conclusions pertaining to ELLs' mastering of the abstract science concept of Newton's Third Law.

Further Research

Physics education research is limited in the area of high school ELLs learning abstract physics concepts. While this study used Newton's Third Law, research on teaching physics concepts in general or other difficult concepts to ELLs is lacking. The author suggests the following list of recommendations for further research:

- To improve data collection by expanding this study with the following changes: (a) having learners interact on the computer individually, (b) making learning more visible with talking to group partners explaining and/or defending mental models, (c) more active monitoring to keep learners on task including asking probing questions, (d) retesting the learners for retention of conceptual developed through the study.
- To develop a comparison study to verify the conclusion from this study, that computer simulations are an effective instructional strategy for ELLs, incorporated into the lesson plan. Verifying data is common practice among scientists.
- To expand this research to other abstract physics concepts, and incorporate computer simulations into lesson plans as an introduction to abstract concepts or to evaluate mental models.
- To discover in which part of the lesson plan computer simulations are most effective.
- To study which approach is most effective when incorporating computer simulations into the classroom.
- To study the effectiveness of computer simulations on abstract physics concepts in lower grades.

Classroom Practices

This research study has several implications for classroom practices related to learners with limited English skills. In this section I discuss four classroom practices.

The main classroom practices are: (1) limit misconceptions, (2) assist learning through scaffolding, (3) assist learners in grasping abstract conceptual understanding, and (4) reinforce conceptual understanding.

First, this study is concerned with misconceptions. Computer simulations are an instructional strategy that can limit the misconceptions of learners from different backgrounds or with limited English skills. Computer simulations provide multiple visual representations to teach or reinforce a scientific concept. When a new concept is introduced, for example, a teacher could assign a computer simulation for all learners to manipulate variables and observe specific results. That way all learners, despite language differences, would have similar experiences to introduce a new concept.

Second, instructional scaffolding can be placed at specific points to assist learners in developing a correct conceptual understanding. Using scaffolding, learners can be directed to specific observations that will assist in developing conceptual understanding.

Third, some concepts are difficult to observe in the real world. Computer simulations can be used to slow down the action or emphasize it in other ways so that learners can observe the results. Visuals can assist learners in grasping abstract concepts.

Finally, concepts must be reinforced to assist learners in maintaining conceptual understanding. Learners must revisit concepts throughout the year. Computer simulations can be a tool to review concepts from different situations and viewpoints, both for immediate repetition and reinforcement or for recurrent assignments throughout the school year.

This study indicated that computer simulations can transform science teaching for learners with limited English skills. Learners are able to manipulate variables and observe the results. Some learners need more time to grasp an abstract concept. Computer simulations can be used over and over again until the learner has an understanding of the abstract concept presented. Computer simulations hold promise in providing a key for all novice learners who may require multiple opportunities to build appropriate conceptual understanding about how the world works.

Conclusions

This exploratory study is the first of its kind to investigate the efficacy of computer simulations in teaching abstract science concepts to secondary learners without prerequisite English language skills. With computer simulations, learners with limited English skills were not at a disadvantage in manipulating variables, even though they neither talked as much or wrote as much as ELLs engaged in hands-on laboratory investigations. ELLs were able to observe the results from manipulating variables.

Table 5.7 displays the percentage gain from the pretest and posttest FCI scores. The pretest and posttest individual scores from the computer simulations participants were averaged. The average percent gain for the computer simulations participants was 50%. The pretest and posttest scores from the hands-on laboratory investigations were averaged. The average percentage gain for the hands-on laboratory investigations participants was 30%. The percent gain for the hands-on laboratory investigations was 20% below the computer simulations participants.

Table 5.7 displays the percentage of correct entries in each student journal. The recordings were quantified using a rubric. The percentage from each group was averaged to produce one score for the computer simulations groups and one score for the hands-on laboratory investigations groups. The hands-on laboratory investigations groups outperformed the computer simulations groups in recording observations, data and answers to specific questions. The videotapes showed the computer simulations groups were more focused on manipulating variables then making entries in the student journals.

Table 5.7 displays the percentage of conceptual conversation pertaining to Newton's Third Law. The transcriptions were quantified using a rubric. The percentage from each group was averaged to produce one score for the computer simulations groups and one score for the hands-on laboratory investigations groups. The hands-on laboratory investigations groups outperformed the computer simulations groups in discussing observations, data and answers to specific questions. The transcriptions exhibit collaborative discussions within the hands-on laboratory investigations groups. The majority of the discussions were associated with setting up the equipment and collecting data. Collaboration among the participants in the computer simulations groups was very limited. The participants were more engaged in manipulating variables. Computer simulations are individually manipulated compared to hands-on laboratory equipment requiring multiple participants to set up equipment and observe the data.

Table 5.7

Evidence of Connections from Comparing Quantitative and Qualitative Data

Treatments	Pretest to Posttest FCI Percent gain	Student Journals	Conceptual Conversation
Computer Simulations	50%	53%	14%
Hands-on Laboratory Investigations	30%	96%	65%

Only the participating computer simulations groups were used.

Computer simulations can visually demonstrate abstract science concepts to ELLs. Investigative research using improved or modified computer simulations for ELLs in teaching abstract concepts is needed. Learning modalities usually associated with homogeneously populated physics classrooms of high-achieving learners are not sufficient in the climate of "science for all" with today's learner populations.

Further research is needed on this special population of learners. The ELL population is growing in public schools today. If these learners are to have the same future as all other learners in America then we as a society, and especially within the education community, need to educate ourselves on the best practices to assist this population of learners. Doors need to be open to these learners so that they have the same opportunities as other learners in America. I recommend further study regarding group composition, particularly in science where at least 40% of class time is required by the state to be spent in laboratory settings.

This study is a first attempt to uncover effective approaches for teaching ELLs in regard to unfamiliar abstract scientific concepts. The approach of using computer simulations can be easily and effectively implemented by school districts. This research indicates promise that computer simulations can result in success for ELLs.

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APPENDIX A: FORCE CONCEPT INVENTORY QUESTIONS

IN ENGLISH (PRE AND POSTTEST)

Pretest

English

Birthdate

____

Initials

____

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).
A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

____ 15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

____ 16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

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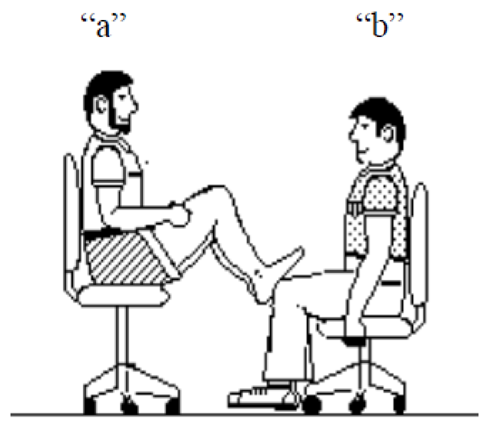
____ 28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:	

(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

____ 4. A large truck collides head-on with a small compact car. During the collision:
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car does not exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

Posttest

English

Birthdate

____

Initials

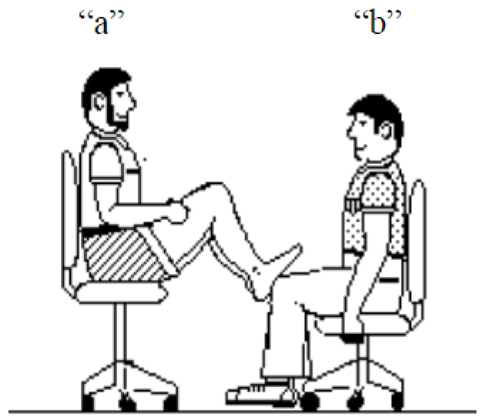
____

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).
A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

____ 15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

____ 16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

Next Page

____ 28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:	

(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

____ 4. A large truck collides head-on with a small compact car. During the collision:
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car does not exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

Pretest

Dutch

Birthdate

____

Initials

____

____ 15. Een zware vrachtauto heft motorpech en wordt door Een kleine auto terug naar de stad geduwd, zoals in de volgende figuur getoond.

Terwijl de auto, nog steeds de vrachtauto voortduwend, aan het versnellen is:
A) is de grootte van de kracht uitgeoefend door de auto op de vrachtauto gelijk aan de grootte van de kracht uitgeoefend door de vrachtauto op de auto.
B) is de grootte van de kracht uitgeoefend door de auto op de vrachtauto kleiner dan de grootte van de
Kracht uitgeoefend door de vrachtauto op de auto.
C) is de grootte van de kracht uitgeoefend door de auto op de vrachtauto groter dan de grootte van de kracht uitgeoefend door de vrachtauto op de auto.
D) draait de motor van de auto waardoor de auto duwt tegen de vrachtauto, maar de motor van de vrachtauto is defect zodat deze niet tegen de auto kan duwen. De vrachtauto wordt voortgeduwd simpelweg omdat hij in de weg van de auto staat.
E) oefenen noch de auto noch de vrachtauto een kracht uit op de ander. De vrachtauto wordt voortgeduwd simpelweg omdat hij in de weg van de auto staat.

____ 16. Een Zware vrachtauto heft motorpech en wordt door een kleine auto terug naar de stad geduwd, Zoals in de volgende figuur getoond. Nadat De auto een constant snelheid heft bereikt waarmee de bestuurder de Vrachtauto wenst voort te duwen:

A) is de grootte van de kracht uitgeoefend door de auto op de vrachtauto gelijk aan de grootte van de kracht uitgeoefend door de vrachtauto op de auto.
B) is de grootte van de kracht uitgeoefend door de auto op de vrachtauto kleiner dan de grootte van de kracht uitgeoefend door de vrachtauto op de auto.
C) is de grootte van de kracht uitgeoefend door de auto op de vrachtauto groter dan de grootte van de kracht uitgeoefend door de vrachtauto op de auto.
D) Draait de motor van de auto waardoor de auto duwt tegen de vrachtauto, maar de motor van de vrachtauto is defect zodat deze niet tegen de auto kan duwen. De vrachtauto wordt voortgeduwd simpelweg omdat hij in de weg van de auto staat.
E) Oefenen noch de auto noch de vrachtauto een kracht uit op de ander. De Vrachtauto wordt voortgeduwd simpelweg omdat hij in de weg van de auto staat.

Next Page

____ 28. In volgende figuur heft student "a" een massa van 95 kg en student "b" 77 kg. Ze zitten op identieke bureaustoelen tegenover elkaar. Student "a" duwt zich plots met de voeten af aan student "b" zoals in de figuur waardoor beide stoelen in beweging komen. Terwijl student "a" zich afduwt en de studenten nog in contact zijn:	

A) oefent geen van beide studenten een kracht uit op de andere student.
B) oefent student "a" een kracht uit op student "b", maar "b" oefent geen kracht op "a".
C) oefent elke student een kracht uit op de andere, maar "b" oefent de grootste kracht uit.
D) oefent elke student een kracht uit op de andere, maar "a" oefent de grootste kracht uit.
E) oefent elke student een kracht uit op de andere, en gelijk in grootte.

____ 4. Een zware vrachtwagen botst frontal met een personenauto. Tijdens de botsing:
A) oefent de vrachtwagen een grotere kracht uit op de auto dan de auto op de vrachtwagen
B) Oefent de auto een grotere kracht uit op de vrachtwagen dan de vrachtwagen op de auto
C) Oefenen noch de vrachtwagen noch de auto een kracht uit op de ander, de auto wordt verpletterd omdat hij in de weg staat van de vrachtwagen
D) Oefent de vrachtwagen een kracht uit op de auto, maar de auto oefent geen kracht uit op de vrachtwagen
E) Oefent de vrachtwagen een kracht uit op de auto die even groot is als de kracht van de auto op de vrachtwagen

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO
QUESTIONS (15 and 16).
A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

____ 15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

____ 16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

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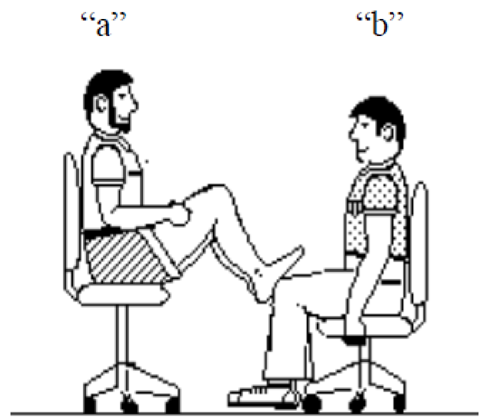
____ 28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:	

(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

____ 4. A large truck collides head-on with a small compact car. During the collision:
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car does not exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

Pretest

French

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Initials

FCI-French TEST MECANIQUE N°1

Utilisez l'énoncé et la figure ci-dessous pour répondre aux deux questions suivantes (15 et 16).
Un gros camion tombe en panne sur une route. Pour retourner à la ville, il se fait pousser par une voiture compacte, tel qu'illustré dans la figure suivante.

____ 15. Pendant que la voiture, poussant toujours le camion, augmente sa vitesse jusqu'à sa vitesse de croisière,
1. la force avec laquelle la voiture pousse le camion est aussi grande que la force du camion sur la voiture.
2. la force avec laquelle la voiture pousse le camion est plus petite que la force du camion sur la voiture.
3. la force avec laquelle la voiture pousse le camion est plus grande que la force du camion sur la voiture.
4. le moteur de la voiture est en marche, alors la voiture pousse le camion, par contre, le moteur du camion est à l'arrêt, alors le camion ne peut pas exercer une force sur la voiture. Le camion n'est poussé vers l'avant que parce qu'il est dans le chemin de la voiture.
5. ni la voiture ni le camion n'exercent de forces l'un sur l'autre. Le camion n'est poussé vers l'avant que parce qu'il est dans le chemin de la voiture.

____ 16. Une fois que le conducteur de la voiture atteint la vitesse de croisière désirée pour pousser le camion,
1. la force avec laquelle la voiture pousse le camion est égale à la force du camion sur la voiture.
2. la force avec laquelle la voiture pousse le camion est inférieure à la force du camion sur la voiture.
3. la force avec laquelle la voiture pousse le camion est supérieure à la force du camion sur la voiture.
4. le moteur de la voiture est en marche, alors la voiture pousse le camion, par contre, le moteur du camion est à l'arrêt, alors le camion ne peut pas exercer une force sur la voiture. Le camion n'est poussé vers l'avant que parce qu'il est dans le chemin de la voiture.
5. ni la voiture ni le camion n'exercent de forces l'un sur l'autre. Le camion n'est poussé vers l'avant que parce qu'il est dans le chemin de la voiture.

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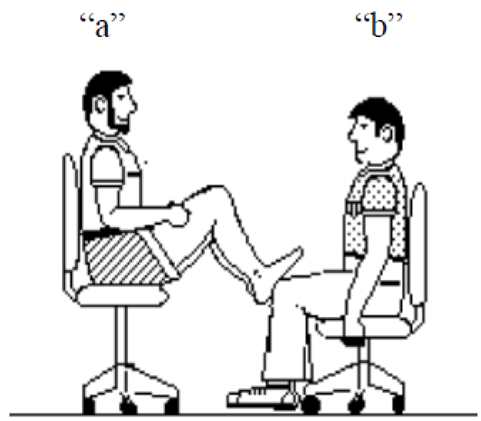
____ 28. Dans la figure ci-dessous, l'élève A a une masse de 75 kg et l'élève B a une masse de 57 kg. Ils sont assis face à face sur des chaises identiques. L'élève A place ses pieds nus sur les genoux de l'élève B, tel qu'illustré. Puis, l'élève A pousse soudainement sur les genoux de l'élève B, provoquant le mouvement des deux chaises. Durant la poussée alors que les deux élèves sont toujours en contact,	

1. aucun des élèves n'exerce une force sur l'autre.
2. l'élève A exerce une force sur l'élève B, mais l'élève B n'exerce pas de force sur A.
3. chaque élève exerce une force sur l'autre, mais l'élève B exerce une force plus grande.
4. chaque élève exerce une force sur l'autre, mais l'élève A exerce une force plus grande.
5. chaque élève exerce autant de force l'un sur l'autre.

____ 4. Un gros camion entre en collision avec une petite voiture compacte. Pendant la collision,
1. le camion exerce une force plus la grande sur la voiture que la voiture sur le camion.
2. la voiture exerce une force plus la grande sur le camion que le camion sur la voiture.
3. aucun des deux n'exerce de force sur l'autre. La voiture se fait frapper simplement parce qu'elle est devant le camion.
4. le camion exerce une force sur la voiture mais la voiture n'exerce pas de force sur le camion.
5. le camion exerce une force aussi grande sur la voiture que la voiture sur le camion.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).
A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

____ 15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

____ 16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

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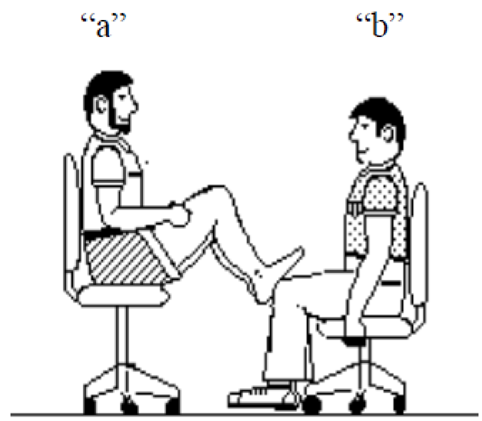
____ 28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:



(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

____ 4. A large truck collides head-on with a small compact car. During the collision:
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car does not exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

Pretest

Spanish

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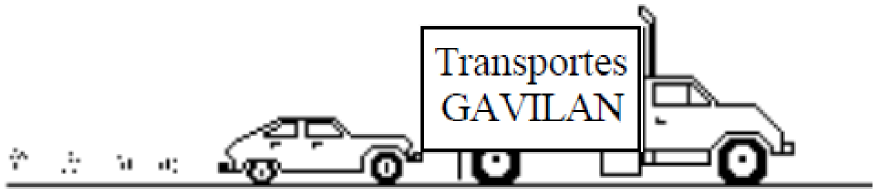
USE LA DESCRIPCIÓN Y LA FIGURA ADJUNTAS PARA CONTESTAR LAS DOS PREGUNTAS SIGUIENTES (15 y 16).
Un camión grande se avería en la carretera y un pequeño automóvil lo empuja de regreso a la ciudad tal como se muestra en la figura adjunta.



15. Mientras el automóvil que empuja al camión acelera para alcanzar la velocidad de marcha:
(A) la intensidad de la fuerza que el automóvil aplica sobre el camión es igual a la de la fuerza que el camión aplica sobre el auto.
(B) la intensidad de la fuerza que el automóvil aplica sobre el camión es menor que la de la fuerza que el camión aplica sobre el auto.
(C) la intensidad de la fuerza que el automóvil aplica sobre el camión es mayor que la de la fuerza que el camión aplica sobre el auto.
(D) dado que el motor del automóvil está en marcha, éste puede empujar al camión, pero el motor del camión no está funcionando, de modo que el camión no puede empujar al auto. El camión es empujado hacia adelante simplemente porque está en el camino del automóvil.
(E) ni el camión ni el automóvil ejercen fuerza alguna sobre el otro. El camión es empujado hacia adelante simplemente porque está en el camino del automóvil.

16. Después de que el automóvil alcanza la velocidad constante de marcha a la que el conductor quiere empujar el camión:
(A) la intensidad de la fuerza que el automóvil aplica sobre el camión es igual a la de la fuerza que el camión aplica sobre el auto.
(B) la intensidad de la fuerza que el automóvil aplica sobre el camión es menor que la de la fuerza que el camión aplica sobre el auto.
(C) la intensidad de la fuerza que el automóvil aplica sobre el camión es mayor que la de la fuerza que el camión aplica sobre el auto.
(D) dado que el motor del automóvil está en marcha, éste puede empujar al camión, pero el motor del camión no está funcionando, de modo que el camión no puede empujar al auto. El camión es empujado hacia adelante simplemente porque está en el camino del automóvil.
(E) ni el camión ni el automóvil ejercen fuerza alguna sobre el otro. El camión es empujado hacia adelante simplemente porque está en el camino del automóvil.

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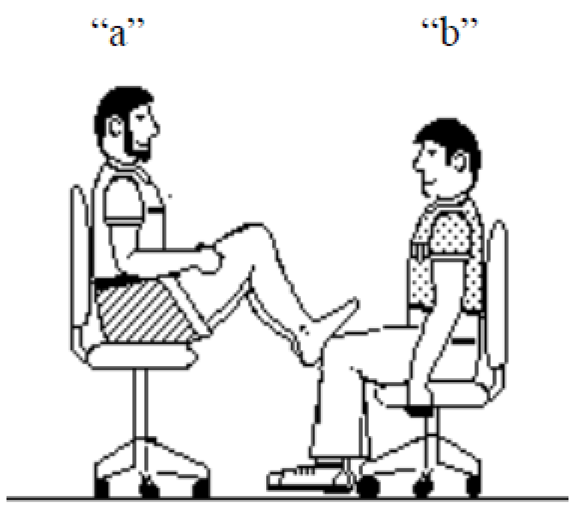
28. En la figura adjunta, el estudiante "a" tiene una masa de 95 Kg y el estudiante "b" tiene una masa de 77 Kg. Ambos se sientan en idénticas sillas de oficina cara a cara. El estudiante "a" coloca sus pies descalzos sobre las rodillas del estudiante "b", tal como se muestra. Seguidamente el estudiante "a" empuja súbitamente con sus pies hacia adelante, haciendo que ambas sillas se muevan. Durante el empuje, mientras los estudiantes están aún en contacto:



(A) ninguno de los estudiantes ejerce una fuerza sobre el otro.
(B) el estudiante "a" ejerce una fuerza sobre el estudiante "b", pero "b" no ejerce ninguna fuerza sobre "a".
(C) ambos estudiantes ejercen una fuerza sobre el otro, pero "b" ejerce una fuerza mayor.
(D) ambos estudiantes ejercen una fuerza sobre el otro, pero "a" ejerce una fuerza mayor.
(E) ambos estudiantes ejercen la misma cantidad de fuerza sobre el otro.

4. Un camión grande choca frontalmente con un pequeño automóvil. Durante la colisión:
(A) la intensidad de la fuerza que el camión ejerce sobre el automóvil es mayor que la de la fuerza que el auto ejerce sobre el camión.
(B) la intensidad de la fuerza que el automóvil ejerce sobre el camión es mayor que la de la fuerza que el camión ejerce sobre el auto.
(C) ninguno ejerce una fuerza sobre el otro, el auto es aplastado simplemente porque se interpone en el camino del camión.
(D) el camión ejerce una fuerza sobre el automóvil pero el auto no ejerce ninguna fuerza sobre el camión.
(E) el camión ejerce una fuerza de la misma intensidad sobre el auto que la que el auto ejerce sobre el camión.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).
A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

____ 15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

____ 16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

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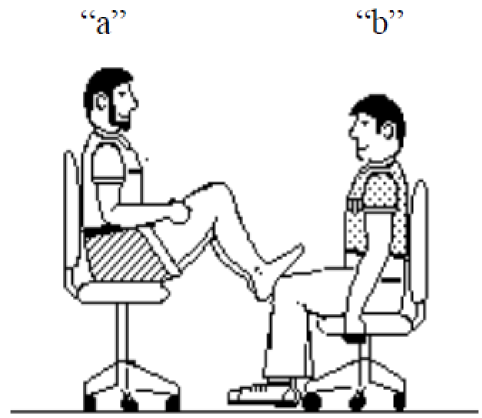
____ 28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:	

(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

____ 4. A large truck collides head-on with a small compact car. During the collision:
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car does not exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

Pretest

Russian

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Initials

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ИСПОЛЬЗУЙТЕ РИСУНОК И УСЛОВИЯ ДЛЯ ОТВЕТА НА СЛЕДУЮЩИЕ ДВА ВОПРОСА (вопросы 15 и 16).

Большой грузовик сломался на дороге, и толкается маленьким автомобилем, как показано на рисунке.

____ 15. Пока автомобиль, толкающий грузовик ускоряется:

(A) Сила, которую автомобиль прикладывает к грузовику равна силе, которую грузовик прикладывает к автомобилю.

(B) Сила, которую автомобиль прикладывает к грузовику меньше силы, которую грузовик прикладывает к автомобилю.

(C) Сила, которую автомобиль прикладывает к грузовику больше силы, которую грузовик прикладывает к автомобилю.

(D) Мотор автомбиля, толкающего грузовик работает, поэтому автомобиль прикладывает силу к грузовику, а мотор грузовика не работает, поэтому грузовик не может прикладывать силу к автомобилю. Грузовик толкается вперед только потому, что он на пути у автомобиля.

(E) Ни грузовик, ни автомобиль не прикладывают силы друг к другу. Грузовик толкается вперед только потому, что он на пути у автомобиля.

____ 16. После того, как автомобиль, толкающий грузовик достиг определенной постоянной скорости:

(A) Сила, которую автомобиль прикладывает к грузовику равна силе, которую грузовик прикладывает к автомобилю.

(B) Сила, которую автомобиль прикладывает к грузовику меньше силы, которую грузовик прикладывает к автомобилю.

(C) Сила, которую автомобиль прикладывает к грузовику больше силы, которую грузовик прикладывает к автомобилю.

(D) Мотор автомбиля, толкающего грузовик работает, поэтому автомобиль прикладывает силу к грузовику, а мотор грузовика не работает, поэтому грузовик не может прикладывать силу к автомобилю. Грузовик толкается вперед только потому, что он на пути у автомобиля.

(E) Ни грузовик, ни автомобиль не прикладывают силы друг к другу. Грузовик толкается вперед только потому, что он на пути у автомобиля.

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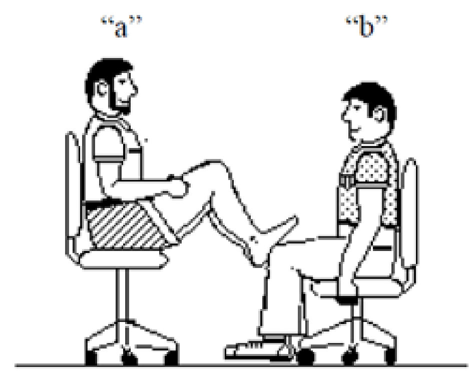
На рисунке справа, масса студента "a" 95 кг, а масса студента "b" 77 кг. Они сидят в совершенно одинаковых креслах лицом к лицу.

Студент "a" упирается ногами в колени студента "b", как показано на рисунке, затем толкает ноги вперед, из-за чего оба кресла откатываются.

Во время толчка, пока суденты касаются друг друга:



(A) Ни один из них не прилагает силы к другому.

(B) студент "a" прилагает силу к студенту "b", но "b" не прилагает силы к "a".

(C) каждый из студентов прилагает силу к другому, но "b" прилагает большую силу.

(D) каждый из студентов прилагает силу к другому, но "a" прилагает большую силу.

(E) каждый из студентов прилагает равную силу к другому

____ 4. Большой грузовик сталкивается лоб в лоб с маленьким автомобилем. Во время столкновения:

(A) Грузовик воздействует на автомобиль с большей силой, чем автомобиль воздействует на грузовик.

(B) Автомобиль воздействует на грузовик с большей силой, чем грузовик воздействует на автомбиль.

(C) Ни грузовик, ни автомобиль не прикладывают силу друг к другу, автомобиль разбивается только потому, что оказывается на пути у грузовика.

(D) Грузовик прилагает силу к автомобилю, но автомомиль не прилагает силу к грузовику.

(E) Грузовик прилагает к автомобилю такую же силу, какую автомобиль прилагает к грузовику.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).
A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

____ 15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

____ 16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

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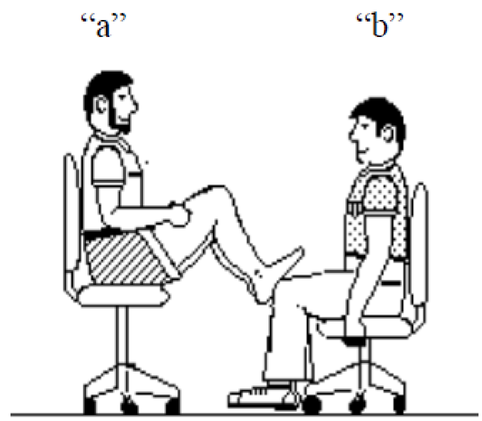
____ 28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other. Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move. During the push and while the students are still touching one another:



(A) neither student exerts a force on the other.
(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".
(C) each student exerts a force on the other, but "b" exerts the larger force.
(D) each student exerts a force on the other, but "a" exerts the larger force.
(E) each student exerts the same amount of force on the other.

____ 4. A large truck collides head-on with a small compact car. During the collision:
(A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
(B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
(C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
(D) the truck exerts a force on the car but the car does not exert a force on the truck.
(E) the truck exerts the same amount of force on the car as the car exerts on the truck.

APPENDIX B: STUDENT JOURNAL FOR

COMPUTER SIMULATIONS GROUPS

Student Journal

1. Birthdate _____ Initials _____

What color are you wearing? _____

2. Birthdate _____ Initials _____

What color are you wearing? _____

3. Birthdate _____ Initials _____

What color are you wearing? _____

Choose a recorder (initials of recorder)

____

Teacher
I can’t touch this chair without the chair in turn touching me.
I can’t exert a force on an object without that object exerting an equal force on me.
A force is a push or pull. Forces are in pairs.
There are two forces between two objects.
It does not matter if the forces are slight nudges or collisions.
When two objects touch, the forces are equal in the amount of force or magnitude.
The forces are in opposite directions.

Newton’s Third Law –definition: “For every action there is an equal but opposite reaction.”

Demo - wall – To show that the inanimate wall exerts a force in the opposite direction as you push against the wall.
The hand exerts a force on the wall; the wall exerts an equal force on the hand.
The force of the hand on the wall is in one direction; the force of the wall on the hand is in the opposite direction.
I am pushing on the wall.
What is the wall doing?
The force of the hand is in one direction.
The force of the wall is in the other direction.
One force is called the action force; the other force is called the reaction force.

Action - Hand exerts a force on wall Reaction – Wall exerts a force on hand
It does not matter which force is called action or reaction. You could write
Action - Wall exerts a force on hands Reaction – Hand exerts a force on wall

The important point is the forces are in pairs. Forces always exist in pairs.
The two forces are equal in strength of force.
The forces are in the opposite direction.

Do – students place a hand on the surface of the table
What is your hand doing?

What is the table doing?

Force of the hand on the table is in one direction
Force of the table on the hand is in the opposite direction.
Write action reaction pairs for the hand on the table?
Action – _____ exerts a force on the _____ Reaction – _____ exerts a force on ____
OR
Action – _____ exerts a force on the _____ Reaction – _____ exerts a force on _____

Objective: To compare the forces exerted by interacting objects on each other.

Fireman and the Door

Open power point –

Right click on website

Click on open hyperlink

The website will open up

Go to the following website

http://w3.shorecrest.org/~Lisa_Peck/Physics/syllabus/mechanics/newtonlaws/Ch6_3rd_

Law/ch6_hewitt/Source_Files/05_01_Hewitt_IF.swf

There is a fireman pushing on the door.
Click on **Show force of fireman on door.**
What did you observe?

Click on **Show force of fireman on floor.**
What did you observe?

Click on **Show forces of ground and door on fireman.**
What did you observe?

What do you observe about the length of the arrow of the fireman on the door compared to the length of the arrow of the door on the fireman?

What do the arrows stand for?

Why are the arrows pointing in opposite directions?

What do you observe about the lengths of the arrows of fireman on ground and force of ground on fireman?

What do the arrows mean?

Why are the arrows pointing in opposite directions?

A force is being applied to the door by the fireman. The door is applying a force on the fireman.

The forces are equal in magnitude or the amount of force is the same. The length of the arrows is the same. The length of the arrows demonstrates the amount of force.

A force is being exerted by the fireman's foot on the ground. The ground is exerting a force on the fireman's foot.
The arrows are the same length. The forces are equal in magnitude or the amount of force is the same.
What do you observe about the directions of the arrows?

The forces are equal in magnitude or amount of force (length of arrow) but the forces are being exerted in opposite directions.

The fireman is pushing on the door.   What is the door doing?

Write the action reaction statements:

Action - _____ exerts a force on _____   **Reaction** – _____ exerts a force on _______

You could have written either this:

Action - Hand exerts a force on door   Reaction – Door exerts a force on hand

Or this:

Action - Door exerts a force on hand   Reaction – Hand exerts a force on door

The fireman's foot is pushing against the ground.
What is the ground doing?

What directions are the arrows pointing?

Compare the length of the arrows. What can you say about the length of the arrows?

What can you say about the amount of force of the foot against the ground and the ground against the foot?

Write the action reaction statements:

Action - _____ exerts a force on ______   **Reaction** – _____ exerts a force on ______

Students should now perform the activities and answer the questions.

Go to the following website

http://webphysics.davidson.edu/course_material/py130/demo/illustration7_5.html

Open power point –

Right click on website

Click on open hyperlink

The website will open up

Impulse & Newton's Third Law
Computer simulation 1 demonstrates collisions between two spheres.

Simulation 1

Please wait for the animation to completely load.

Click on computer **simulation 1.**
Click on the **step>> button** and observe the two balls moving toward each other.

How does the size of the red ball compare to the size of the blue ball?

What did you observations about the size of the two green arrows?

What direction is the green arrow pointing for the blue ball?

What direction is the green arrow pointing for the red ball?

After the balls hit what happens to the red ball?

After the balls hit what happens to the blue ball?

What do you observations about the size of the two green arrows after the collision?

What direction is the green arrow pointing for the blue ball after the collision?

What direction is the green arrow pointing for the red ball after the collision?

Observe the graph.

Notice the blue area of the graph pertaining to the collision of the blue ball.
Notice the red area of the graph pertaining to the collision of the red ball.
How to the graphs compare?

Write a generalized statement concerning the amount of force of the blue ball on the red ball and the red ball on the blue ball during the collision.

What can you say about the force experienced by each ball during the collision?

Write the action reaction statements:

Action - _____ exerts a force on ______ **Reaction** – ______ exerts a force on _____

Now right the statements the opposite way:

Action - _____ exerts a force on ______ **Reaction** – ______ exerts a force on _____

Are the forces "cancelling" each other? (Hint: do the arrows disappear.)

What is your evidence for the forces not cancelling out?

The sizes of the graph are equal therefore the forces are?

The graphs are in different direction because the forces are what?

Forces are in ____________ directions but equal in _____________

Change recorders (initials of new recorder) _____

Go to the following website: http://phet.colorado.edu/en/simulation/forces-1d

Open power point –

Right click on website

Click on open hyperlink

The website will open up

Click on **Run Now**

Place the cursor on the file cabinet.

Try to drag the cabinet to the right.
Notice the blue and red arrows.
Compare the lengths of the red and blue arrows.

What generalized statement can you make about the sizes of the arrows.

What generalized statement can you make about the directions of the arrows.

Write the action reaction statements:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _____

Now right the statements the opposite way:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _____

Click on the **Graph Applied Force.**

Click on the file cabinet.

Try to drag the file cabinet to the right.
Stop before the cabinet starts to move.
Notice the blue and red numbers on the graph.
What generalized statement can you make about the size of the red graph and the size of the blue graph.

Record the blue number (applied force). _______________

Record the red number (friction force). _______________

What did you notice about the applied force and the friction force?

What did you notice about the red and blue graph?

What direction is the red arrow pointing compared to the blue arrow pointing?

Why is one graph up and the other graph down?

Write the action reaction statements:

Action - _____ exerts a force on _____ **Reaction** – _____ exerts a force on ______

Now right the statements the opposite way:

Action - _____ exerts a force on _____ **Reaction** – _____ exerts a force on ______

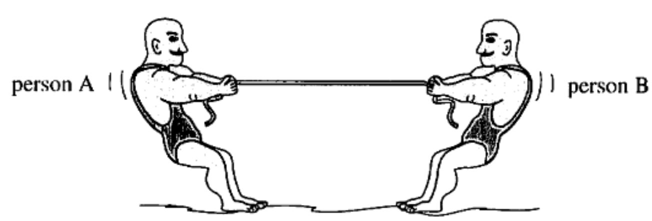
Are the forces "cancelling" each other? (Hint: the graph)

What is your evidence for your answer?

Prediction

Examine the forces each person exerts on the other in a tug of war.

Suppose that you have a tug-of-war with someone who is the same size and weight as you. You each both pull as hard as you can, and it is a standoff. One of you might move a little in one direction or the other, but mostly you are both at rest or where you started.



Predict the relative magnitudes of the forces between person A and person B. Place a check next to your prediction.

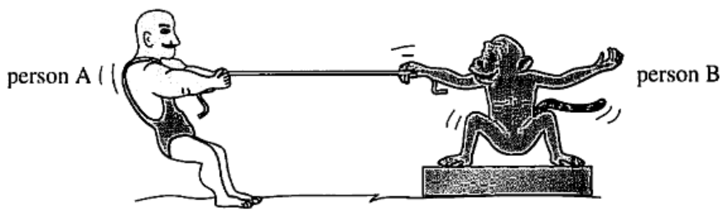
___ Person A exerts a larger force on person B.

___ The people exert the same size force on each other.

___ Person B exerts a larger force on person A.

Prediction

Suppose now that you have a tug of war with someone who is much smaller and lighter than you. As before, you both pull as hard as you can and it is a stand-off. One of you might move a little in one direction or the other.



Predict the relative magnitudes of the forces between person A and person B. Place a check next to your prediction.

___ Person A exerts a larger force on person B.

___ The people exert the same size force on each other.

___ Person B exerts a larger force on person A.

Gravity Force Lab

http://phet.colorado.edu/en/simulation/gravity-force-lab

Open power point –

Right click on website

Click on open hyperlink

The website will open up

Click on Run Now
Record the amount of force of m2 (red) by m1 (blue) ________________
Record the amount of force of m1 (blue) by m2 (red) _________________
Which sphere is larger?

Click on the red sphere.
Drag the front of the red sphere from 4m to 3m.
Record the amount of force or magnitude of the force on m2 by m1. ________
Record the amount of force or magnitude of the force on m1 by m2. _________

Make a statement about the amount of force for m1 and m2.

Notice the black arrows. What directions do the arrows point?

Write a generalized statement about the size of the arrows.

Write an action reaction statement.

Action - _____ exerts a force on ______ **Reaction** – _______ exerts a force on ______

Which direction is the arrow pointing for force on m2 by m1?

Which direction is the arrow pointing for force on m1 by m2?

Write a statement about the direction of the forces.

Drag the front of the red sphere as close as you can without touching the blue sphere.
Record the amount of force or magnitude of the force on m2 by m1. ________

Record the amount of force or magnitude of the force on m1 by m2. _________

Make a statement about the amount of force for m1 and m2.

Write an action reaction statement.

Action - _____ exerts a force on ______ **Reaction –** _____ exerts a force on ______

Which direction is the arrow pointing for force on m2 by m1?

Which direction is the arrow pointing for force on m1 by m2?

Write a statement about the direction of the forces.

Click on **Reset All.**
Watch the arrows as you drag the red sphere closer to the blue sphere.
Make a generalized statement concerning the size of the arrows.

The blue sphere is larger. Does the size of the object affect the size of the force?

The arrows are always the pointing in the __________ direction (same or opposite)

Why are the arrows the same length?

Whenever one object exerts a force on a second object, the second object exerts a force on the first object. The two forces are equal and opposite.

The rocket is burning fuel. The escaping air is the force. The air speeding out the back end of the rocket applies an opposite reaction force to the rocket, moving the rocket forward.

Exhaust exits from the back of the rocket. The exhaust acts on the rocket pushing it upwards. The rocket has an equal and opposite action on the exhaust, expelling it forwards.

Write the action reaction statements for a rocket:

Action - _____ exerts a force on _____ **Reaction** – _____ exerts a force on ______

Now right the statements the opposite way:

Action - _____ exerts a force on _____ **Reaction** – _____ exerts a force on ______

A soccer player kicks the ball. The force to the ball reacts by pushing back against the player's foot. The soccer player feels pressure on his foot when he kicks the ball.

Write the action reaction statements:

Action - _____ exerts a force on ______ **Reaction** – ______ exerts a force on _____

Now right the statements the opposite way:

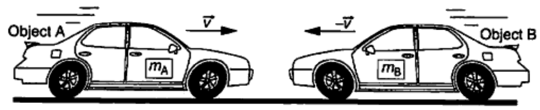
Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on ______

Which exerts a greater force the foot on the ball or the ball on the foot? (Arrows are always the same length)

Change recorders (initials of new recorder) _____

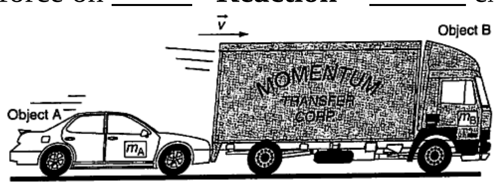
Predictions concerning Collisions
In this investigation we want to compare the forces exerted by the objects on each other during a collision.

1. What can we say about the forces two objects exert on each other during a collision?
a. Prediction Suppose two objects have the same mass and are moving toward each other at the same speed but in opposite directions.



Predict the magnitudes of the forces between object A and object B during the collision. Place a check next to your prediction.
________ Object A exerts a larger force on object B.
________ The objects exert the same size force on each other.
________ Object B exerts a larger force on object A.
Write the action reaction statements:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on ____



At first the car doesn't push hard enough to make the truck move. Then, as the driver pushes harder on the gas pedal, the truck begins to accelerate. Finally, the car and truck are moving along at the same constant speed.
Place a check next to your predictions of the relative magnitudes of the forces between objects A and B.
Before the truck starts moving:
_____ the car exerts a larger force on the truck.
_____ the car and truck exert the same size force on each other.
_____ the truck exerts a larger force on the car.
Write the action reaction statements:

Action - _____ exerts a force on _____ **Reaction** – _____ exerts a force on ______

While the truck is accelerating:
_____ the car exerts a larger force on the truck.
_____ the car and truck exert the same size force on each other.
_____ the truck exerts a larger force on the car.
Write the action reaction statements:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _______

After the car and truck are moving at a constant speed:

______ the car exerts a larger force on the truck.
______ the car and truck exert the same size force on each other.
______ the truck exerts a larger force on the car.
Write the action reaction statements:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on ______

What general statement can you make concerning forces and Newton's Third Law?

Smaller car pushing the larger truck
Go to the following Newton's Third Law website
http://sites.google.com/site/physicsflash/home/third-law
Open power point –

Right click on website

Click on open hyperlink

The website will open up

There might be a box at the bottom of the screen. Click on the box (pop up) to

open the program

Click on **Play** and watch the car push the truck.
What did you observe about the directions of the red and blue arrows?

Click on **restart** and then click on **play** and observe the length of the arrows.
What did you observe about the length of the red and blue arrows?

What does the length of the arrows means?

Is the size of the car and the truck the same?

Does the size of the object matter in the size of the force?

How does the length of the arrows compare?

Change the size of the force car and the mass of the box by moving the scale up or down in the top right corner.

Can one object exert a force on another without the second object exerting a force on the first?

What general statement can you make about forces?

What general statement can you make about the direction of forces?

Write the action reaction statements:

Action - _____ exerts a force on **_____**

Reaction – **______** exerts a force on **______**

APPENDIX C: STUDENT JOURNAL FOR HANDS-ON LABORATORY INVESTIGATIONS ACTIVITIES

Student Journal

1. Birthdate _____ Initials _____

What color are you wearing? _____

2. Birthdate _____ Initials _____

What color are you wearing? _____

3. Birthdate _____ Initials _____

What color are you wearing? _____

Choose a recorder (initials of recorder)

____

Teacher
I can't touch this chair without the chair in turn touching me.
I can't exert a force on an object without that object exerting an equal force on me.
Forces are in pairs.
There are two forces between two objects.
It does not matter if the forces are slight nudges or collisions.
When two objects touch, the forces are equal in the amount of force or magnitude.
The forces are in opposite directions.

Newton's Third Law –definition: "For every action there is an equal but opposite reaction."

Demo - wall – To show that the inanimate wall exerts a force in the opposite direction as you push against the wall.
The hand exerts a force on the wall; the wall exerts an equal force on the hand.
The force of the hand on the wall is in one direction; the force of the wall on the hand is in the opposite direction.
I am pushing on the wall.
What is the wall doing? (pushing back with an equal force)
The force of the hand is in one direction.
The force of the wall is in the other direction. Opposite directions.

One force is called the action force; the other force is called the reaction force.

Action - Hand exerts a force on wall Reaction – Wall exerts a force on hand
It does not matter which force is called action or reaction. You could write
Action - Wall exerts a force on hands Reaction – Hand exerts a force on wall

The important point is the forces are in pairs. Forces always exist in pairs.
The two forces are equal in strength of force.
The forces are in the opposite direction.

Do – students place a hand on the surface of the table
What is your hand doing? (exerting a force on the table)
What is the table doing? (exerting a force on the hand – forces are equal)
Force of the hand on the table is in one direction
Force of the table on the hand is in the opposite direction.
Write action reaction pairs for the hand on the table?

Action – ____ exerts a force on the ____ Reaction – ____ exerts a force on ____

OR

Action – _____ exerts a force on the _____ Reaction – _____ exerts a force on _____

Objective: To compare the forces exerted by interacting objects on each other.

Rubber Bands and Spring Scales Lab
A force is a push or pull.
All individual forces can be traced to an interaction between one object and another object.
In this investigation we will compare the forces exerted by objects interacting with each other.
Hold a green rubber band between your right and left hands. Gently pull with your left hand. Does your right hand experience a force?

Does your right hand apply a force to the rubber band? (Hint: Does the rubber band get smaller?)

How do you know the right hand applies a force?

Is the rubber band moving to the right or the left?

What is the direction of the force applied by the rubber band on your right hand?

What is the direction of the force applied by the rubber band on your left hand?

Does the magnitude of the forces applied by the rubber band on each hand feel the same?

The forces are equal and opposite.
Write the action reaction statements:
Action - _____ exerts a force on ______ **Reaction** – _____ exerts a force on ______

Now right the statements the opposite way:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _______

Are the pulling forces "cancelling" each other? (Do you feel a force even though the forces are in the opposite directions?)

Now hold a rubber band between your right hand and a white spring scale. Pull gently with your right hand.
Does your right hand experience a force?

How do you know?

Does your right hand apply a force to the rubber band?

How do you know?
What direction is the force of the right hand compared to the force applied by the spring scale?

Read the spring scale. Read the scale with the **N**. Record the amount of force? ________

The forces are equal and opposite. What is the amount of force applied by your right hand?

Does the magnitude of the forces applied by the rubber band on each hand feel the same?

Write the action reaction statements:
Action - _____ exerts a force on _____ **Reaction** – _____ exerts a force on ______

Now right the statements the opposite way:
Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _____

Now place the rubber band between two spring scales. Pull gently.
Record the readings of the two spring scales. (Make sure you read the N (newtons) scale

How do you know the forces are equal in amount?

How do you know the forces are in opposite directions?

Write the action reaction statements:
Action - _____ exerts a force on ______ **Reaction** – _____ exerts a force on _____

Now right the statements the opposite way:

Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _______

Stretch a rubber band between your thumb and first finger. Which is pulling with the greater force, the thumb or the finger?

As you increase the stretch which side is being pulled with more force toward the other; the thumb toward the finger? Or the finger toward the thumb? (Hint: the readings on the spring scale)

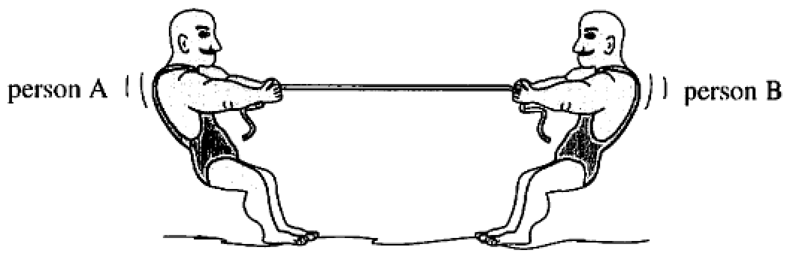
Write the action reaction statements:
Action - _____ exerts a force on _____ **Reaction –** _____ exerts a force on ______

Now right the statements the opposite way:
Action - _____ exerts a force on _____ **Reaction –** ______ exerts a force on ______
Are the pulling forces "cancelling" each other?

Explain. (Hint: Do the forces disappear?)

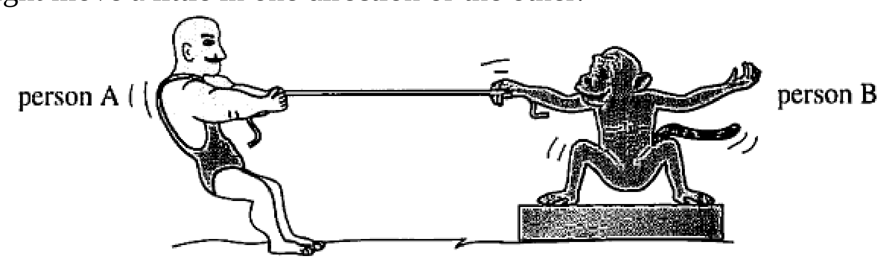
Predictions

Examine the forces each person exerts on the other in a tug of war.
Suppose that you have a tug-of-war with someone who is the same size and weight as you. You each both pull as hard as you can, and it is a standoff. One of you might move a little in one direction or the other, but mostly you are both at rest or where you started.



Predict the relative magnitudes of the forces between person A and person B. Place a check next to your prediction.
___ Person A exerts a larger force on person B.
___ The people exert the same size force on each other.
___ Person B exerts a larger force on person A.

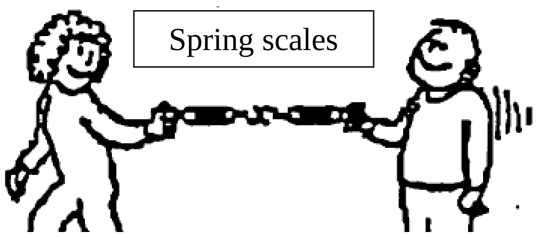
Suppose now that you have a tug of war with someone who is much smaller and lighter than you. As before, you both pull as hard as you can and it is a stand-off. One of you might move a little in one direction or the other.



Predict the relative magnitudes of the forces between person A and person B. Place a check next to your prediction.
___ Person A exerts a larger force on person B.
___ The people exert the same size force on each other.
___ Person B exerts a larger force on person A.

Change recorders (initials of new recorder) _____

Tug of War Lab
Materials: Rope, yellow spring scales
Do not pull too hard or you could damage the spring scales.
1. Hook two spring scales together. Gently pull on **one** of the spring scales like in the diagram.



Record the amount of force or magnitude from one of the spring scale. _________

Now record the magnitude or the amount of force from the other spring scale. ________

What can you tell me about the two numbers?

How did the two forces (pulls) compare to each other?
Was one pull force significantly different from the other pull force in direction?

Can you and your partner pull in a way that will produce a higher reading on one scale than the other? (Gently pull the spring scales. Be careful not to pull too hard.)

Can you and your partner pull in a way that will produce a reading of zero on one scale but not on the other?

Explain your answer.

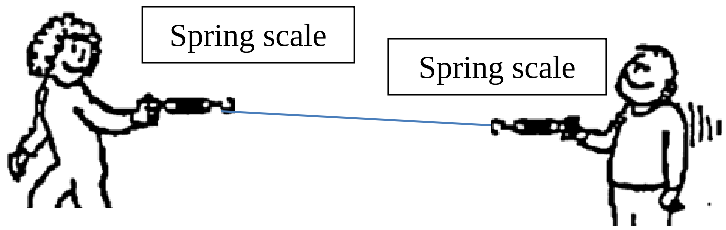
How did your observations compare to your predictions?

Are the pulling forces "cancelling" each other?   What is your evidence for your answer? (Do the forces disappear?)

What is the direction of the force on the spring scale on the right?

What is the direction of the force on the spring scale on the left?

2. Now add a piece of rope between the two spring scales.
Gently pull the spring scales.



Gently pull on **one** of the spring scales.
Record the amount of force or magnitude of the spring scale. _________
Now record the magnitude or the amount of force from the other spring scale. ________

How did the two readings from the spring scales compare to each other in force or magnitude?

Was one pull force significantly different in direction from the other pull force?
How did your observations compare to your predictions on page 7?

Can you pull harder on your spring scale and get a larger number than the table? **(Be careful not to pull to hard.)**

What is the direction of the force applied by the right hand?

What is the direction of the force applied by the left hand?

3. Gently pull on **both** of the spring scales at the same time.
Do not pull to hard or you could damage the spring scales.
Record the amount of force or magnitude for each spring scale. ________ __________

How did the two pulls compare to each other in force or magnitude?

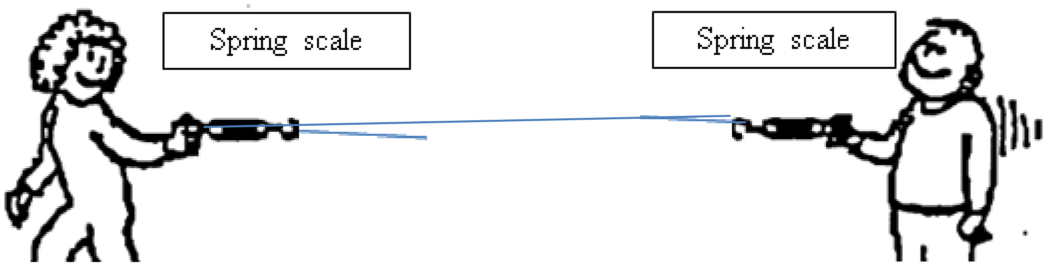
Was one force significantly different from the other force?

How did your observations compare to your predictions?

4. **Make a prediction -** Does it matter how long the rope is? Record your groups' thoughts.

Get a longer piece of rope.

Attach the two spring scales to the ends of the rope.



Pull on each side of the rope.
Record the amount of force or magnitude of each spring scale. _______ __________

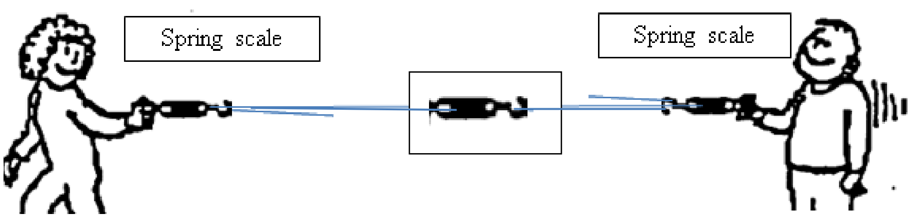
What did you find out?

What is the direction of the force on the spring scale on the right?

What is the direction of the force on the spring scale on the left?

5. **Make a prediction** - Does it matter if a spring scale is added between the two long ropes? Record your groups thoughts.

Add another segment of rope and another spring scale.



Attach a spring scale in the middle of the two ropes. There are still two spring scales attached on the ends.
Gently pull on each side of the spring scale.
Record the amount of force or magnitude of each spring scale.

__________ __________ _____________

What did you find out? Does it matter how long the rope is?

Change recorders (initials of new recorder) _____

6. **Make a prediction -** Does it matter if a spring scale is attached to a table instead of a person? Record your thoughts.

Take a piece of rope and attach the rope to the table leg. Place a spring scale on the opposite end of the rope.
You are holding on to the spring scale.
Record the magnitude of the force from the spring scale. ___________
Predict what a second spring scale would read if the spring scale was attached between the rope and the table.

Does the table pull back as you pull on the spring scale?

Does it matter if the spring scale is held by a person or attached to the table?

Will the magnitude of force reading be different for each spring scale?

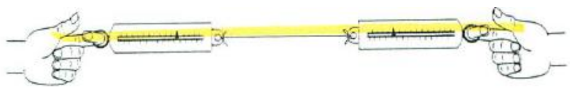
What can you conclude about the two forces (your pull on the rope and the table's pull on you)?

Can you pull harder on your spring scale and get a larger number than the table?
Why?

Are the pulling forces "cancelling" each other?   What is your evidence for your answer?

What is the direction of the force on the spring scale side?

What is the direction of the force on the table side?
What statement can you make about the direction of the forces?



Write the action reaction statements:

Action - _____ exerts a force on _____   **Reaction** – ______ exerts a force on ________

Now right the statements the opposite way:

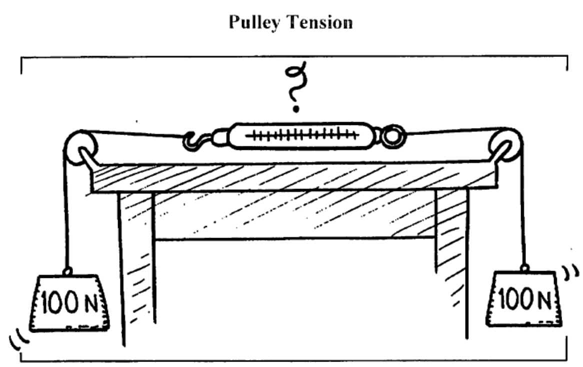
Action - _____ exerts a force on _____   **Reaction** – ______ exerts a force on ________

Write a statement below about your observations.

Prediction:
A soccer player kicks the ball. The force to the ball reacts by pushing back against the player's foot. The soccer player feels pressure on his foot when he kicks the ball.
Write the action reaction statements:
Action - _____ exerts a force on _____ **Reaction** – ______ exerts a force on _______

Now right the statements the opposite way:
Action - _____ exerts a force on ______ **Reaction** – ______ exerts a force on _______

What is the reading of the spring scale in the middle of the rope in the diagram below?



a. What is the magnitude of the force that the spring scale is exerting on the left?

b. What is the magnitude of the force that the spring scale is exerting on the right?

c. What is the direction of the force that the spring scale is exerting on the left?

d. What is the direction of the force that the spring scale is exerting on the right?

Balloon Lab
Blow up a balloon and hold the balloon close. Let go of the balloon.
Record your observations.

Which way did the air escape?

Which way did the balloon move?

Write the action reaction statements:

Action - _____ exerts a force on ______ **Reaction** – _____ exerts a force on ______

The action reaction pair is shown by the arrows, draw in the other arrow and write the reaction.

Fist hits wall

Wall hits fist

Head bumps ball

____

Hand touches nose

____

APPENDIX D: TELPAS RATINGS FOR THE TOTAL NUMBER OF PARTICIPANTS USED FOR RANDOM NUMBER GENERATOR, LISTED IN ORDER OF PARENTAL CONSENT FORM RECEIVED

	Birthday Initials	Gender	TELPAS Rating	Grade	Random Assignments
1	8/21/1994 JR	M	Spanish AH	10	CS-5
2	5/2/1994 JC	M	Spanish AH-3.6	12	CS-2
3	12/19/1995 JD	M	Dutch/Flemish-I	11	H-3
4	4/26/1996 MM	F	Spanish AH-3.9	11	CS-6
5	6/3/1994 AV	M	Spanish AH	12	H-2 (H-7)
6	3/13/1998 QN	F	Vietnamese A	9	CS-7
7	3/9/1996 OR	F	Thai I-1.8	10	H-4 (No Show)
8	10/2/1994 IRA	F	Spanish A-3.7	11	H-3 (H-7)
9	5/30/1997 CH-C	M	Spanish AH-3.6	10	CS-3
10	8/20/1996 KG	M	Spanish AH-3.6	10	H-7 (No Show)
11	12/29/1994 SA	M	French I-2.1	11	H-2
12	10/27/1996 AS	F	Spanish AH	9	CS-4
13	8/5/1993 DC	M	Spanish A-2.9	12	H-6 (No Show)
14	2/3/1996 DC	M	Spanish AH-3.7	11	CS-7
15	10/5/1995 FZ	F	Spanish B-1.2	12	H-1
16	7/27/1998 MCG	F	Spanish AH	9	CS-7
17	4/12/1997 JH	M	Spanish A-3.0	10	H-1
18	10/24/1997 JG	M	Spanish A-2.9	10	CS-3
19	12/30/1995 IR	F	Spanish A-2.9	10	CS-4
20	6/16/1998 VB	M	Spanish B-1.2	9	H-7 (No Show)
					continue

	Birthday Initials	Gender	TELPAS Rating	Grade	Random Assignments
21	1/10/1996 AG	F	Russian-I	11	H-3 (H-5)
22	3/9/1996 AA	M	Spanish AH-3.1	R-9	CS-2
23	7/12/1999 JF	M	Spanish AH	9	H-4 (No Show)
24	11/24/1995 MS	F	Spanish AH-3.9	10	CS-3
25	9/16/1996 LZ	M	Spanish A-3.1	10	H-2 (H-6)
26	5/19/1994 NR	F	Spanish AH-3.9	12	CS-6
27	5/20/1994 RR	M	Spanish AH-3.9	11	CS-5
28	1/6/1994 IS	M	Spanish AH-3.9	12	H-5 (No Show)
29	3/5/1995 ML	M	Spanish AH-3.6	R-10	CS-2
30	12/30/1994 EM	M	Spanish I-2.0	10	CS-5
31	5/9/1996 MP	F	Spanish AH-3.6	10	H-4 (No Show)
32	10/13/1994 MJM	F	Spanish A-2.8	11	CS-1
33	12/16/1997 MM	M	Spanish I	9	H-3 (H-7)
34	12/2/1994 DC	F	Spanish I-2.0	12	H-3
35	5/14/1996 AB	F	Spanish A-2.9	11	CS-4
36	6/30/1994 JR	M	Spanish A	12	H-5 (No Show)
37	5/23/1994 EH	F	Spanish AH-3.8	12	CS-1
38	7/23/1996 JC	M	Spanish AH-3.9	11	H-1
39	6/24/1996 JH	F	Spanish AH	9	H-6 (No Show)
40	6/29/1997 SGR	F	Spanish AH-3.9	10	CS-3
41	2/8/1995 KA	F	Spanish B-1.2	11	CS-7 (No Show)
42	9/12/1994 JP	F	Spanish AH-3.6	11	H-3
43	12/11/1993 WM	M	Spanish A-2.8	11	H-2
44	5/7/1994 CR	F	Spanish AH-3.9	12	CS-1

APPENDIX E: TELPAS AVERAGE RATINGS FOR COMPUTER SIMULATIONS LEARNERS

Participant	TELPAS Average Rating	Grade	Language Chosen for Pretest	Language Chosen for Posttest
5/7/1994 CR	Spanish AH-3.9	12	E	E
5/23/1994 EH	Spanish AH-3.8	12	E	S
10/13/1994 MJM	Spanish A-2.8	11	E	E
5/2/1994 JC	Spanish AH-3.6	12	E	E
3/9/1996 AA	Spanish AH-3.1	R-9	E	E
3/5/1995 ML	Spanish AH-3.6	R-10	S	S
11/24/1995 MS	Spanish AH-3.9	10	E	E
5/30/1997 CH-C	Spanish AH-3.6	10	S	S
10/24/1997 JG	Spanish A-2.9	10	S	E
5/14/1996 AB	Spanish A-2.9	11	S	S
10/27/1996 AS	Spanish AH	9	E	S
12/30/1995 IR	Spanish A-2.9	10	S	E
5/20/1994 RR	Spanish AH-3.9	11	E	E
8/21/1994 JR	Spanish AH	10	E	E
12/30/1994 EM	Spanish I-2.0	10	S	S
4/26/1996 MM	Spanish AH-3.9	11	S	E
6/29/1997 SGR	Spanish AH-3.9	10	E	E
5/19/1994 NR	Spanish AH-3.9	12	E	E
7/27/1998 MCG	Spanish AH	9	S	S
3/13/1998 QN	Vietnamese A	9	E	E

APPENDIX F: TELPAS AVERAGE RATINGS FOR THE HANDS-ON LABORATORY INVESTIGATIONS LEARNERS

Participant	TELPAS Average Rating	Grade	Language Chosen for Pretest	Language Chosen for Posttest
7/23/1996 JC	Spanish AH-3.9	11	S	E
10/5/1995 FZ	Spanish B-1.2	12	S	S
4/12/1997 JH	Spanish A-3.0	10	S	S
12/11/1993 WM	Spanish A-2.8	11	S	S
6/3/1994 AV	Spanish AH	12	E	E
9/16/1996 LZ	Spanish A-3.1	10	E	E
12/19/1995 JD	Dutch/Flemish-I	11	E	D
10/1/1996 AG	Russian-I	11	R	R
10/2/1994 IRA	Spanish A-3.7	11	E	E
12/16/1997 MM	Spanish I	9	E	E

APPENDIX G: COMPUTER SIMULATIONS ELEMENTS USED TO DESCRIBE ELLS' CONCEPTUAL DEVELOPMENT OF NEWTON'S THIRD LAW

Computer Simulations	+3	+2	+1	0
Fireman and Door				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
e. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Impulse and Newton's Third Law				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
d. Action reaction statements	Both statements written out	1½ statements written out	One statement written out	Less than one statement written out
			continue	

Computer Simulations	+3	+2	+1	0
e. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Man Pushing a Filing cabinet				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
d. Forces cancel	Correct answer			Wrong or no answer
e. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
f. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Predictions				
a. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Gravity Force Lab				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
			continue	

Computer Simulations	+3	+2	+1	0
c. Direction of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
e. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Predictions – Soccer				
a. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Predictions - Collisions				
a. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
b. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Predictions – Car Pushing Truck				
a. Prediction answered correctly	Correct answer			Wrong or no answer
b. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
c. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
			continue	

Computer Simulations	+3	+2	+1	0
Car and Truck Simulation				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correct	Some of the answers correct	Wrong or no answers
d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
e. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed

APPENDIX H: HANDS-ON LABORATORY INVESTIGATIONS ELEMENTS USED TO DESCRIBE ELLS' CONCEPTUAL DEVELOPMENT OF NEWTON'S THIRD LAW

Hands-on Laboratory Activities	+3	+2	+1	0
Rubber Bands				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
e. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Rubber Bands and Spring Scale				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
			continue	

e. Discussed concepts	All concepts discussed	Majority concepts discussed	Some concepts discussed	No concepts discussed
Hands-on Laboratory Investigations	+3	+2	+1	0
Predictions				
a. Discussed concepts	All	Most	Some	None
Spring Scales				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
d. Forces cancelling	Correct answe			Wrong or no answer
e. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
f. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Spring Scales and Rope				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
			continue	

d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
e. Discuss Concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed
Hands-on Laboratory Invest.	+3	+2	+1	0
Predictions – Add Third Spring Scale				
a. Discussed concepts	All	Most	Some	None
Prediction – Spring Scale/Table				
a. Prediction answered correctly	Both	One and half	One	None
b. Discussed concepts	All	Most	Some	None
Prediction – Soccer				
a. Prediction answered correctly	Correct answer			Wrong or no answers
b. Action reaction statement	Both	One and half	One	None
c. Discussed concepts	All	Most	Some	None
Balloon Laboratory				
a. Answered all the questions	All questions answered	Majority of the questions answered	Some of the questions answered	None of the questions answered
b. Magnitude of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
c. Direction of forces	Correct answers	Majority of the answers correc	Some of the answers correc	Wrong or no answers
d. Action reaction statements	Both statements written out	One and a half statements written out	One statement written out	Less than one statement written out
e. Discussed concepts	All concepts discussed	Majority of concepts discussed	Some concepts discussed	No concepts discussed