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Assessment of Student Knowledge of the Weak and Strong Nuclear Forces

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The University of Southern Mississippi

ASSESSMENT OF STUDENT KNOWLEDGE OF THE WEAK AND STRONG NUCLEAR FORCES

by

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

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ABSTRACT

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The purpose of this study was to determine if the use of active-learning activities to teach weak force and strong force to students enrolled in various courses at The University of Southern Mississippi, Hattiesburg campus and Gulf Park campus at different class times would increase their knowledge. There were eighty-six students that took part in this study. The study was conducted in the lab classes of an introductory astronomy survey course (AST 111), an introductory algebra-based physics course (PHY 112), and an introductory calculus-based physics course (PHY 202) during fall semester, 2014. Each class was randomly assigned as active-learning or direct instruction. A pretest followed by lecture was administered to all groups. The active-learning group performed four activities whereas the direct group watched a video irrelevant to the lesson. At the end of the lesson, the same post-test was given to all groups. Various statistical methods were used to analyze the differences in mean pretest and posttest scores. Overall, results show that the mean posttest scores were higher than the mean pretest scores. Findings support the use of active-learning activities work to the small number of students or the equal number of students in a group. The mean posttest scores of the direct instruction classes were higher than those of the active-learning groups.

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May 2015

DEDICATION

Above all I would like to dedicate my parents, Mr. Surya Ratna Shakya and Mrs. Pragya Devi Shakya for their tremendous effort and support for my higher education. Also I am very grateful to my American parents Dr. William B. Arnett and Mrs. Delores Arnett for their great help and motivation so that I could pursue this goal. Last but not the least, I am thankful to my husband and children, Dr. Biju Bajracharya, son Yeju and daughter Yomah for the sacrifices they had to go through.

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I am and remain in his awesome, brilliant shadow.

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LIST OF ABBREVIATIONS

AST	- Astronomy
AST 111	- An introductory astronomy survey course
df	- Degrees of Freedom
FCI	- Force Concept Inventory
GPC	- Gulf Park Camus
IRB	- Institutional Review Board
NumPy	- Fundamental Package for Scientific Computing in Python
PH	- Physics
PHY112	- an introductory algebra-based Physics course
PHY202	- an introductory calculus-based Physics course
Python	- A Computer Programming Language
SCALE-UP	- Student-Centered Activities for Large Enrollment Undergraduate Physics
SciPy	- An Open Source Scientific Python Library
SH	- Science and Humanity
USM	- The University of Southern Mississippi

CHAPTER I

INTRODUCTION

At the most basic of levels, physics can be described as the study of how objects and substances maintain or change their states. For example, mechanics often concerns itself with how the state of an object's motion (velocity) can be changed by speeding it up, slowing it down, or making it turn. In this context, a "force" in physics was how nature supplies a change – gravity can make an object fall, or static electricity on a balloon can make a person's hair stand out. High school and college physics courses tend to examine these basic forces and their interactions. Other physical science courses, such as astronomy, are even more restrictive, usually only covering those portions of physics with direct consequences (such as gravity's role in determining how planets orbit the Sun) for the topic at hand.

An everyday force-like friction between two surfaces or tension in a rope can ultimately be broken down into a combination or application of simpler, more basic forces. By contrast, gravity and electromagnetism (the combination of electricity and magnetism) are considered by physicists to be "fundamental;" that is, they cannot be broken down in this fashion.

However, physicists also recognize two other fundamental forces, which are called the weak nuclear force and the strong nuclear force. The weak force was evident via radioactive decay of isotopes such as carbon-14 or uranium-238, and brought itself into public consciousness at Hiroshima. The strong force was responsible for nuclear fusion, such as that which occurs in the even more destructive hydrogen bombs and the source of energy in the core of the Sun. But because the actual operations of the weak and strong forces happen at the scale of atomic nuclei, they are more difficult to observe directly. Furthermore, they were both discovered and elucidated more recently than gravity and electromagnetism. For these reasons, typical high school and college introductory physics and astronomy courses give them little attention, if they cover them at all.

The purpose of this study was to create a set of lessons regarding the weak and strong nuclear forces, teach them to various college physics and astronomy students, and assess the results. As part of the investigation, we also considered differences in knowledge gains between traditional (lecture-oriented) instruction and guided inquiry (active-learning) instruction. We hope to create and show others how to implement lessons that can teach these otherwise-ignored, though important, topics in physics to introductory college-level students.

Constructivism was a theory adopted by various educational scientists and researcher about how humans learn and interpret the knowledge they receive from teachings and interactions with their own experiences and realities. Fosnot (Twomey Fosnot, 1989) defines constructivism by reference to four principles: learning, in an important way, depends on what we already know; new ideas occur as we adapt and change our old ideas; learning involves inventing ideas rather than mechanically accumulating facts; and meaningful learning occurs through rethinking old ideas and coming to new conclusions about new ideas which conflict with our old ideas. A productive, constructivist classroom, then, consists of learner-centered, active instruction. In such a classroom, the teacher provides students with experiences that allow them to hypothesize, predict, manipulate objects, pose questions, research, investigate, imagine, and invent. The teacher's role is to facilitate this process (Gray, n.d.).

In the mid- and latter-twentieth century, Jean Piaget and Jerome Bruner were among the leaders in forwarding the constructivist subset of cognitive theory. Bruner posited that discovery leads one to become a constructionist (Anglin, 1973). Processing stimuli from a problem that has been presented and working to a solution fundamentally leads to learning in the problem solver. Learning occurs as the solution was discovered. This learning requires that certain facts must already be known, but the discovery leads to new insights concerning the relationship between various facts that are known (Evans, Bonura, & Vehec, 2007). Constructivists emphasize that individuals build new meanings upon previous meanings that they have acquired through life experiences (Cox-Petersen, A. M., & Olson, J. K., 2000). Constructivist teaching fosters critical thinking and creates active and motivated learners. Zemelman, Daniels, and Hyde (Zemelman, S., Daniels, H., & Hyde, A., 1993) tell us that learning in all subject areas involves inventing and constructing new ideas. They suggest that constructivist theory be incorporated into the curriculum, and advocate that teachers create environments in which children can construct their own understandings. Fosnot (Twomey Fosnot, 1989) recommends that a constructivist approach be used to create learners who are autonomous, inquisitive thinkers who question, investigate, and reason. A constructivist approach frees teachers to make decisions that will enhance and enrich students' development in these areas (Gray, n.d.).

Knowledge is something that was acquired by an individual who undergoes training or was educated via traditional classroom teaching methods or other types of methods including digital media, online classroom, practical experiments, etc. There are several definitions of knowledge. The Oxford Dictionary defines it as facts, information, and skills acquired by a person through experience or education; the theoretical or practical understanding of a subject. Knowledge is derived from information, but it is richer and more meaningful than information. It includes familiarity, awareness, and understanding gained through experience or study, and results from making comparisons, identifying consequences, and making connections (What is Knowledge, n.d).

An individual who undergoes training or education needs to be assessed to find out how much he/she was influenced or impacted by the training. The change in his knowledge, skill, disposition or ability to apply theory was called learning and development. For quantitative or qualitative evaluation, how much he/she was impacted from the teaching or learning processes, an institution or faculty has to undergo assessment which consequently proposes or provides the solutions to improve teaching or learning methods. Assessment was a tool to gauge the outcome of the teaching or learning processes. There was no specific definition of the assessment. The different authors have defined it in various ways.

Assessment was the process of gathering information using various methods to systematically gauge the effectiveness of the institution and academic programs to document student learning, knowledge, behaviors, and skills as a result of their collegiate experiences (What is Assessment, n.d.). Palomba and Banta (Palomba, C., & Banta, T., 1999, p. 4) state that "assessment was the systematic collection, review, and use of information about educational programs undertaken for the purpose of improving student learning and development." Bachman states that "assessment can draw information from a wide range of elicitation, observation and data collection procedures, including multiple-choice tests, extended responses such as essays and portfolios, questionnaires and observations (Bachman, 2004). The results of assessment can be reported both quantitatively, as numbers, such as tests, scores, ratings or rankings and qualitatively, as verbal, descriptions, or as visual or audio image." The Walvoord defines assessment as "the systematic collection of information about student learning, using the time, knowledge, expertise, and resources available, in order to inform decision about how to improve learning" (Walvoord, 2010, p. 2).

Assessment means basing decisions about curriculum, pedagogy, staffing, advising, and student support upon the best possible data about student learning and the factors that affect it (Walvoord, 2010). According to Thomas Angelo Assessment was "an ongoing process aimed at understanding and improving student learning. It involves making our expectations explicit and public; setting appropriate criteria and high standards for learning quality; systematically gathering, analyzing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain, and improve performance. When it was embedded effectively within our institutional system, assessment can help us focus our collective attention, examine our assumptions, and create a shared academic culture dedicated to assuring and improving the quality of higher education" (Angelo, 1995, p. 7).

Assessment was the process of gathering data. More specifically, assessment was the way instructors gather data about their teaching and their students' learning (Hanna & Dettmer, 2004). The most common teaching method was instructor-led or classroom teaching, including several activities like pre-tests, observations and examinations. The data gathered from these activities usually ends up in the grading of student course work. But assessment should be done in every day classroom activities, which should properly recognize the student's weaknesses and strengths. Based on these different activities of assessment, assessment can be divided into three categories: diagnostic, formative, and summative assessment.

Diagnostic assessment, also known as pre-assessment, was the identification of students' current knowledge of a subject, their skill sets and capabilities before undergoing learning processes. This will provide a baseline for understanding how much learning has taken place after undergoing learning processes. Not only this, it will also give a better plan of what to teach and how to teach it. The types of diagnostic assessment are (Mickelsen, 2012-13.):

- Pre-tests (on content and abilities),
- Self-assessments (identifying skills and competencies),
- Discussion board responses (on content-specific prompts),
- Interviews (brief, private, 10-minute interview of each student)

Formative assessments take place during a learning activity to provide the instructor with information regarding how well the learning objectives of a given learning activity are being met (Diagnostic and Formative Assessment, n.d.). It gives knowledge about how well students understand specific course concepts or how well the instructor performs, which will give us the required improvements. Its objective was not the grading, but information gathered in this assessment was used to adjust the teaching and learning activities while they are happening. This ensures students achieve targeted learning goals and instructor was performing well. Types of Formative Assessment include (Mickelsen, 2012-13.):

- Observations during in-class activities of student's non-verbal feedback during lecture
- Homework exercises as review for exams and class discussions

- Reflection journals that are reviewed periodically during the semester
- Question and answer sessions, both formal-planned and informal-spontaneous
- Conferences between the instructor and student at various points in the semester
- In-class activities where students informally present their results
- Student feedback collected by periodically answering specific question about the instruction and their self-evaluation of performance and progress

Summative assessment takes place after the learning has been completed and provides information and feedback that sums up the teaching and learning process. Typically, no more formal learning was taking place at this stage, other than incidental learning which might take place through the completion of projects and assignments. Typically summative assessments are used as a part of the grading process at the end of the course or curriculum. Types of summative assessment are (Mickelsen, 2012-13):

- Examinations (major, high-stakes exams)
- Final examination (a truly summative assessment)
- Term papers (drafts submitted throughout the semester would be a formative assessment)
- Projects (project phases submitted at various completion points could be formatively assessed)
- Portfolios (could also be assessed during its development as a formative assessment)
- Performance
- Student evaluation of the course (teaching effectiveness)
- Instructor self-evaluation

Knowledge Assessments are conducted to help organizations obtain an indication of their health in terms of knowledge flow, knowledge creation and transfer, and ultimately knowledge management processes, strategies, and approaches. The knowledge assessment will most often identify performance gaps between what the organization was doing and what it should be doing, and highlight the gaps between what the organization currently knows and what it should know to perform at the desired level. The knowledge assessment will lead to a knowledge strategy, which in turn helps the organization develop knowledge management approaches and methods to close the gaps ("The Knowledge Assessment," n.d.).

Statement of the Problem

The purpose of this study was to determine if the use of the active-learning activities to teach weak force and strong force to the students enrolled in various courses at The University of Southern Mississippi, Hattiesburg campus and gulf park campus at different class time increases their knowledge.

Research Questions and Hypotheses

The data will be analyzed to address the following research questions and hypotheses:

Research Question 1

What was the impact of active-learning activities on students' knowledge of weak and strong nuclear force?

Specific Research Question 2: Are there differences between the pretest scores and posttest scores, regardless of method?

- H1: There will be no statistical difference between pretest and posttest scores, regardless of method.

Specific Research Question 3: Are there significant differences in pretest and posttest scores between students who participate in active-learning activities and students who do not participate in active-learning activities?

- H1: Research Hypothesis Three

There will be significant differences in pretest and posttest scores between students who participate in active-learning activities and students who do not participate in active-learning activities.

Specific Research Question 4: Does time of day influence in pretest scores and posttest scores of the students?

- H1: Research Hypothesis four

There will be significant differences in pretest and posttest scores between students who attend afternoon classes and those who attend the evening classes.

Delimitations

In this study, participants were students in an introductory astronomy survey course (AST 111), an introductory algebra-based physics course (PHY 112), and an introductory calculus-based physics course (PHY 202) from the University of Southern Mississippi, Hattiesburg and Gulf Park campus during fall semester 2014. Only data of those students who provided informed consent were used in the study.

Limitations

The population sample was the potential limitation of this study. Only eight lab classes were used for this study. The sample size of Gulf Park campus was very small (5 per class) for comparison between groups. The result of this study are limited to fall 2014 semester.

Assumptions

- It was assumed that the lectures delivered to various groups of students were of equal depth.
- It was assumed that students who participated in active-learning activities did not share or discuss the idea with students who were not participating in active-learning activities.
- It was assumed that students participated fully in the active-learning activities.
- It was assumed that students took time to answer tests accurately.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Active-learning is the term referring to several instruction models of learning. Several authors have used different meaning and approaches to define the active-learning. Bonwell and Eison's study (1991) states that active-learning is not just listening, but also reading, writing, discussing, or engaging in the problem solving skills. It points out that many instructors assert that all learning is inherently active and thus students are actively involved in listening to formal presentations in the classroom. It says that students who are actively involved must engage in higher-order thinking tasks such as analysis, synthesis and evaluation. It proposes that strategies promoting active-learning be defined as instructional activities involving students doing things and thinking about what they are doing.

Several research studies show that students give preference to the strategies of traditional lectures. However, other research studies show that for evaluating student's achievement, students' skills in thinking and writing should be developed; skills which can be enhance with active-learning strategies (Bonwell & Eison, 1991). One of the ways to modify the traditional lecture is to incorporate active-learning in the classroom.

Objectives and Strategies of Active-learning

Class discussion is one the most common strategies with an objective to promote long-term retention of information, to motivate students toward further learning, to allow students to apply information in new settings, or to develop students' thinking skills. To achieve these objective educators must be knowledgeable of alternative techniques and strategies for questioning and discussion and must create a supportive intellectual and emotional environment that encourages students to take risks. There are several other strategies that can influence favorably students' attitudes and achievement including visual-based instruction, interactive presentations, debate, drama, role playing and simulation and peer teaching (Bonwell & Eison, 1991).

In practice, these strategies have not been successfully executed because there is some barriers that resists on the adapting the changes on traditional strategies. So, it was necessary to identify and understand these barrier including the powerful influence of education tradition, faculty self-perceptions, and self-definition of roles, the discomfort and anxiety that change creates and the limited incentives for faculty to change. But there are certain specific obstacles associated with the use of active-learning including limited class time, a possible increase in preparation time, the potential difficulty of using the strategies in large classes, and lack of resource materials (Bonwell &, 1991). The single greatest barrier of all is the risk. Those risks may include students will not participating, faculty feeling a loss of control, or faculty being criticized for teaching in unorthodox ways. Although there are risks or barriers, active-learning can be successfully executed to get the desired outcome through careful and thoughtful planning.

To implement these strategies, it must begin with faculty members' efforts. An excellent first step could be by selecting strategies that promote active-learning that the instructor can feel comfortable. Such low-risk strategies can be easily executed which may be short duration, structured and planned focused on subject matter that was neither too abstract nor too controversial, and familiar to both the faculty member and the students. It should stimulate and support faculty members' efforts to change by highlighting the instructional importance of active-learning in various formats including the newsletters and publications. It should be the subject matter of faculty development workshops and the instructional method used to facilitate such programs. And it is important to provide follow-up and support for faculty members' efforts to change. Academic administrators can help these initiatives by recognizing and rewarding excellent teaching in general and the adoption of instructional innovations in particular. There is a need for more rigorous research to provide a scientific foundation to guide future practices in the classroom (Bonwell & Eison, 1991).

Most importantly, this research suggest to focus more on new qualitative and quantitative research concepts which has never been explored before which could significantly enhance the outcome of instructional methods and students' learning.

Methods of Active-Larning

There are several active-learning models that have been defined by several researchers. However, implementation of these models or strategies needs to be studied for their effectiveness.

Active-learning, through which students become active participants in the learning process, is an important means for development of student skills (Bonwell & Eison, 1991). During the use of active-learning processes, students participate in learning activities that encompass analysis, synthesis and evaluation as well as the exploration of values and attitudes. Although there was no common definition of active-learning, different educators or researchers have established their own working definition to promote active-learning strategies. Such strategies includes visual-based instruction, reading, writing, interactive classes, problem-solving, computer-based instruction, debates, drama, simulations, games, peer teaching, etc.

According to the research project SCALE-UP (Robert, n.d.), "Student-Centered Active-learning Environment for Undergraduate Programs", an active-learning environment is a place where student teams are given interesting things to investigate while their instructor roams—asking questions, sending one team to help another, or asking why someone else got a different answer. In this research model, every group of students are carefully structured into teams and given many opportunities to interact with each other and the instructor. Teams are labeled (labeled A, B, C etc.). Each sitting at a round table with white boards nearby and a laptop for searching the web. The majority of class time is spent on 10 or 15 minutes of hands-on activities, simulations, or interesting questions and problems. For science classes, there are usually some longer, hypothesis-driven lab activities where students write detailed reports. Social interaction between students and teachers appear to be the “active ingredient” that makes the approach work. This research model’s fundamental approach of active, collaborative, social learning has been reported in hundreds of studies. Physics, chemistry, math, biology, astronomy, engineering, and even literature courses have utilized this approach. The rooms look more like restaurants than classrooms. They are made more spacious and carefully designed to facilitate interactions between people. For larger classes, a teaching assistant provides additional help. The instructor typically wears a wireless microphone to make it easier to gain everyone’s attention for class-wide discussions. Often students working on an activity will skip their break in the middle of a two-hour class so they can continue “pondering” an intriguing question (Robert, n.d.).

There are several schools which have adopted this approach in general physics in teaching forces: Florida State, Florida International, Penn State-Erie, University of Pittsburg, Clemson, and North Carolina State (Robert, n.d.). They all report increased scores as measured by the Force Concept Inventory (FCI). At Florida State, normalized gains on from the first (Spring 2008) and second (Summer 2008) implementations of

General Physics were approximately 50%, far surpassing the typically seen 23% for traditional courses. Florida International University notes, “These courses have been extremely successful, in terms of student learning outcomes, faculty assessments, and recruiting. The average student performance on the FCI in the modeling-based [studio physics] courses was roughly a factor of 2.5 better than in our traditional courses.” At Penn State-Erie, over 550 students have enrolled in SCALE-UP physics, as of the summer of 2008. Scores on the FCI post-test have increased from an average score of 46%correct before SCALE-UP to 74% correct since SCALE-UP began. The University of Pittsburgh reports what they call “striking” gains on a test of electricity and magnetism concepts. Positive impacts are manifested in other areas as well. Chemistry faculty have published findings of learning gains. An internal report on the Engineering Statics course at Clemson reports (Schiff, n.d., p. 1), “One of the common concerns expressed by my colleagues was that I must not be covering as much material since I am using class time to complete activities. My response was that I cover the same amount of material as other instructors.” NC State notes the same situation in Physics. Biology learning was being studied at the University of Minnesota, Florida Gulf Coast University, and the University of Colorado.

Results showed that SCALE-UP students demonstrated better improvement in conceptual understanding than Lecture/Lab classes by achieving higher normalized gains for the Mechanics semester pre/post force and motion concept tests. FCI was the Force Concept Inventory developed by Hestenes, et al. FMCE was the Force and Motion Conceptual Evaluation developed by Thornton and Sokoloff. The FCI national average was from Hake’s 6,000 student study comparing Interactive Engagement classes with traditional Lecture/Laboratory classes.

Subatomic Approach of Weak and Strong Nuclear Forces

Physics, one of the oldest academic disciplines, is the science of underlying principles behind how things work in the universe. This subject has been studied and explored by several enthusiasts, scientists and researchers from the advent of science and philosophy. To understand how things work, a branch of physics called particle physics, deals with the nature of particles and their dynamics. The behavior or interactions of these particles was developed and summarized during the middle and late 20th century by the theory called Standard Model which corporates the electromagnetic, weak, and strong nuclear interactions that mediate the dynamics of the known subatomic particles. The current formulation of this model was finalized in the mid-1970s upon experimental confirmation of the existence of quarks. Since then, discoveries of the bottom quark (1977), the top quark (1995), and the tau neutrino (2000) have given further credence to the Standard Model (Standard Model, n.d.).

The Standard Model of particle physics is the quantum theory that includes the theory of strong interactions and the unified theory of weak and electromagnetic interactions. It was the collection of theories that describe the smallest experimentally observed particles of matter and the interactions between energy and matter. There are three categories of particles in matter: fermions, leptons, and bosons. Quarks and leptons are fermions. The fundamental bosons provide three forces: electromagnetism, the strong nuclear force and the weak nuclear force.

There are six particles in the quark group including: up, down, charm, strange, top and bottom. The lepton group includes the electron, muon, tau, electron neutrino, muon neutrino, and tau neutrino. The bosons include the photon, gluon, Z particle, W particle and the Higgs. Photon, gluon, Z particle and W particle are force carriers.

The distinction between quarks is referred to as flavor. Each of the flavors can have three colors, red, green, and blue. The antiquarks are colored anti-green, anti-red, and anti-blue. Mesons are quark-antiquark pairs, and are made up of three quarks. The quarks are held together by the gluons to form mesons and baryons (Rosenbaum, n.d.).

The extended standard model includes the gravitational force which constitutes the fundamental interactions. Thus, these fundamental interactions have been identified as four fundamental forces popularly named as the four fundamental forces of nature. The four fundamental forces of nature can be listed as below:

a) Strong Interaction
b) Electromagnetic Force
c) Weak Force
d) Gravitational Force

Strong Interaction

Strongest of the four fundamental forces, strong interaction is a very short range strong force which holds a nucleus together against the enormous forces of repulsion of the protons. Yukawa modeled the strong force as an exchange force in which the exchange particles are pions and other heavier particles. The range of a particle exchange force was limited by the uncertainty principle (Fundamental Forces, n.d.).

The strong force is responsible for keeping quarks together to form a nucleus holding together neutrons and protons. Neutrons and protons are neutral and positive charge particles. It uses gluons as its force carrier. The three valence quarks that make up each proton account for about one percent of its mass; the rest comes from interactions among the quarks and gluons (Walsh, 2012).

The proton and neutron attract each other by the exchange of subatomic particles called meson which is composed of one quark and one antiquark bound together by strong interaction. The quantum chromo dynamic theory states that the strong force is the color force, where color is like charge, but in this case there are three. Since the protons and neutrons which make up the nucleus are made from quarks, and the quarks are considered to be held together by the color force, the strong force between nucleons may be considered to be a residual color force. The individual gluons and quarks are contained within the proton or neutron and force between gluons does not diminish as they are separated, it was impossible to break apart a proton or a neutron.

Weak Force

Weak interactions involve the exchange of the intermediate vector bosons, the W and the Z which are responsible for the decay of massive quarks and leptons into lighter quarks and leptons result into changes from one flavor of quark into another. Therefore, all flavor changes are due to the weak interaction. During these changes, the total of mass and energy is conserved, some of the original particle's mass is converted into kinetic energy, and the resulting particles always have less mass than the original particle that decayed.

The role of the weak force in the transmutation of quarks makes it the interaction involved in many decays of nuclear particles which require a change of a quark from one flavor to another. It was in radioactive decay, such as beta decay, that the existence of the weak interaction was first revealed. The weak interaction was the only process in which a quark can change to another quark, or a lepton to another lepton - the so-called "flavor changes" (Fundamental Forces, n.d.).

The discovery of the W and Z particles in 1983 was hailed as a confirmation of the theories which connect the weak force to the electromagnetic force in electroweak unification. The weak interaction acts between both quarks and leptons, whereas the strong force does not act between leptons. "Leptons have no color, so they do not participate in the strong interactions; neutrinos have no charge, so they experience no electromagnetic forces; but all of them join in the weak interactions." (Griffiths, 2004, p. 65).

Properties of the Fundamental Forces (Steineker, 2010)

- The strong interaction is very strong, but very short-ranged. It acts only over ranges of order 10^{-13} centimeters and is responsible for holding the nuclei of atoms together. It is basically attractive, but can be effectively repulsive in some circumstances.
- The electromagnetic force causes electric and magnetic effects such as the repulsion between like electrical charges or the interaction of bar magnets. It is long-ranged, but much weaker than the strong force. It can be attractive or repulsive, and acts only between pieces of matter carrying electrical charge.
- The weak force is responsible for radioactive decay and neutrino interactions. It is a very short range force and, as its name indicates, it is very weak.
- The gravitational force is weak, but very long ranged. Furthermore, it is always attractive, and acts between any two pieces of matter in the Universe since mass is its source.

CHAPTER III

METHODOLGY

Introduction

The goal of this research was to evaluate whether the use of an active-learning lesson with four activities or a traditional lecture had on student learning. The four activities were designed to illustrate the concepts associated with weak nuclear force and strong nuclear force and were developed by a faculty member in the Department of Physics and Astronomy. The lesson was taught to undergraduate physics and astronomy students on the Hattiesburg and Gulf Coast campuses of The University of Southern Mississippi during fall semester 2014.

My research study was performed during a lab session of an introductory astronomy survey course (AST 111), an introductory algebra-based physics course (PHY 112), and an introductory calculus-based physics course (PHY 202). Individual classes were randomly selected to be either receive a traditional lecture or an active-learning lesson. To begin each session, the lab instructor took attendance and gave quizzes regarding their previous week's lab, which took 15 to 20 minutes. The lab instructor would then introduce me as that day's guest instructor and inform the students that I was conducting a research study on student understanding of the weak and strong nuclear forces.

For the traditional lecture sessions, I began by getting permission from the students for their participation in the study and had the students create 4-digit identification codes to be used for their pre-test, post-test, and activity sheets. The pre-test was given on student's understanding of the weak and strong nuclear forces (see

Appendix D). After the pre-test was collected, I gave a lecture about the weak and strong nuclear forces, followed by a video from the *Conceptual Physics* series by Paul G. Hewitt, which lasted about 1 hour. The post-test was given after the conclusion of the video, after which the students continued with their normal lab activities.

The Active-learning sessions began in the same fashion, with the substitution of an active-learning lesson rather than the showing of a video. The active lesson consisted of four activities (see Appendix D):

- The first activity simulated radioactivity via the flipping of coins. Students were given eight pennies. The pennies were flipped once, the coins showing “tails” were set aside and the number of coins remaining were recorded in a table. The process was repeated until all the coins had turned up tails.
- The second activity also simulated radioactivity, but used playing die rather than coins. Die showing six were set aside and the remaining number of die were recorded in a second table.
- The third activity simulated radioactivity by placing two carts on a track next to each other, one with extra mass added to it. A button was pushed on one of the carts that suddenly extended an arm, thereby pushing the carts apart.
- The fourth activity simulated nuclear fusion by pushing two carts together. The carts each had a set of magnets such that the carts would repel each other if left to themselves, but also duct tape that would hold them together if the pieces of tape could connect with each other. Students would push the carts together, at differing amounts of force, until the carts touched and stuck to each other.

About one hour (the same amount of time as the duration of the video in the direct instruction sessions) was given for students to complete the active lesson. After the completion of the active lesson, students were given the post-test, and then continued on with their normal lab activities.

Participants

The targeted group was undergraduate students, enrolled in physics and astronomy at the Hattiesburg and Gulf Park Campus (GPC) of The University of Southern Mississippi (USM): AST 111, PHY 112 and PHY 202. All participants were undergraduate students enrolled in the fall 2014 laboratory sessions at USM. The study was open for both males and females, physics and astronomy students. The multiple sections of each course were randomly assigned as direct lecture or active-learning group. AST 111: 2 sections; PHY 112: 2 sections; PHY 202; 2 sections and AST 111: 2 sections from the GPC. The distribution of total number of participants from various courses and different groups was as follows.

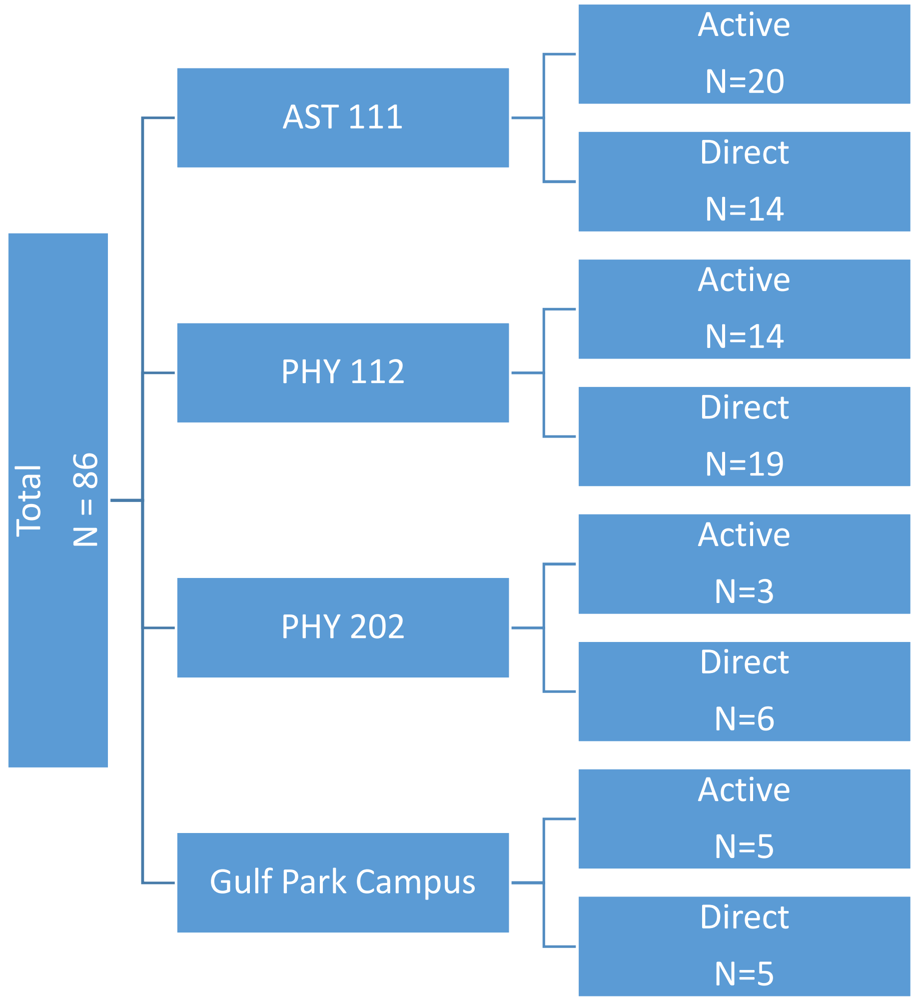

Figure 3.1. Distribution of Participants from various Courses and Groups.

Instrument

The instrument used in this study was a set of questionnaires (Appendix D) that included pretests and posttests used to determine knowledge gain reflected by participants' test scores. The pretest and the posttest consisted of eighteen multiple choice items; six of them were demographic questions. The pretests and posttests were administered to all students and the lesson taught to the students was approached within the context of the weak and strong nuclear force. These pre-tests and post-tests were administered before and after the learning activities conducted during the fourth week of

Fall Semester 2014 of Physics and Astronomy laboratory Classes at USM. Scoring was done by determining, for each student, the number of correct responses. These scores were averaged to determine the score of pretest and posttest of each individual session. The student instrument was intended to assess student motivation and excitement toward learning, improvement of students test scores, and attitude toward activities in the classroom.

Procedure

Students attended lab as usual. Upon approval of The University of Southern Mississippi's IRB (see Appendix A), an oral presentation of the research study (see Appendix B) was given to the students. Then the consent forms (see Appendix C) were distributed to the students to read and sign. Students who gave consent created a four-digit code to include on each data sheet. Those who did not gave their consent did not write a code on their data sheet. All consent forms were placed in a secure storage facility separate from pre posttest documents. The records of this study will be kept private. Any report of this research that was made available to the public will not include their names or any other individual information by which they could be identified. All students who participated in lab, either in the direct lecture or active-learning groups, received a grade of 100 for that lab session. Students were not forced or pressured in any way to participate in the study. They voluntarily chose to participate and were given the opportunity to stop participation any time if they felt uncomfortable or did not wish to participate for any reason.

A pretest/posttest (see Appendix D) design was used in this study. A pretest of 18 multiple choice questions was administered to all students at the beginning of class.

Participants in the direct and active-learning groups were taught a lesson on weak and strong nuclear forces (see Appendix F). The lecture lasted for about 40 minutes.

All students took a pretest and heard the same lecture. Students were asked to remain in the class until completion of the posttest were finished. Students in the active-learning groups followed a step-by-step procedure to perform a guided-inquiry lesson (see Appendix E) that included four activities and took about 1 hour. Students in the direct lecture groups watched a 1-hour video called Conceptual Physics. All students took the same test again as a posttest. Then, all the data sheets were collected. The data sheets with a four-digit code was used for statistical analysis. The study occurred within the normal laboratory sessions. The activities did not involve chemicals or electronics of any kind.

Research Design

To address the research question, a quantitative research design was used. A pre-test/post-test, active-learning group versus direct lecture group design was used. The multiple laboratory sections of each course were randomly assigned as direct lecture or active-learning group. The students in the active-learning group were given a pretest, then a lecture, then participated in a guided-inquiry lesson with four activities, then they took the same test again as a posttest. Students followed a step-by-step procedure to perform the activities and answer analysis questions in groups of three or four students. Each student submitted their own data sheets. Students in the direct lecture group were given the same pretest as the experimental group and heard the same lecture. Then they watched a 1-hour video on Conceptual Physics. They then took the same posttest as the active-learning group. Results that would support the proposed Hypothesis would be an increase in student scores in the active-learning group on the posttest, but not the direct lecture group, leading to a conclusion that the use of this guided inquiry lesson was effective.

Data Analysis

The data were analyzed to address the research questions and hypotheses. Two-sample t-tests were used to determine if there was a difference between the two groups: active-learning and direct lecture groups. The variables used were the average scores of the groups on the pretest and the posttest score. A two-sample t-test was used to compare mean post-test scores for both instruments to determine if there was a difference between the groups after the active-learning process.

This study was designed to determine if the use of an active-learning process would make a difference in the learning of the students. The students involved in this study provided a great deal of data.

Data Analysis Tools

There are numerous software tools available for statistical data analysis. These tool packages vary from open source to commercial products suited for small size to huge data sets both available for academic and commercial units. One such tool was Python programing language, an open source platform which was preferred for both building customized tools and statistical data analysis. The most established numerical analysis packages, NumPy and SciPy are the fundamental packages in Python for scientific computing and data analysis in Python, which are built together to provide many user-friendly and efficient numerical routines like integration, optimization and more. Matplotlib was a Python package used to create customized and interactive graphs. Among several varieties of development platform environments, Spyder (Scientific PYthon Development EnviRonment) was selected as a software tool which was very much similar to commercial Matlab. With the combination of these Python packages, data analysis was conducted and appropriate graphs were created.

CHAPTER IV

RESULTS AND ANALYSIS OF DATA

The purpose of this study was to determine if the use of active-learning activities to teach weak force and strong force to the students enrolled in various courses at The University of Southern Mississippi, Hattiesburg campus and Gulf Park campus at different class time increases their knowledge. The achievement of the students was examined on the basis of their scores on the pretest and posttest scores of students who participated in active-learning activities and those who participated in direct lecture. Data were collected from the students enrolled in an introductory astronomy survey course (AST 111), an introductory algebra-based physics course (PHY 112), and an introductory calculus-based physics course (PHY 202) from the University of Southern Mississippi, Hattiesburg and Gulf Park campus during fall semester 2014 during their labs. Results were used to determine if there was a difference in knowledge and performance of students on posttest based on active-learning activities or direct lecture. Additionally, results were examined to determine if different times of the day influenced students' performance and knowledge assessment who participated in active-learning activities and those who did not.

Findings

Data were first analyzed quantitatively by using descriptive statistics and frequencies. This study included 86 participants (N=86). Table 4.1 shows a representation of the demographic characteristics of the participants based on gender, class year, ethnicity, courses taken, honor student and financial aid. Participants were not evenly distributed based on demographic categories. The majority of the participants were female, mostly in junior year, Caucasian, having financial aid but not all as an honor student. Participants were composed of 49 females (57 %) and 36 males (41.9%). The number of freshman students was 10 (11.6%), 22 (25.6%) sophomore, 33 (38.4%) junior and 20 (23.3%) senior. The distribution of participants according to ethnicity included 14 African Americans (16.3%), 1 Asian/ Asian American (1.2%), 63 Caucasians/ Non-Hispanic (73.3%), 4 Hispanics (4.7%), and 3 others (3.5%). The total number of students who had taken high school physics was 33 (24.4%), high school physical science was 38 (28.2%), community/junior college physics was 7 (5.2%), college physical science was 30 (22.2%), and 11 (8.2%) were also in Honor's College. The data of courses taken by 16 (11.8%) students were missing. Since students were apply to choose more than one option, the total number (N=135) for this variable was different than the actual total. Among them 16 (18.6%) were Honor's College students. Students who had financial aid comprised 63 (73.3%) of the sample. The demographic data of 1 (1.2%) student was missing.

Table 4.1

Frequency Statistics of Gender, Class, Ethnicity, Honor Student and Financial Aid Status

Variable		***Frequency***	***Percent***
Gender			
Male		36	41.9%
Female		49	57.0%
Missing		1	1.2%
	Total	86	100.0%
Year			
Freshman		10	11.6%
Sophomore		22	25.6%
Junior		33	38.4%
Senior		20	23.3%
Missing		1	1.2%
	Total	86	100.0%

Table 4.1 (continued).

Variable	Frequency	Percent
Ethnicity		
African-American	14	16.3%
Asian/Asian American	1	1.2%
Caucasian/non-Hispanic	63	73.3%
Hispanic	4	4.7%
Other	3	3.5%
Missing	1	1.2%
Total	86	100.0%
Courses		
High School Physics	33	24.4%
High School Physical Science	38	28.2%
Community/Jr College Physics	7	5.2%
College Physical Science	30	22.2%
Honor College	11	8.2%
Missing	16	11.8%
Total	135	100.0%
Honor's College		
Yes	16	18.6%
No	69	80.2%
Missing	1	1.2%
Total	86	100%
Financial Aid		
Yes	63	73.3%
No	22	25.6%
Missing	1	1.2%
Total	86	100.0%

There were 42 students in the active-learning group (48.8%) and 44 in the direct group (51.2%). Table 4.2 shows a representation of the demographic characteristics of the participants based on active-learning and direct lecture groups. The majority of the participants in the active-learning group were female (28 or 67%). The number of students in their sophomore and junior years was high (14 or 33%). Most of the students, (30 or 71.4%) in this group were Caucasians/Non-Hispanic. For this group, most of the students had taken high school physical science (21 or 30%) and high school physics (20 or 28.6%). Only 9 (21%) students were Honor's College students and 33 (78.6%) of the total reported having financial aid.

The total number of students in the direct lecture group was 44. The majority of the participants in the direct lecture group were male 20 (50%). There were 19 (43%) students in their junior year. Most of the students in this group were Caucasians/ Non-Hispanic (33 or 75%). The number of students who had taken high school physical science and college physical science was 17 (26.2%). Only 7 (16%) students were Honor's College students and 30 (68%) out of total number of students had financial aid.

Table 4.2

Frequency Statistics of Variables for Active-learning and Direct Lecture Group.

Variable		**Active**		**Direct**	
Gender		***Frequency***	***Percent***	***Frequency***	***Percent***
Male		14	33.0%	22	50.0%
Female		28	67.0%	21	48.0%
Missing		0	0.0%	1	2.0%
	Total	42	100.0%	44	100.0%
Year		4	10.0%	6	14.0%
Sophomore		14	33.0%	8	18.0%
Junior		14	33.0%	19	43.0%
Senior		10	23.8%	10	23.0%
Missing		0	0.0%	1	2.0%
	Total	42	100.0%	44	100.0%
Ethnicity					
African-American		8	19.0%	6	14.0%
Asian/Asian American		1	2.4%	0	0.0%
Caucasian/non-Hispanic		30	71.4%	33	75.0%
Hispanic		1	2.4%	3	7.0%
Other		2	4.8%	1	2.0%

Table 4.2 (continued).

Variable	**Active**		**Direct**	
Gender	***Frequency***	***Percent***	***Frequency***	***Percent***
Missing	0	0.0%	1	2.0%
Total	42	100.0%	44	100.0%
Courses				
High School Physics	20	28.6%	13	20.0%
High School Physical Science	21	30.0%	17	26.2%
Community/Jr College Phy	3	4.3%	4	6.2%
College Physical Science	13	18.6%	17	26.2%
Honor College	6	8.6%	5	7.7%
Missing	7	10.0%	9	13.8%
Total	70	100.0%	65	100.0%
Honor's College				
Yes	9	21.0%	7	16.0%
No	33	78.6%	36	82.0%
Missing	0	0.0%	1	2.0%
Total	42	100.0%	44	100.0%
Financial Aid				
Yes	33	78.6%	30	68.0%
No	9	21.4%	13	30.0%
Missing	0	0.0%	1	2.0%
Total	42	100%	44	100%

There were 50 students in the afternoon group (58.1%) and 36 in the evening group (41.9%). Table 4.3 shows a representation of the demographic characteristics of the participants based on time of the day: afternoon and evening. The majority of the participants in the afternoon group were female 32 (64%). The number of students from junior year was high 18 (36%). Most of the students in this group (35 or 70%) were Caucasians/ Non-Hispanic. For this group, most of the students had taken high school physical science (25 or 30.9%) and high school physics (20 or 28.6%). Only 9 (18%)

students were Honor's College students and 39 (78%) of the total reported having financial aid. The demographic data of 1 student was missing.

The total number of students in the evening group was 36. The majority of the participants in this group were male 19 (52.8%). There were 15 (41.7%) students in their junior year. Most (28 or 77.8%) of the students in this group were Caucasians/ Non-Hispanic. The number of students who had taken college physical science was 14 (25.9%) and high school physical science was 23 (28.4%). Only 7 (19.4%) students were Honor's College students and 24 (66.7%) of the student had financial aid. None of the students were missing demographic records in this group.

Table 4.3

Frequency Statistics of Variables of Different time of the day.

Variable		***Afternoon***		***Evening***	
Gender		***Frequency***	***Percent***	***Frequency***	***Percent***
Male		17	34.0%	19	52.8%
Female		32	64.0%	17	47.2%
Missing		1	2.0%	0	0.0%
	Total	50	100.0%	36	100.0%
Year					
Freshman		5	10.0%	5	13.9%
Sophomore		15	30.0%	7	19.4%
Junior		18	36.0%	15	41.7%
Senior		11	22.0%	9	25.0%
Missing		1	2.0%	0	0.0%
	Total	50	100.0%	36	100.0%
Ethnicity					
African-American		9	18.0%	5	13.9%
Asian/Asian American		1	2.0%	0	0.0%
Caucasian/non-Hispanic		35	70.0%	28	77.8%
Hispanic		2	4.0%	2	5.5%
Other		2	4.0%	1	2.8%
Missing		1	2.0%	0	0.0%
	Total	50	100.0%	36	100%

Table 4.3 (continued).

Variable / *Gender*	*Afternoon* *Frequency*	*Afternoon* *Percent*	*Evening* *Frequency*	*Evening* *Percent*
Courses				
High School Physics	23	28.4%	10	18.5%
High School Physical Science	25	30.9%	13	24.1%
Community/Jr College Physics	3	3.7%	4	7.4%
College Physical Science	16	19.8%	14	25.9%
Honor College	4	4.9%	7	13.0%
Missing	10	12.3%	6	11.1%
Total	81	100.0%	54	100.0%
Honor's College				
Yes	9	18.0%	7	19.4%
No	40	80.0%	29	80.6%
Missing	1	2.0%	0	0.0%
Total	50	100.0%	36	100.0%
Financial Aid				
Yes	39	78.0%	24	70.7%
No	10	20.0%	12	29.3%
Missing	1	2.0%	0	0.0%
Total	50	100.0%	36	100.0%

At the beginning of the study, the active-learning groups and the direct lecture groups were determined randomly. The pretest was given to all the students enrolled in different courses as well as different times of the day. Then the lecture on weak and strong nuclear force was given. For the direct lecture group the video was shown which was nearly equivalent in the time taken for the active-learning activities. The video was completely irrelevant to weak and strong nuclear forces. The video was followed by the posttest. For the active-learning group, the lecture was followed by the activities related to weak and strong nuclear forces. Then the posttest was given at the end of class.

To establish that the active-learning and direct lecture groups were similar to begin, a t-test indicates pretest scores were not significantly different t (84) = 0.876, p=0.384 between these two groups. The test indicates that the posttest scores were also not significantly different t (84) = - 1.268, p= 0.210. Similarly, the afternoon and evening pretest were not different t (84) = 0.871, p= 0.388. Therefore, the two groups as well as the different time of the day can be assumed to be equivalent on pretest scores.

Table 4.4

Pretest Scores differences by method

Pretest	t-value	df
Active Vs. Direct	0.876	84
Afternoon Vs. Evening	0.871	84

At first, the difference between mean posttest score and mean pretest score of the active-learning group and the direct lecture group for different courses (AST 111, GPC, PHY 112 and PHY 202) was compared. Figure 4.1 shows the difference in mean posttest and mean pretest scores of different groups for different courses.

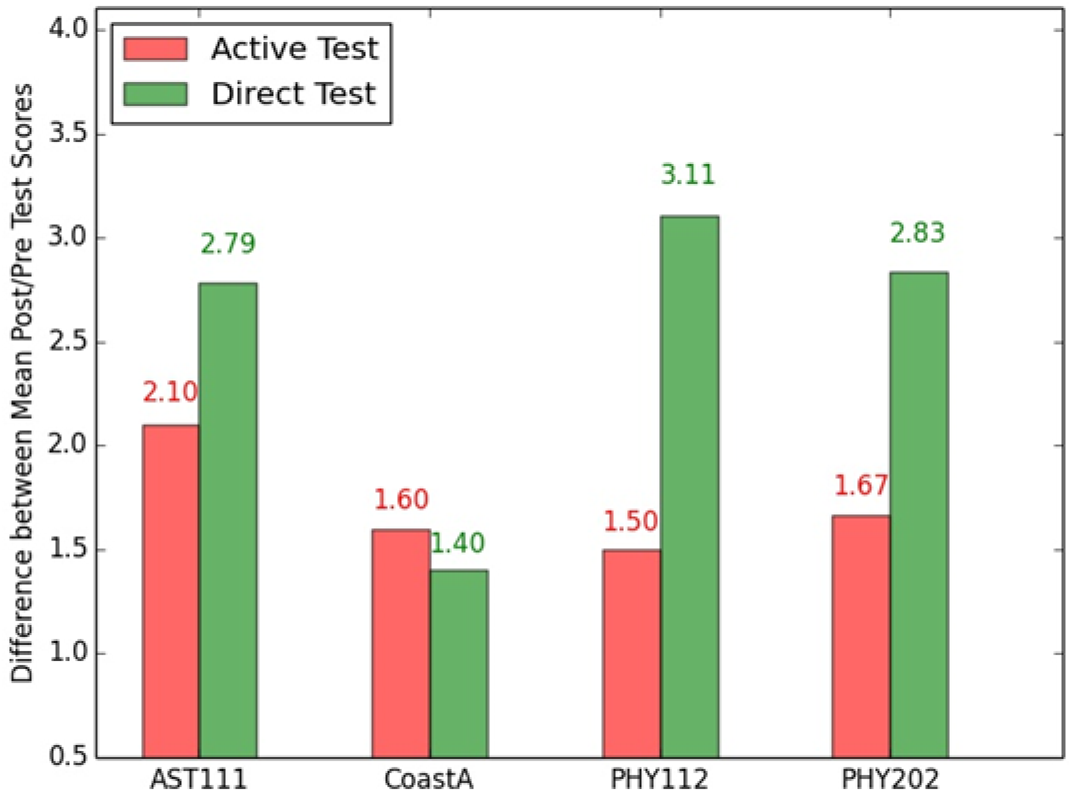

Figure 4.1. Differences by Active and Direct Method.

Figure 4.1 shows that for all courses, the difference shows a posttest score mean was higher than the mean pretest score. But for AST 111, PHY 112 and PHY 202 groups, the difference in posttest mean and pretest mean were higher for the direct lecture group than the active-learning group. But, for the students at Gulf Park campus, the difference in posttest mean and pretest mean were higher for the active-learning group than direct lecture group.

The mean pretest score of the direct group was subtracted from the mean pretest score of the active group. Similarly, the mean posttest score of direct group was subtracted from the mean posttest score of the active-learning group. Figure 4.2 shows the difference in two mean pretest scores and two mean posttest scores between the two groups for various courses.

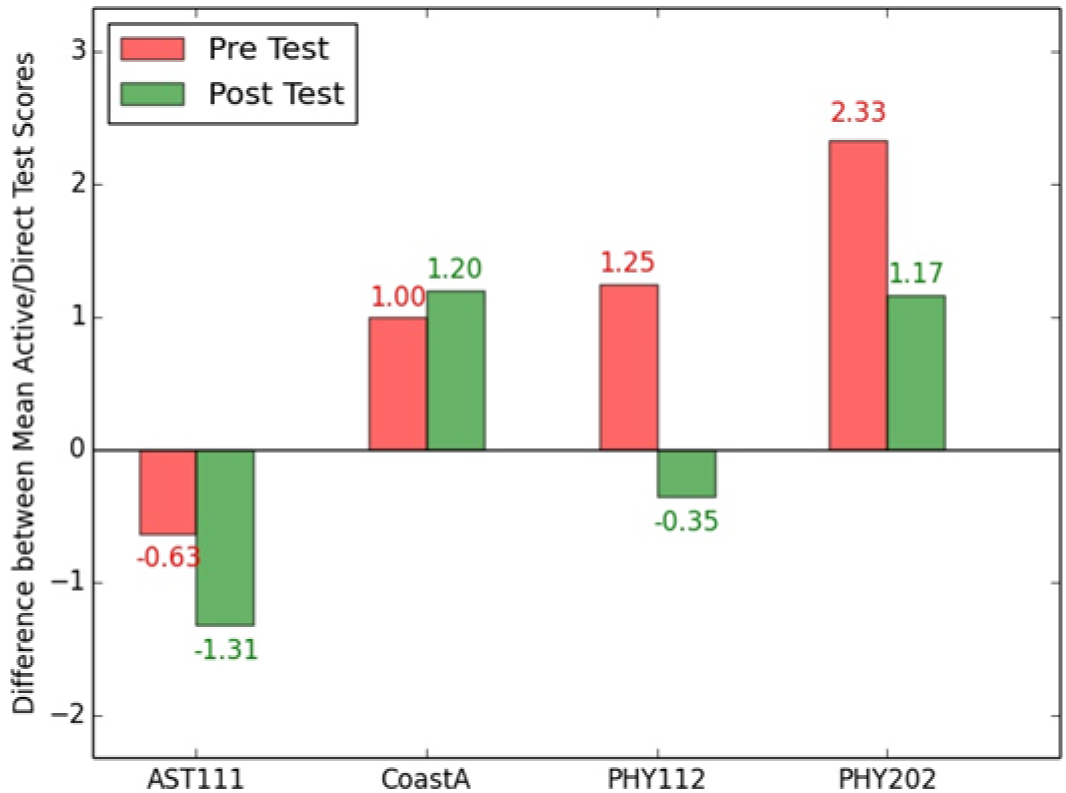

Figure 4.2. Differences by Course.

For AST 111 course, the mean pretest score for active-learning group was less than the mean pretest score for the direct lecture group by 0.6. Similarly, the mean posttest score for the active-learning group was less than the mean posttest score for the direct lecture group by 1.3. In contrast, for the AST 111 course at the GPC, the mean pretest score for the active-learning group was greater than the mean pretest score for the direct lecture group by the value of 1. Further, the mean posttest score for the active-learning group was greater than the mean posttest score for the direct lecture group by the value of 1.2. For PHY 112, the mean pretest score for the active-learning group was greater than the mean pretest score for the direct lecture group by 1.3. But for the mean posttest score, the value went down by 0.3 which represents that the mean posttest score for the active-learning group was less than the mean posttest score for the direct lecture group. Similarly, for PHY 202 course, the mean pretest score and mean posttest score for the active-learning group was greater than that of the direct lecture group by the value of 2.3 and 1.2, respectively.

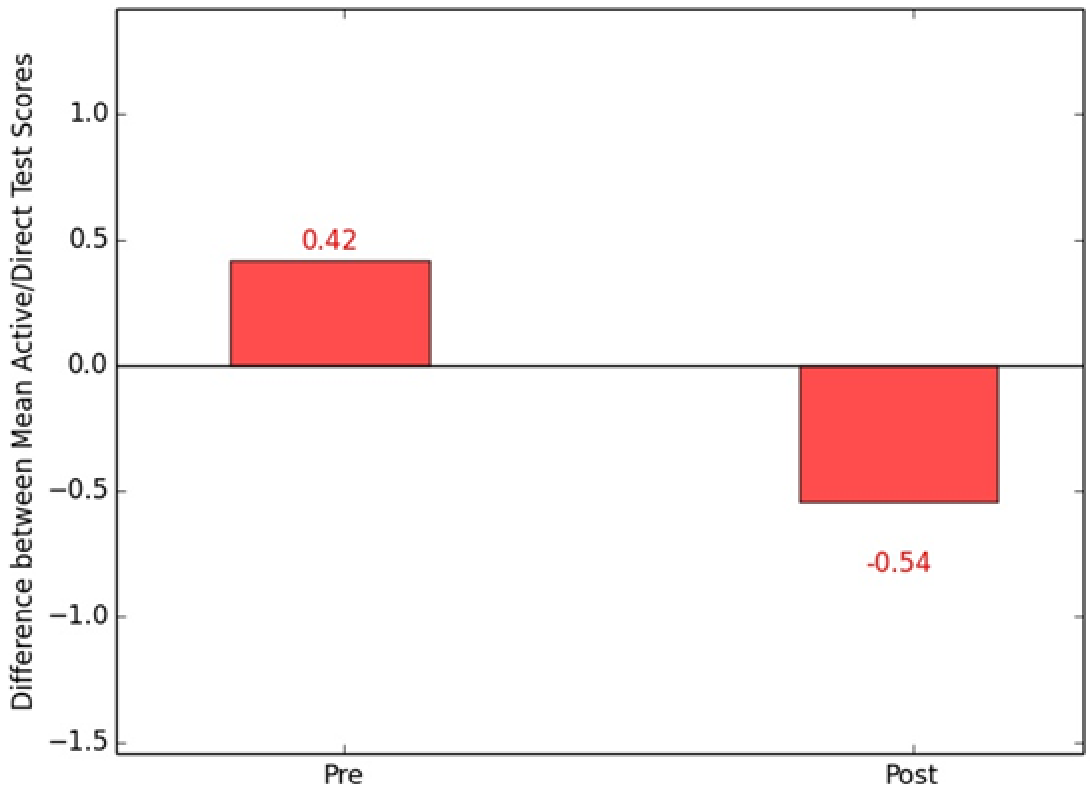

Figure 4.3. Difference between Pre and Posttest by Method.

Figure 4.3 shows the differences between two mean pretest scores and two mean posttest scores of active-learning group and direct lecture groups, respectively. The difference between the two mean pretest score values was positive, indicating that the mean pretest score of the active-learning group was greater than the direct lecture group by a value of 0.4. But the difference between the two posttest scores of two groups was negative, indicating that the mean posttest score of the active-learning group was less than that of the direct lecture group by the value of 0.5.

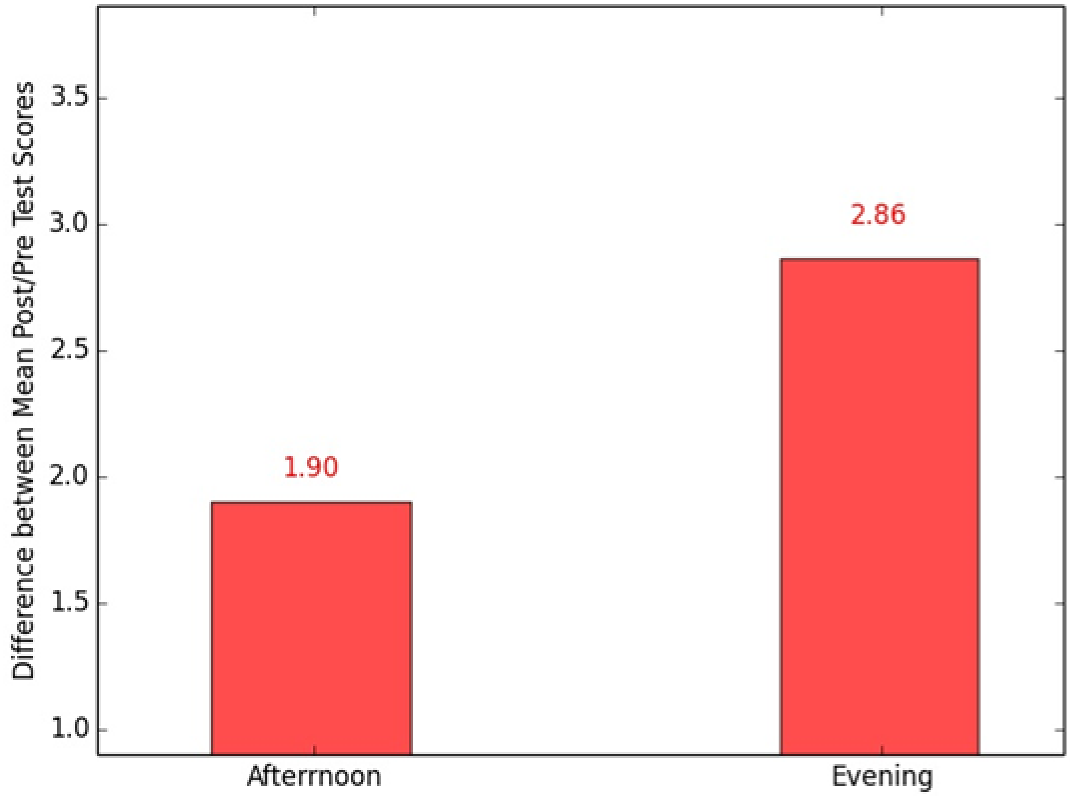

Figure 4.4. Difference between Pre and Posttest by Time.

Next, the difference between the mean posttest and mean pretest for the afternoon group and the evening group was analyzed. Figure 4.4 represents the difference in the means for two groups. Both differences are positive. It indicates that for both groups, the mean posttest was higher than the mean pretest. Also the results indicate that the difference in mean posttest and pretest scores for the afternoon group was a value of 1.9, whereas for the evening group has a value of 2.86. Also, the result indicates that the differences in means was high for the evening group.

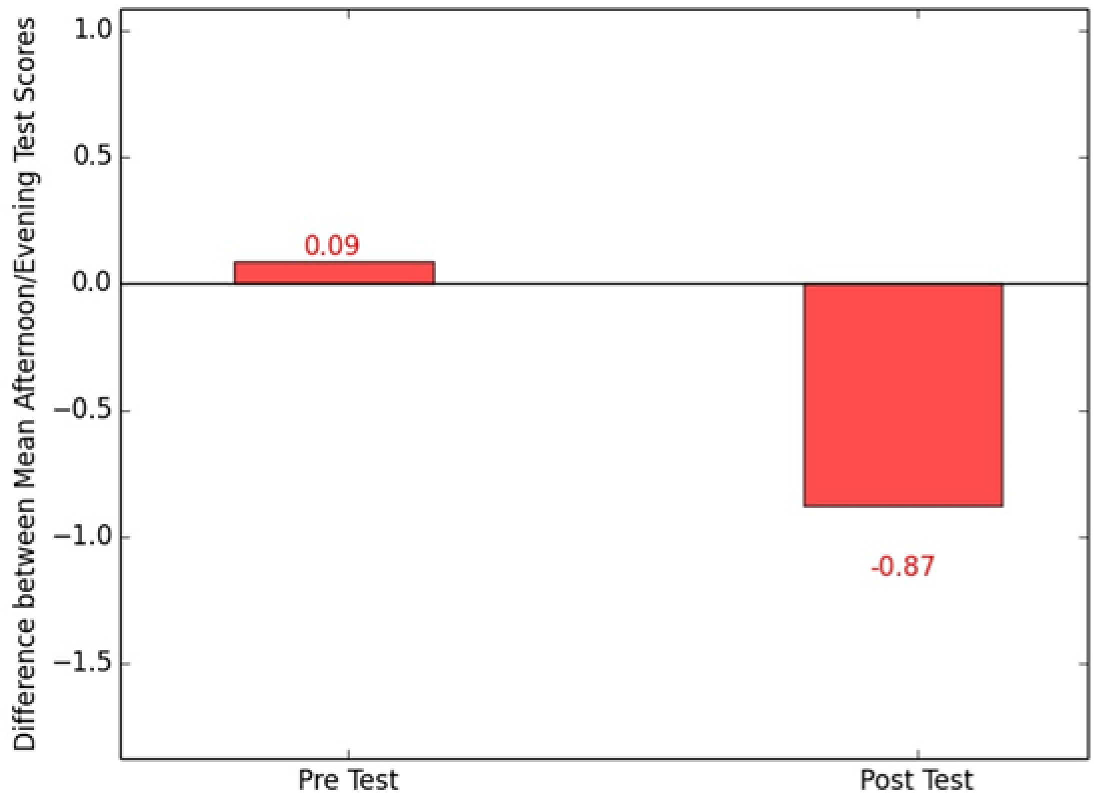

Figure 4.5. Difference between Scores by Time.

Next, the difference between the mean test scores of the afternoon group and the evening group was analyzed. Figure 4.5 represents the difference of two mean pretest scores and two mean posttest scores of the afternoon and the evening groups. The differences between pretest score was positive, however the difference between two mean posttest scores was negative. This indicates that the mean pretest score of the afternoon group was greater than the mean pretest score of the evening group by 0.09 value. But the mean posttest scores of the afternoon group was less than the mean posttest scores of the evening group by the value of 0.87.

Results of Research Question One

What was the impact of active-learning activities on students' knowledge of weak and strong nuclear force?

The analysis of descriptive statistics revealed a difference in mean posttest scores and mean pretest score. Further, there was a difference between the active-learning and the direct lecture groups. For the AST 111 course, the difference in posttest mean and pretest mean was higher for the direct lecture group than the active-learning group. Similarly for PHY 112 and PHY 202, the difference in posttest mean and pretest mean were higher for the direct lecture group than the active-learning group. However, for the GPC, the difference in posttest mean and pretest mean was higher for the active-learning group than the direct lecture group. The results indicate that on these learning activities, participation in the active-learning worked for the students at the Gulf Park campus (GPC) only.

Results of Research Question and Hypothesis Two

Are there differences between the pretest score and posttest score, regardless of method?

Descriptive analyses reveal that the overall mean posttest score was greater than the mean pretest score. Mean scores of total students are reported in Table 4.5.

Table 4.5

Pretest and Posttest Means of Total Students

Total	N	Mean
Pre	86	6.52
Post	86	8.82

Results of Research Question and Hypothesis Three

Are there significant differences in pretest and posttest scores between students who participate in active-learning activities and students who do not participate in active-learning activities?

Descriptive analyses revealed that students who participated in active-learning activities had lower posttest scores than students who did not. Results of the mean pretest and posttest for the active and direct groups are summarized in Table 4.6.

Table 4.6

Pretest and Posttest Means by method

Group	N	Pretest	Posttest
Active	42	6.74	8.55
Direct	44	6.32	9.09

Results of Research Hypothesis Three

There will be significant differences in pretest and posttest scores between students who participate in active-learning activities and students who do not participate in active-learning activities.

An independent t-test using Post/Pre difference as dependent variable and method as the independent variable was conducted to determine if a statistically significant difference exists among the mean posttest scores of the active and direct groups for all courses. The result reveals that the students who participated in active-learning activities score were not significantly different from the direct group, $F(1, 84) = 0.025$, $p = 0.876$.

Results of Research Question and Hypothesis Four

Does time of day influence pretest scores and posttest scores of the students?

Descriptive analyses reveal that students who enrolled in the afternoon class have lower posttest scores than the students who enrolled in the evening class. Results of mean pretest and posttest for the afternoon and the evening classes are summarized in Table 4.7.

Table 4.7

Pretest and Posttest Means by time

Class	N	Pretest	Posttest
Afternoon	50	6.56	8.46
Evening	36	6.47	9.33

There will be significant differences in pretest and posttest scores between students who enrolled in afternoon class than those student who enrolled in evening class.

An independent t-test was conducted to determine if a statistically significant difference exists among the mean posttest scores of the afternoon class students and the evening class students for all courses. The result reveals that the students who enrolled in the afternoon classes score were significantly higher from the evening classes, t= - 2.082, p= 0.040. Hence, time of the day does make a difference.

Summary of Results

The research questions were answered by conducting descriptive statistics, frequencies, and t-tests. This study analyzed the posttest scores and pretest scores of students at The University of Southern Mississippi, Hattiesburg campus and Gulf Park campus and compared the scores of the direct group who did not participate in active-learning activities and the active group who participated in activities. The results of these research questions indicate that students who participate in the active-learning activities do not have statistically higher scores than students who do not participate in activities, therefore, research hypotheses one and two and three were not supported.

CHAPTER V

SUMMARY AND CONCLUSION

The overall purpose of this dissertation was to analyze mean pre-test and post-test scores on a traditional lecture lesson and an active-learning lesson and its impacts learning. With the research outcome of this dissertation work, the statistical analysis of the active-learning activity will add contributions to the field of educational science especially on the active-learning. The statistical analysis on data collected from eight classes have demonstrated improved learning matrix on the active-learning on some classes. Most popular open source statistical programming language, python has been used to analysis of data. Finally, the effort of investigation of this research work has put forward an experimental analysis on the active classroom activities.

Description of Sample

The participants in this study included 86 (N=86) individuals. They were comprised of 49 females and 36 males. The ethnic distribution of the subjects included 63 Caucasians, 14 African Americans, 4 Hispanics, 3 others and 1 Asians. The number of freshman students 10, sophomore 22, and junior students were 33 and senior 20. The overwhelming majority of the participants were Caucasian and female mostly in junior class year. This may be explained by considering that among U.S. and naturalized citizens, women earned over 340,000 science and engineering associate’s, bachelor’s, master’s, and Ph.Ds. in 2010. Furthermore, there are historically fewer minorities in the science and medical fields (Department for Professional Employees, AFL-CIO, 2012). Majority of the students 30, had history of taking high school physical science. Furthermore, large number of students 63, reported having financial aid and 16 of them also are honor students. These different lab classes of various courses were randomly chosen to participate in the active-learning or direct lecture groups. There were 42 students in the active-learning group and 44 students in the direct lecture group.

Results of Research Question One

What was the impact of active-learning activities on students' knowledge of weak and strong nuclear force for various course groups?

The result of data score analysis from this experimental study compared pre-posttest scores on active versus direct teaching methods and implemented in laboratory classroom environment. Both of these methods required an equal amount of time. The results found were mixed. Students made statistically significant learning in two groups; at the Gulf Park Campus (GPC) and PHY 202 course groups. The range of mean scores on the pre-test were significantly higher for GPC, PHY 112 and PHY 202. However, the post-test scores were statistically significant for GPC and PHY 202 course groups only. For the AST 111 course, the difference in posttest mean and pretest mean were higher for the direct lecture group than the active-learning group. Overall, the results indicated that participation in active-learning activities worked for students at the GPC only. Furthermore, the analysis shows that the difference in mean posttest scores was positive for GPC and PHY 202. The active-learning activities seemed to work only for these two groups as their mean posttest scores increased. However, following Cronbach (1975), a number of separate local studies in various environments would be more informative, to see whether and how the findings generalize to other situations and to refine and study the effect of various parameters. In any case, gain differences between instructional modes were thus far not found to be of statistical or practical significance compared to the observed natural variation of students, teachers and classrooms. It was of interest to consider possible reasons why this might be so, viewed from a number of perspectives.

Results of Research Question and Hypothesis Two

Are there significant differences in pretest and posttest scores between students who participate in the active-learning activities and students who do not participate in the active-learning activities?

Descriptive analyses revealed that students who participated in the active-learning activities had lower posttest scores than students in the direct lecture. However, the posttest scores overall were higher than the pretest scores. The mean posttest scores of the active-learning group was not statistically different from the mean posttest scores of the direct learning group. In three out of four courses, the mean posttest scores of the active-learning group was found to be significantly lower. Hence, we can argue that the mean posttest scores were significantly higher for the direct lecture groups than the active-learning groups.

Instruction based on active-learning aims to actively engage learners in the processes of science concepts that involve student's experience on observation, inference and experiments. Whereas in instruction based on direct learning, the lesson structure and purpose are made clear. Direct instruction may be preferred by some learners and it may be an important factor on the learning process.

There are a number of ways to learn new concepts that allow individual students to be involved in the learning process. These different ways of learning does not produce the same result. There are various factors that affect the learning processes. These various factors can be the target students' groups, their age, ethnicity, and subject matter, type of delivery or type of category or class, whether or not explicit instructions are provided. With this reality, the approach to learning a new concept should be different in different modes, active and direct modes used in this research study. Regardless of the instructional method used to deliver the knowledge, students need to actively participate in the learning process to build their own science concepts and associate with the activities they might already know, might have heard of or might have seen while making sense of the concept and interpret by themselves. Usually, students will adjust themselves and make their own approaches of learning, in response to the nature of instruction methods. However, it may take some time for this adjustment. But when students encounter new instructional methods and a new teacher, achievement may not change based on direct or active-learning processes. So the differences in these instructional methods might not be significant, or even if significant, there may be other factors at play in the learning process.

Limitations

There were limitations during the study:

- This study was conducted only with AST 111, PHY 112 and PHY 202. If other courses such as PHY 111 and PHY 201 were included, the results may have been different.
- This study was limited to students enrolled for fall semester 2014. If the study had been conducted for an entire academic year, additional data would have been available.
- This study was limited to only the Hattiesburg and Gulf Park Campus of the University of Southern Mississippi. If other colleges had been examined, additional data would have been available.
- This study was limited to pre-tests and post-tests. If additional types of tests were administered, additional data would have been available.

- This study's instruments included activities that leads to an example of weak and strong nuclear forces. If there were some activities that could directly relate to weak and strong forces, then the results may have been different.
- This study's data was collected only for the fall of 2014 school year. If the study could have been conducted for additional years, additional data would have been available.
- This study was limited to only a portion of the time allotted to lab. Students had to complete their normal lab after completing the study. If additional time had been available, results may have been very different.
- If the weak force and strong nuclear force lesson had been divided into two lessons, results may have been different.

Recommendations for Future Research

This study was conducted to determine whether active-learning activities had an impact on student's knowledge of weak and strong nuclear forces. This study was conducted by the researcher on a sample size of 86 participants during a one time visit to various lab classes. A larger sample size is recommended, a designated lab session should be utilized to conduct the study, and additional courses should be included in future research. The researcher recommends that the lesson on weak force and strong nuclear force be taught across two different labs in order to better describe the lesson in detail as well as to not rush the activities. Another recommendation for future research would be to extend this study at community colleges so that there would be more data for comparison.

APPENDIX A

IRB APPROVAL LETTER

THE UNIVERSITY OF
SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

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

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

PROTOCOL NUMBER: 14062502
PROJECT TITLE: Assessment of Student Knowledge of the Weak and Strong Nuclear Forces
PROJECT TYPE: New Project
RESEARCHER(S): Pramila Shakya
COLLEGE/DIVISION: College of Science and Technology
DEPARTMENT: Center for Science and Math Education
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF APPROVAL: 07/29/2014 to 07/28/2015

Lawrence A. Hosman, Ph.D.
Institutional Review Board

APPENDIX B

ORAL PRESENTATION

I am asking you to take part in a research study regarding to the knowledge assessment of weak force and strong force. This lesson will take place during this lab session and will take the normal amount of time. This was an opportunity to learn about weak and strong forces in nature. There are no risks to participate in this study. All identifying information such as your signed Informed Consent form will kept separate from your activity sheets. Neither your lab instructor nor your course instructor will know your identity on the pretest, activity sheets or posttest. Taking part in this study was completely voluntary. If you choose to be in the study you can withdraw at any time without consequences of any kind. You may choose to leave for a particular question, or simply not answer a particular question. Participating in this study does not mean that you are giving up any of your legal rights. The records of this study will be kept private. Any report of this research that was made available to the public will not include your name or any other individual information by which you could be identified. This study has been reviewed by the University of Southern Mississippi's Institutional Research Board.

You may **c**ontact me at my email address or phone number, if you have questions or want a copy or summary of the study results.

______________________________ ________________

Pramila Shakya
Center for Science and Math Education
The University of Southern Mississippi
601-266-2763
pramila.shakya@eagles.usm.edu

Date

APPENDIX C

Students Participate Consent Form
Pramila Shakya
Center for Science and Math Education
The University of Southern Mississippi
601-266-2763
pramila.shakya@eagles.usm.edu

You are invited to take part in a research study regarding to the knowledge assessment of weak force and strong force of nature.

What the study was about: This study is designed to explore the understanding of student's content knowledge about the weak and strong nuclear forces.

What you will be asked to do: As a participant, you will be asked to participate in an approximately one-hour long class. The questions will be asked from the lesson/activity done in class.

Risks and Benefits: there are minimal risk to participate in this study. All identifying information such as your signed I/C form will kept separate. Neither your lab instructor nor your course instructor will know your identity.

Taking part was voluntary: Taking part in this study is completely voluntary. If you choose to be in the study you can withdraw at any time without consequences of any kind. You may choose to leave for a particular question, or simply not answer a particular question. Participating in this study does not mean that you are giving up any of your legal rights.

Your answers will be confidential: The records of this study will be kept private. Any report of this research that was made available to the public will not include your name or any other individual information by which you could be identified.

If you have questions or want a copy or summary of the study results: Contact the researcher at the email address or phone number above. You will be given a copy of this form to keep for your records. If you have any questions, contact The University of Southern Mississippi Institutional Research Board chair.

Statement of Consent: I have read the above information and have received answers to any questions. I consent to take part in the research study of weak force and strong force of nature. I am at least 18 of age.

______________________________ __________________

Participant's Signature Date

APPENDIX D

Code: ____________________

Nuclear Forces Test

Please choose the best answer for each question.

1. Which was the strongest of the four fundamental forces?
   (a) Electromagnetism
   (b) Gravity
   (c) Strong Nuclear Force
   (d) Weak Nuclear Force

2. How would you describe the range (reach) of the electromagnetic force?
   (a) Long
   (b) Short

3. How would you describe the range of the strong nuclear force?
   (a) Long
   (b) Short

4. How would you describe the range of the weak nuclear force?
   (a) Long
   (b) Short

5. Was the strong nuclear force attractive or repulsive?
   (a) Attractive
   (b) Repulsive

6. Was the weak nuclear force attractive or repulsive?
   (a) Attractive
   (b) Repulsive

7. The strong nuclear force was responsible for
   (a) The falling of an object when it was dropped
   (b) Bolts of lightning
   (c) Radioactive decay
   (d) Nuclear fusion in the core of the Sun

8. The weak nuclear force was responsible for
   (a) The falling of an object when it was dropped
   (b) Bolts of lightning
   (c) Radioactive decay
   (d) Nuclear fusion in the core of the Sun

9. An important concept for understanding radioactive decay was the *half-life*. Which of the following statements was true concerning a sample of radioactive material?
   (a) After two half-lives worth of time, none of the original sample remains
   (b) After two half-lives worth of time, ¼ of the original sample remains
   (c) After two half-lives worth of time, ½ of the original sample remains
   (d) After two half-lives worth of time, ¾ of the original sample remains

10. Which of the following statements was true about the radioactive decay of atomic nuclei?
    (a) The decay of an individual nucleus can be predicted
    (b) The decay of a large sample of nuclei can be predicted
    (c) Radioactive decay cannot be predicted in any fashion

11. Suppose two free protons are placed near each other. Because of the electromagnetic force, the two protons will
    (a) Attract each other
    (b) Repel each other
    (c) Remain stationary

12. Individual particles are bound together in an atomic nucleus by
    (a) Electrical forces
    (b) Gravitational forces
    (c) Strong nuclear forces
    (d) Weak nuclear forces

13. What was your gender? (a) Male (b) Female	14. Which class (year) are you in? (a) Freshman (b) Sophomore (c) Junior (d) Senior
15. What was your ethnicity? (a) African-American (b) Asian/Asian-American (c) Caucasian/ non-Hispanic (d) Hispanic (e) Other	16. Which of the following courses have you taken? (check all that apply) (a) High School Physics (b) High School physical science (c) Community/ Jr college physics (d) College physical science (e) Enrolled in Honor college
17. Are you an Honor Student? (a) Yes (b) No	18. Do you receive financial aid? (a) Yes (b) No

Nuclear Forces Test

Please choose the best answer for each question. ***Answers are in red boldface.***

1. Which was the strongest of the four fundamental forces?

   (e) Electromagnetism
   (f) Gravity
   (g) Strong Nuclear Force
   (h) Weak Nuclear Force

2. How would you describe the range (reach) of the electromagnetic force?

   (c) Long
   (d) Short

3. How would you describe the range of the strong nuclear force?

   (c) Long
   (d) Short

4. How would you describe the range of the weak nuclear force?

   (c) Long
   (d) Short

5. Was the strong nuclear force attractive or repulsive?

   (c) Attractive
   (d) Repulsive

6. Was the weak nuclear force attractive or repulsive?

   (c) Attractive
   (d) Repulsive

7. The strong nuclear force was responsible for

   (e) The falling of an object when it was dropped
   (f) Bolts of lightning
   (g) Radioactive decay
   (h) Nuclear fusion in the core of the Sun

8. The weak nuclear force was responsible for

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(g) Radioactive decay
(h) Nuclear fusion in the core of the Sun

9. An important concept for understanding radioactive decay was the *half-life*. Which of the following statements was true concerning a sample of radioactive material?

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(f) After two half-lives worth of time, ¼ of the original sample remains
(g) After two half-lives worth of time, ½ of the original sample remains
(h) After two half-lives worth of time, ¾ of the original sample remains

10. Which of the following statements was true about the radioactive decay of atomic nuclei?

(d) The decay of an individual nucleus can be predicted
(e) The decay of a large sample of nuclei can be predicted
(f) Radioactive decay cannot be predicted in any fashion

11. Suppose two free protons are placed near each other. Because of the electromagnetic force, the two protons will

(d) Attract each other
(e) Repel each other
(f) Remain stationary

12. Individual particles are bound together in an atomic nucleus by

(e) Electrical forces
(f) Gravitational forces
(g) Strong nuclear forces
(h) Weak nuclear forces

APPENDIX E

NUCLEAR FORCES

Purpose

To learn about the weak and strong nuclear forces

Objectives

- To simulate radioactive decay
- To deduce the notion of half-life for radioactivity
- To estimate the range at which the weak force operates
- To simulate hydrogen fusion
- To estimate the range at which the strong force operates
- To show how energy can be generated from weak and strong force reactions

Materials

- Coins
- Rolling die
- Graph paper
- Scientific calculator
- Carts with tracks
- Metal bars (weights)
- Duct tape

Introduction

Physicists have identified four fundamental forces in nature. Two of them – gravitation and electromagnetism – are familiar to us via everyday life. But two others – nicknamed the "strong" and the "weak" force – are not as obvious. The purpose of this lab was to elucidate the properties of the weak and strong forces.

The weak force was responsible for radioactive decay. While radioactive decay was often thought of first as only destructive – the cause of cancers and atomic bombs – it also provides many positive benefits, from treatment of cancer to dating of ancient remains and beyond.

The strong force was responsible for binding atomic nuclei together. Without it, atoms heavier than hydrogen could not exist and the Sun would not generate light.

While both weak and strong forces operate at the atomic level, and so are difficult to see directly, we can run experiments that simulate their behaviors.

Part #1: Simulating radioactive decay with coins

1. Each team has 8 coins. Place the coins on your table (or countertop etc.) next to each other, face up (as seen in Figure 1 below). Note the number of coins was recorded in Table 1.

Figure 1. Eight coins together, all showing heads.

2. Flip each coin once. If the coin comes up heads, return it to its place. If the coin comes up tails, set it aside.

3. Count the number of heads remaining. Record the number of heads in Table 1 under the column "Run #1" and the row "Flip #1".

4. Repeat this process, recording the number of heads remaining under Run #1 until all the coins have turned up tails. It was not necessary to fill in all the possible entries under Run #1.

5. Return the coins to their original arrangement (8 all showing heads) and repeat this process for Runs #2 etc. until five total runs have been completed.

6. Calculate the average number of heads for each **ROW** (Flip #) and record those results in the column marked “Average”.

7. Plot the results on a sheet of graph paper. The horizontal axis will be the Run number and the vertical axis will be the average number of heads.

8. Draw a smooth curve through the plotted points to show the general behavior of the coin flipping.

9. When you are finished with the lab, label the graph and staple it to the back of this handout.

Table 1. Simulations of Radioactive Decay: Coin Flips.

Flip #	Run #1	Run #2	Run #3	Run #4	Run #5	Average
0	8	8	8	8	8	8
1	_____	_____	_____	_____	_____	______
2	_____	_____	_____	_____	_____	______
3	_____	_____	_____	_____	_____	______
4	_____	_____	_____	_____	_____	_____
5	_____	_____	_____	_____	_____	______
6	_____	_____	_____	_____	_____	______
7	_____	_____	_____	_____	_____	______
8	_____	_____	_____	_____	_____	______
9	_____	_____	_____	_____	_____	______
10	_____	_____	_____	_____	_____	______

10. What are the odds, when flipping a fair coin, of it coming up heads? (What do you think we mean by the term “fair”?)

11. We started each run with 8 heads. How many, ideally, do you think we should have after one complete run?

Part #2: Simulating radioactive decay with playing die

Not all real atomic nuclei decay the same way. In this exercwase, we will simulate the way in which this difference might make itself evident.

1. Each team has 8 playing die (see Figure 2 below). Note the number of die was recorded in Table 3.

Figure 2. Eight playing die.

2. We will follow a similar procedure with the playing die as we did with the coins, with two differences. First, we "roll" dice instead of flipping them; second, do not set a die aside unless it comes up as a "six".

3. As before, record your results (the time in Table 4). Stop after 10 rolls, even if you still have die remaining.

4. As before, calculate an average number of die after each set of rolls and record the result in Table 4.

5. Plot the results on a sheet of graph paper. The horizontal axis will be the Run number and the vertical axis will be the average number of die remaining.

6. Draw a smooth curve through the plotted points to show the general behavior of the dice rolling.

7. When you are finished with the lab, label the graph and staple it to the back of handout.

8. What are the odds, when rolling a fair die, of it coming up six?

9. We started each run with 8 die. How many runs did it take, on average, to get to only four die remaining?

Table 2. Simulations of Radioactive Decay: Die Rolling.

Flip #	Run #1	Run #2	Run #3	Run #4	Run #5	Average
0	8	8	8	8	8	8
1	_____	_____	_____	_____	_____	_____
2	_____	_____	_____	_____	_____	_____
3	_____	_____	_____	_____	_____	_____
4	_____	_____	_____	_____	_____	_____
5	_____	_____	_____	_____	_____	_____
6	_____	_____	_____	_____	_____	_____
7	_____	_____	_____	_____	_____	_____
8	_____	_____	_____	_____	_____	_____
9	_____	_____	_____	_____	_____	_____
10	_____	_____	_____	_____	_____	_____

10. Briefly describe how the two experiments (coin flipping, die rolling) are similar.

11. Briefly describe how the two experiments are different.

12. Real radioactive decay was characterized by a nucleus' "half-life". What do you think was meant by this term?

Part #3: Energy generation by the weak force.

1. Place two carts on a track, held together by Velcro attached to the carts (see Figure 3). Note the wheels of each cart fit into grooves on the track.

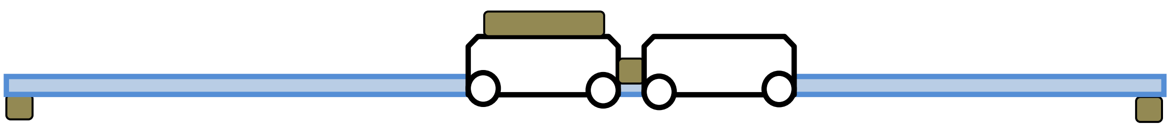

Figure 3. Two carts on a grooved track, with strips of Velcro holding them together. Some weights have been added to the left-handed cart.

2. Place two bars (weights) on the track at left. This will of course make the cart on left heavier.

3. A button on the cart can be pushed that will suddenly extend a plastic arm (ask the instructor for help in finding and/or using it if necessary). Push the button and watch what happens to the carts. Sketch the behavior of the carts on Figure 4 below, using arrows to depict the direction of motion of each cart.

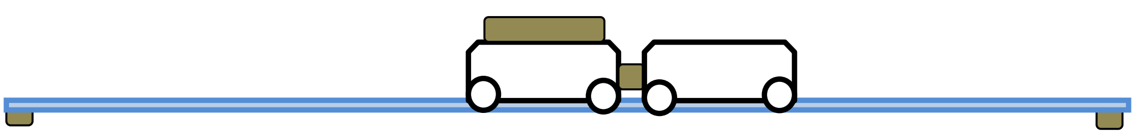

Figure 4. Two carts on a grooved track, after they are forcibly separated.

4. Reset the carts and perform the experiment again. Which cart moves faster – the heavier cart or the lighter cart? Why do you think it works out that way?

5. *Kinetic energy* was the term physicists use to describe energy of motion. Does this experiment absorb or release energy? Briefly compare the behavior of the carts before and after pushing the button.

Part #4: Strong force simulations

1. Look carefully at a cart. On the end of a cart opposite the side with Velcro, you should note some small disks embedded inside the cart. These are magnets.

2. Place both carts on the grooved track again, This time at opposite ends of the track, with their magnets facing each other (see Figure 5). Neither cart should have any weights on it.

Figure 5. Two carts on a grooved track, with their magnetic ends facing each other.

3. Gently push the carts toward each other. Briefly describe what happens to the carts after they meet.

4. Get a small piece of duct tape. Roll it into a cylinder, sticky-side out, and attach it to the magnetic ends of one cart.

5. Again, gently push the carts toward each other. Briefly describe what happens to the carts after they meet.

6. Try the experiment again, but this time push the carts harder, so they move more quickly toward each other (take care to keep the carts on the track!). Continue increasing the speed until the carts react differently upon colliding.

7. Briefly describe how the carts reacted once they were moving with sufficient speed.

8. With the tape holding the carts together, hold the carts up (carefully!) so that one cart dangles vertically underneath the other. Which exerts a stronger force, the tape or the magnets?

Part #5: Summary

Assume the magnets represent the electrical charges of protons, the button (that extends the plastic arm) represents the weak nuclear force, and the duct tape or Velcro represents the strong nuclear force. Then address the following questions:

1. Does radioactive decay imply an attractive force or a repulsive force? Briefly defend your answer.

2. Recall the idea of “fairness” for the coin flips. Was radioactive decay a random process or a deterministic (i.e. the result was pre-determined) process? Briefly defend your answer.

3. Does the flipping of one coin affect the result of the flipping of its neighbors? What does that say about the range (reach) of the force involved? Briefly defend your answer.

4. Protons carry positive charges. What do positive charges attempt to do – pull each other together (attraction) or push each other apart (repulsion)?

5. What can we say about the relative reach ("range") of electrical forces? Hint: Do the magnets of the carts need to touch each other in order to affect each other?

6. What can we say about the relative range of the strong nuclear force? Hint: Does the duct tape need to touch both carts in order to hold them together?

7. What can we say about the relative range of the weak nuclear force? Hint: Does the plastic extending arm need to touch both carts in order to push them apart?

8. Reconsider the radioactive decay experiments. Which force was at work here – electricity, the strong force, or the weak force?

9. Does a weak force reaction absorb or release energy? Hint: Review the results of the experiments in Part #3.

10. Does a strong force reaction absorb or release energy? Hint: Did the collision (that stuck the carts together in Part #4) make a sound?

11. Which force (strong or weak) takes small atomic nuclei and makes them larger? Which force (strong or weak) takes large atomic nuclei and makes them smaller?

12. Which force – strong nuclear or electricity – was stronger?

13. Atomic nuclei consist of two particles – protons and neutrons. Protons carry positive electric charges and neutrons are electrically neutral. What represented the protons in our experiment – the magnets or the duct tape? Which represented the neutrons?

14. Neutrons are electrically neutral, so they exert no electrical forces. What type of force do neutrons exert? Recall your answer to the preceding question.

15. The temperature of a gas increases as the average speed of its individual particles increases. Consider the experiment where the carts were pushed toward each other. In which case does it represent a higher temperature – when the carts are

pushed gently (so they move slowly) or when the carts are pushed harder (so they move quickly)?

16. In which case was it more likely for the strong force to bind together individual nuclear particles – when they are moving slowly or moving quickly?

17. In which case was it more likely for the strong force to bind together individual protons – when the gas was hot or when it was cool?

18. The Sun uses hydrogen fusion to produce its energy, with the first step of the process being the collision of two protons that bind together. What would you say about the likely conditions (such as temperature) inside the Sun?

Nuclear Forces

Answers in red boldface

Purpose

To learn about the weak and strong nuclear forces

Objectives

- To simulate radioactive decay
- To deduce the notion of half-life for radioactivity
- To estimate the range at which the weak force operates
- To simulate hydrogen fusion
- To estimate the range at which the strong force operates
- To show how energy can be generated from weak and strong force reactions

Materials

- Coins
- Rolling die
- Graph paper
- Scientific calculator
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- Metal bars (weights)
- Duct tape

Introduction

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The weak force was responsible for radioactive decay. While radioactive decay was often thought of first as only destructive – the cause of cancers and atomic bombs – it also provides many positive benefits, from treatment of cancer to dating of ancient remains and beyond.

The strong force was responsible for binding atomic nuclei together. Without it, atoms heavier than hydrogen could not exist and the Sun would not generate light.

While both weak and strong forces operate at the atomic level, and so are difficult to see directly, we can run experiments that simulate their behaviors.

Part #1: Simulating radioactive decay with coins

12. Each team has 8 coins. Place the coins on your table (or countertop etc.) next to each other, face up (as seen in Figure 1 below). Note the number of coins was recorded in Table 1.

Figure 1. Eight coins together, all showing heads.

13. Flip each coin once. If the coin comes up heads, return it to its place. If the coin comes up tails, set it aside.

14. Count the number of heads remaining. Record the number of heads in Table 1 under the column “Run #1” and the row “Flip #1”.

15. Repeat this process, recording the number of heads remaining under Run #1 until all the coins have turned up tails. It was not necessary to fill in all the possible entries under Run #1.

16. Return the coins to their original arrangement (8 all showing heads) and repeat this process for Runs #2 etc. until five total runs have been completed.

17. Calculate the average number of heads for each column (Flip #) and record those results in the row marked “Average”.

18. Plot the results on a sheet of graph paper. The horizontal axis will be the Run number and the vertical axis will be the average number of heads.

19. Draw a smooth curve through the plotted points to show the general behavior of the coin flipping.

20. When you are finished with the lab, label the graph and staple it to the back of this handout.

Answers (numbers in Table #1, graph) depends on experiment run by students.

Table 1. Simulations of Radioactive Decay: Coin Flips.

Flip #	Run #1	Run #2	Run #3	Run #4	Run #5	Average
0	8	8	8	8	8	8
1	_____	_____	_____	_____	_____	______
2	_____	_____	_____	_____	_____	______
3	_____	_____	_____	_____	_____	______
4	_____	_____	_____	_____	_____	______
5	_____	_____	_____	_____	_____	______
6	_____	_____	_____	_____	_____	______
7	_____	_____	_____	_____	_____	______
8	_____	_____	_____	_____	_____	______
9	_____	_____	_____	_____	_____	______
10	_____	_____	_____	_____	_____	______

21. What are the odds, when flipping a fair coin, of it coming up heads? (What do you think we mean by the term "fair"?)

50%. A "fair" coin means it was not biased towards any particular result.

22. We started each run with 8 heads. How many, ideally, do you think we should have after one complete run?

The odds favor a result of 4 heads after one complete run. (Note, though, that this does not prevent other possible results)

Part #2: Simulating radioactive decay with playing die

Not all real atomic nuclei decay the same way. In this exercise, we will simulate the way in which this difference might make itself evident.

13. Each team has 8 playing die (see Figure 2 below). Note the number of die was recorded in Table 3.

Figure 2. Eight playing die.

14. We will follow a similar procedure with the playing die as we did with the coins, with two differences. First, we "roll" dice instead of flipping them; second, do not set a die aside unless it comes up as a "six".

15. As before, record your results (this time in Table 4). Stop after 10 rolls, even if you still have die remaining.

16. As before, calculate an average number of die after each set of rolls and record the result in Table 4.

17. Plot the results on a sheet of graph paper. The horizontal axis will be the Run number and the vertical axis will be the average number of die remaining.

18. Draw a smooth curve through the plotted points to show the general behavior of the dice rolling.

19. When you are finished with the lab, label the graph and staple it to the back of this handout.

20. What are the odds, when rolling a fair die, of it coming up six?

    Since there are 6 sides to a die, the odds will be 1 out of 6.

21. We started each run with 8 die. How many runs did it take, on average, to get to only four die remaining?

    Answer depends on experiment.

Table 2. Simulations of Radioactive Decay: Die Rolling.

Flip #	Run #1	Run #2	Run #3	Run #4	Run #5	Average
0	8	8	8	8	8	8
1	_____	_____	_____	_____	_____	______
2	_____	_____	_____	_____	_____	______
3	_____	_____	_____	_____	_____	______
4	_____	_____	_____	_____	_____	______
5	_____	_____	_____	_____	_____	______
6	_____	_____	_____	_____	_____	______
7	_____	_____	_____	_____	_____	______
8	_____	_____	_____	_____	_____	______
9	_____	_____	_____	_____	_____	______
10	_____	_____	_____	_____	_____	______

22. Briefly describe how the two experiments (coin flipping, die rolling) are similar.

Ideally, individual flips and rolls both give random results.

23. Briefly describe how the two experiments are different.

The odds of getting a "six" on a roll are lower (1/6) than the odds of getting a "heads" on a coin flip (1/2).

24. Real radioactive decay was characterized by a nucleus' "half-life". What do you think was meant by this term?

"Half-life" means the amount of time it takes (on average) for half of the nuclei to decay.

Part #3: Energy generation by the weak force.

6. Place two carts on a track, held together by Velcro attached to the carts (see Figure 3). Note the wheels of each cart fit into grooves on the track.

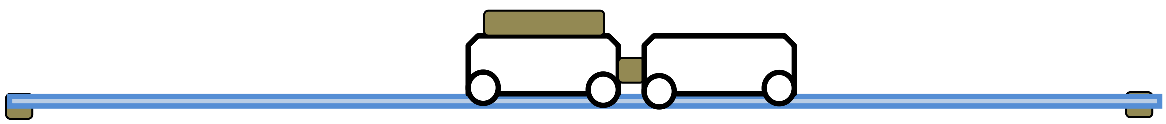

Figure 3. Two carts on a grooved track, with strips of Velcro holding them together. Some weights have been added to the left-handed cart.

7. Place two bars (weights) on the track at left. This will of course make the cart on left heavier.

8. A button on the cart can be pushed that will suddenly extend a plastic arm (ask the instructor for help in finding and/or using it if necessary). Push the button and watch what happens to the carts. Sketch the behavior of the carts on Figure 4 below, using arrows to depict the direction of motion of each cart.

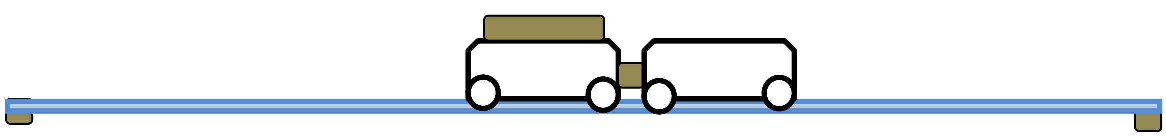

Figure 4. Two carts on a grooved track, after they are forcibly separated.

9. Reset the carts and perform the experiment again. Which cart moves faster – the heavier cart or the lighter cart? Why do you think it works out that way?

The light cart moves faster because it has less mass than the heavy cart (mass in physics was the reswastance of an object to a change of its velocity).

10. *Kinetic energy* was the term physicists use to describe energy of motion. Does this experiment absorb or release energy? Briefly compare the behavior of the carts before and after pushing the button.

The experiment releases kinetic energy – the carts are moving after the button was pushed.

Part #4: Strong force simulations

9. Look carefully at a cart. On the end of a cart opposite the side with Velcro, you should note some small disks embedded inside the cart. These are magnets.

10. Place both carts on the grooved track again, this time at opposite ends of the track, with their magnets facing each other (see Figure 5). Neither cart should have any weights on it.

Figure 5. Two carts on a grooved track, with their magnetic ends facing each other.

11. Gently push the carts toward each other. Briefly describe what happens to the carts after they meet.

The magnets push the carts apart.

12. Get a small piece of duct tape. Roll it into a cylinder, sticky-side out, and attach it to the magnetic ends of one cart.

13. Again, gently push the carts toward each other. Briefly describe what happens to the carts after they meet.

The magnets push the carts apart when the carts are moving slowly (or are gently pushed toward each other)

14. Try the experiment again, but this time push the carts harder, so they move more quickly toward each other (take care to keep the carts on the track!). Continue increasing the speed until the carts react differently upon colliding.

15. Briefly describe how the carts reacted once they were moving with sufficient speed.

The tape may hold the carts together when they are moving faster (or are pushed together more vigorously).

16. With the tape holding the carts together, hold the carts up (carefully!) so that one cart dangles vertically underneath the other. Which exerts a stronger force, the tape or the magnets?

The tape should hold the carts together.

Part #5: Summary

Assume the magnets represent the electrical charges of protons, the button (that extends the plastic arm) represents the weak nuclear force, and the duct tape or Velcro represents the strong nuclear force. Then address the following questions:

19. Does radioactive decay imply an attractive force or a repulsive force? Briefly defend your answer.

Decay implies a repulsive force (refer to the experiment where the button was pushed).

20. Recall the idea of "fairness" for the coin flips. Was radioactive decay a random process or a deterministic (i.e. the result was pre-determined) process? Briefly defend your answer.

Decay was a random process (refer to the randomness of the coin flips and dice rolling).

21. Does the flipping of one coin affect the result of the flipping of its neighbors? What does that say about the range (reach) of the force involved? Briefly defend your answer.

The result of flipping one coin doesn't affect how other coins are flipped, which implies that the force behind radioactive decay was very short range.

22. Protons carry positive charges. What do positive charges attempt to do – pull each other together (attraction) or push each other apart (repulsion)?

Positive charges repel each other.

23. What can we say about the relative reach ("range") of electrical forces? Hint: Do the magnets of the carts need to touch each other in order to affect each other?

The magnets did not need to touch each other in order to repel each other, which imply that such forces work at long dwastances.

24. What can we say about the relative range of the strong nuclear force? Hint: Does the duct tape need to touch both carts in order to hold them together?

The pieces of duct tape need to touch, which implies the range of the strong force was short.

25. What can we say about the relative range of the weak nuclear force? Hint: Does the plastic extending arm need to touch both carts in order to push them apart?

The plastic arm needs to touch both carts, which implies the range of the weak force was short.

26. Reconsider the radioactive decay experiments. Which force was at work here – electricity, the strong force, or the weak force?

The weak force – the experiments show objects breaking apart and working at short ranges.

27. Does a weak force reaction absorb or release energy? Hint: Review the results of the experiments in Part #3.

Weak force reaction release energy (for example, the experiment with the bar breaking apart the carts).

28. Does a strong force reaction absorb or release energy? Hint: Did the collision (that stuck the carts together in Part #4) make a sound?

Strong force reactions also release energy – the carts release sound (sound energy) when they hit each other.

29. Which force (strong or weak) takes small atomic nuclei and makes them larger? Which force (strong or weak) takes large atomic nuclei and makes them smaller?

Strong force reactions combine nuclei together to make larger nuclei; weak force reactions break nuclei apart to make smaller nuclei.

30. Which force – strong nuclear or electricity – was stronger?

The strong force was stronger than electricity (for example, the stickiness of the tape overcomes the repulsion of the magnets)

31. Atomic nuclei consist of two particles – protons and neutrons. Protons carry positive electric charges and neutrons are electrically neutral. What represented the protons in our experiment – the magnets or the duct tape? Which represented the neutrons?

The magnets represent the protons, since they try to push the carts apart; the tape represents the neutrons, since it tries to hold the carts together.

32. Neutrons are electrically neutral, so they exert no electrical forces. What type of force do neutrons exert? Recall your answer to the preceding question.

Neutrons exert forces that are short range and attractive, which means they exert the strong force.

33. The temperature of a gas increases as the average speed of its individual particles increases. Consider the experiment where the carts were pushed toward each other. In which case does it represent a higher temperature – when the carts are pushed gently (so they move slowly) or when the carts are pushed harder (so they move quickly)?

Hard pushes represent higher temperatures.

34. In which case was it more likely for the strong force to bind together individual nuclear particles – when they are moving slowly or moving quickly?

Strong forces are more likely to hold nuclei together when they are moving quickly (so that the repulsion from electricity doesn't have as much time to work).

35. In which case was it more likely for the strong force to bind together individual protons – when the gas was hot or when it was cool?

Similarly, the strong force has a better chance to work when the gas was hot.

36. The Sun uses hydrogen fusion to produce its energy, with the first step of the process being the collision of two protons that bind together. What would you say about the likely conditions (such as temperature) inside the Sun?

The temperature inside the Sun was very hot.

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