The Effectiveness Of Teaching Methods Designed To Improve Student Engagement And Retention Of Physics Subject Matter For Both Science And Non-science Majors

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THE EFFECTIVENESS OF TEACHING METHODS
DESIGNED TO IMPROVE STUDENT
ENGAGEMENT AND RETENTION OF PHYSICS
SUBJECT MATTER FOR BOTH SCIENCE AND
NON-SCIENCE MAJORS

by

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The necessity of students’ engagement with the subject matter for successful learning is well-documented in education research in general, and in physics education research in particular. This study examines the merits of two different programs designed to improve student learning through enhanced student engagement with the material. The target populations of the two programs are different: One is the group of students taking a physical science class as part of the general curriculum required of non-science, non-engineering majors; the other is the group of students, mostly in engineering disciplines, who must take the calculus-based introductory physics sequence as part of their majors’ core curriculum. The physical science class is required for non-science majors due to the importance of having a science-literate public. To improve this group’s engagement with the subject matter, Physics in Films approaches the subject in the context of scenes taken from popular Hollywood films. Students’ learning in the class is evaluated by comparison between performance on pre- and post-tests. The students are also polled on their confidence in their answers on both tests, as an improved belief in their own knowledge is one of the goals of the class. For the calculus-based physics group, a large issue is retention within the major. Many students change to non-science majors before the completion of their degree. An improved understanding of the material in the introductory physics sequence should help alleviate this problem. The Physics Suite is a multi-part introductory physics curriculum based on physics education research. It has been shown to be effective in several studies when used in its entirety. Here, portions of the curriculum have been used in select sections of the introductory physics classes. Their effectiveness, both individually and in conjunction, is studied. Students’ mastery of concepts is evaluated using pre- and post-tests, and effects on class performance and retention within the major are examined. Input from both groups of students in the study was obtained through interviews and surveys.
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**List of Acronyms**

**ILD** *Interactive Lecture Demonstrations*, the component of *The Physics Suite* used in select sections of the lecture component of the introductory physics sequence.

**ECCE** *Electric Circuits Concept Evaluation*, the diagnostic test used as the pre- and post test to measure learning in Physics II.

**ESRS** Electronic student response system, allows student interaction in large lecture settings.

**FCAT** Florida Comprehensive Assessment Test.

**FMCE** *Force and Motion Concept Evaluation*, the diagnostic test used as the pre- and post test to measure learning in Physics I.

**NSES** The National Science education Standards.

**NSF** The National Science Foundation.

**PER** Physics Education Research.

**PHY2048** Physics I, the first course in the calculus-based introductory physics sequence. The subject matter is Newtonian Mechanics.

**PHY2049** Physics II, the second course in the calculus-based introductory physics sequence. The subject matter is Electricity & Magnetism and Optics.

**PiF** Physics in Films, the name of the set of courses designed to provide an introduction to physical science principles in the context of scenes taken from popular Hollywood films.

**RITE** Research Initiative for Teaching Effectiveness, supports UCF faculty in formulating and implementing research on effective teaching practices in higher education.

**RTP** *Real-Time Physics*, the component of *The Physics Suite* used in select sections of the lab component of the introductory physics sequence.

**STEM** University degree majors that fall into the categories of Science, Technology, Engineering, or Mathematics.

**TF** Traditional Format, term used for those sections of the introductory physics courses, lecture and lab, not using curriculum from *The Physics Suite*.

**UCF** The University of Central Florida.
1 INTRODUCTION

There are two projects described in this paper. Both examine a modification to the way physics is taught to the University of Central Florida (UCF) students. But the target populations of the two projects are different. *Physics in Films* is an alternative version of the physical science course offered to non-science majors. These students are not studying to become scientists or engineers, but they will become members of the voting and purchasing public, so a general understanding of the principles of science, and an ability to recognize real science, are vital to their role in society. The course uses the popularity of Hollywood films to generate interest in science and to engage students that have traditionally been resistant to taking science courses. Scenes that lead to teachable science moments are identified in films and then used in class to concretize abstract physical concepts. With the wide variety of movies available, different "flavors" of the course, each specializing in a certain genre of film, have been created. This creates an audience of students with a high level of interest in the teaching tool and helps enhance their learning experience.

The second project targets those students that are studying to become scientists and engineers, or to work in the technology field. These students take the introductory calculus-based physics sequence, a pair of courses designed to provide the foundation that their more detailed, more specifically focused upper division classes build on. Failure to master the subject matter in these fundamental introductory courses is often cited as the reason so many students drop out or change majors out of disciplines related to science, technology, engineering and mathematics (STEM). *The Physics Suite* is a curriculum, based on physics education research (PER), designed to increase students’ involvement with the instruction through active participation in inquiry-style activities. Components of *The Physics Suite* have been used in several sections of the introductory calculus-based physics courses and the corresponding lab courses over the past few years, and the effects on learning are examined here.

1.1 Motivation for the Projects

Over the past couple of decades there has been a growing concern that the United States is falling behind much of the rest of the developed world in education in the fields of science and technology. General knowledge of science in the U.S. population is low, and seems to be declining even
further. Meanwhile, the use of, and dependence on technology is rapidly increasing. Also, the number of U.S. citizens graduating with degrees in STEM disciplines is declining, and this threatens the ability of the nation to lead in development and production of new technologies which will be so important to the world in the coming decades. These two populations are where the two groups of students in this study are headed. The physical science students will graduate and become members of the general population, a population where science literacy is necessary. The students in the calculus-based physics classes are heading into STEM degree programs, where they will need a strong foundation in introductory physics to succeed. These are the motivations for *Physics in Films* and the implementation of *The Physics Suite* at UCF.

1.1.1 Science Literacy in the U.S.

The required curriculum for UCF non-science majors includes a class in physical science. A similar course is required for graduation at most universities and many two-year colleges. Unfortunately, many students approach the class with apprehension. Registration in this required course is often postponed until the student’s last semester, increasing the student’s anxiety. Sometimes the students are worried that the mathematics required in the course will be too difficult, but more often, they simply feel that the subject matter is boring. They view knowledge of physical science and an understanding of the scientific process as irrelevant to their lives. This misconception is dangerous to the student and to our society in general. Without this knowledge, the distinction between science and pseudoscience becomes blurred, and people become vulnerable to those who would exploit that blurred distinction. For example, surveys have shown that 15% of Americans do not believe that humans have ever reached the moon, up to a quarter believe in astrology, and almost one third are unaware that the Earth orbits the sun (1). Although most students who take this type of course will not work directly in science or the technology industry, they will constitute the majority of the population in our country. Their attitudes toward science will be reflected in the public officials they elect, the policies of school boards on which they sit, and the behavior of corporations that they patronize. Without a scientifically literate public, meaningful public discussion of important scientific and ethical issues will be virtually impossible. The lack of distinction between science and pseudoscience will lead to public fear and opinion not founded on fact.

This problem is reflected in, and may be at least partially due to the portrayals of, and attitudes toward science in the popular media. This is apparent in the very films chosen for use in the *Physics in Films* classes. The abandonment of attention to scientific detail and, in fact, the adoption of the attitude that realistic portrayal of scientists and physical situations is not dramatic or entertaining is not limited to the film industry. This attitude has become prevalent throughout our society over
the past several decades. Scientists have been increasingly depicted as dull, close-minded and unimagination or dangerous, sometimes diabolical.

Another trend is the increasing popularity of the theme of the supernatural as something very real, with characters living otherwise very normal lives immersed in activities involving magic or ghosts. In his 1998 commentary in Science, Douglas Hofstadter recounts a story of his experience with his eight-year old son’s reading material. The boy was reading the Goosebumps series. This series has done a great service in popularizing reading among young children. However, it is filled with children portrayed as open-minded and intelligent heroes confronting supernatural beings in which their dull and stuffy parents refuse to believe. Hofstadter’s son then brought home a library book, another ghost story. Again, the parents in the story were skeptical, refusing to attribute the evidence to ghosts. The children set out to reveal the truth, and, in this story, through scientific investigation they uncover a very real explanation of the haunting. The library book was written in the early 1960’s. The Goosebumps series was written in the 1990’s (2). Similar themes occur in television and movies, with the heroes of the story increasingly portrayed as “enlightened,” while the scientific community is portrayed as the close-minded naysayers.

There has been much discussion of this dilemma at many levels, and various organizations are attempting to address it. The Federal Government has instituted the National Science Education Standards (NSES) as part of the No Child Left Behind program. On the state level, Florida seriously considered requiring a passing grade for the science section of the Florida Comprehensive Assessment Test (FCAT) as part of the graduation requirements for high school students. UCF is making a concerted effort to improve the effectiveness of the physical science course through the development of Physics in Films.

1.1.2 Science, Technology, Engineering and Mathematics Degrees in the U.S.

The pace of technological development and the application of new technologies has never been greater than now. Communication, transportation, medicine, banking, and education; local, national, and international security; even entertainment, have all come to rely heavily on the latest technologies. The U.S. faces a critical epoch in the coming decades, with great modifications needed in terms of energy usage, production and resources; and overhaul of much of its communication, transportation and power transport infrastructure. Even before 1960, Nobel laureate in economics Robert Solow had demonstrated that more than half of the growth of per-hour output in the U.S. during the twentieth century was due to advances made in knowledge, largely knowledge related to technology (3, 4). As the twenty-first century advances this should only increase. Yet as the importance of the careers that are held by their graduates increases, the STEM programs of US universities are not producing more graduates. The number of STEM bachelor’s degrees
awarded by U.S. universities has declined 18% over the last twenty years, even as the number of college graduates has increased. The portion of bachelor’s degrees awarded in STEM fields has dropped 40%. The number of U.S. citizens who earned doctoral degrees in engineering fields in 2007 had dropped 23% from what it had been ten years earlier (1). Retention of the students within the STEM majors is a challenge for UCF as well as universities nationally (4, 5, 6). The introductory physics courses are one of the first large hurdles that students must clear on their way to a STEM degree. By using the methods of The Physics Suite, UCF is attempting to maximize their chance of success.

1.2 Advantages of U.C.F. and the Department of Physics in Executing the Projects

UCF is a large university. The U.S. Department of Education National Center for Education Statistics ranked UCF as the sixth largest university in the country based on a Fall 2006 enrollment of 46,646 students (7). Since that time, the university’s enrollment has grown to over 55,000 making UCF the third largest university in the United States going into the Fall 2009 semester (8, 9, 10). The calculus-based introductory physics courses, Physics I (Newtonian Mechanics) and Physics II (Electricity and Magnetism with some Optics) are required for all students of the College of Engineering and Computer Science. This college alone had an enrollment of over 6000 in the spring of 2009 (11). The large number of Engineering and Computer Science students going through the introductory classes each semester, along with the students from the College of Sciences, which includes the Physics Department, and a large contingent of students from other colleges taking the department’s physical science classes, including Physics in Films, make UCF’s Physics Department the second-largest in the country based on the number of credit-hours taught per semester (12). The teaching of the calculus-based introductory classes is a large-scale operation, with ten to twelve lecture sections of eighty to over one-hundred students taught each semester, along with twenty to twenty-two lab sections of thirty to thirty-five students each. These large numbers have allowed for the studies to measure the benefits of the courses with a fairly large sample of students over a few semesters.
2 LITERATURE REVIEW

Getting students engaged with the subject is often troublesome in physics classes, and particularly with the physical science class taught as part of the general education requirement for non-science majors. Some of the methods found most effective are outlined here. Students’ active participation in the learning process is understood to be vital to successful learning. This has been shown to be especially true with the demanding subject matter of the calculus-based physics sequence. There is an overview of various strategies for achieving this given here. Finally, with retention in STEM majors such a focus in U.S. universities, a successful UCF program and its methods are outlined.

2.1 Methods of Engagement

There has been extensive research done on the teaching and learning, and much of it specifically on teaching and learning in science. Physics in Films makes use of popular media to communicate the ideas of science to a population less likely to pursue such knowledge without a context that captures their attention. The student’s engagement with the topic is essential for significant learning to take place. Researchers in other disciplines have also investigated the use of films as a teaching tool. One particularly effective method of engagement is direct confrontation of preconceptions held by students. There are many sources of preconceptions, including, to some extent, the popular media used in the course. In this case, the method is to compare the treatment of the situation in the film with the way it would unfold in reality.

2.1.1 Using Popular Media

Many of the students in the target audience of Physics in Films are moviegoers, and some of them avid fans. When offered an opportunity to study science in a way that includes watching films, they enthusiastically take it. The use of movies to increase student interest and performance has proved successful not only in quantitative sciences (13), but also in other disciplines such as psychology (14, 15, 16, 17). In particular, the use of specially selected short clips to illustrate single specific concepts (14) is parallel to the approach taken by Physics in Films.
2.1.2 Addressing Preconceptions

In general, the learning process can be derailed in a variety of ways. Often, a student won’t learn a new concept if he or she lacks some prerequisite knowledge needed to understand the new concept. This lack of knowledge, known as a null learning impediment, is usually easily diagnosed and remedied. The student is completely aware that he does not understand, and by the student’s own effort or timely evaluation, the teacher should also be aware. A more subtle obstacle to learning is known as a substantive learning impediment. Substantive learning impediments occur when new ideas are related to misconceptions present in the student’s cognitive structure. These impediments are more dangerous than null learning impediments because they may go undetected. The student believes that he has understood the new concept, and it makes sense in the framework of his prior knowledge (18). It may even deepen his belief in the underlying misconception. There may be several layers of misunderstanding before anyone, student or teacher, realizes that there is a problem.

Hollywood is often willing to sacrifice scientific accuracy for the sake of drama. The problem with this is that many people, without the tools for critical analysis, accept what they see onscreen as realistic and accurate. They begin to build a foundation for their understanding of the physical workings of the world around them based on the unrealistic portrayals in popular media, rather than a careful observation of the real world. This flawed conceptual framework then leads to substantive learning impediments that are difficult to diagnose and correct.

Many misconceptions are developed from early childhood through everyday experience and clash with scientific laws that seem counterintuitive when viewed from the framework of that experience, e.g. Newton’s First Law. These everyday observation-based misconceptions can usually be corrected by careful scientific observation and some understanding of the factors that hid the true behavior. Misconceptions learned in a social context, including those learned while watching movies and television are often harder to eliminate. The source of these misconceptions is often viewed as having an authority greater than the student’s own observations (19). The hope is that students of Physics in Films, armed with some solid knowledge of physical science and tools for applying that knowledge, will view the dramatization in films with a more critical eye and therefore be less susceptible to developing misconceptions.

2.2 Physics Education Research

The major theme of much of PER has been to shift the central focus of the physics classroom away from the teacher. Instead, the students themselves, as learners, play the major role in class. The elevated importance of the students’ active participation in the delivery of the lesson, interaction
with the teacher and classmates, and reflection on their own thought processes are basis of the pedagogy in the current physics classroom (20, 21, 22, 23).

2.2.1 Inquiry

Inquiry is a widely used term in science education. Often, it refers to the very nature of science itself. In this, it seems to be an appropriate and effective method to use in the instruction of science. The National Research Council has incorporated it into their National Science Education Standards recommendations, both as an understanding of how science is undertaken and as a method of teaching and learning. Although there is some variance in specific definitions of what inquiry teaching and learning are, there is a consensus that inquiry is a pedagogy based on constructivist ideas of knowledge, and that it can be applied in different degrees.

The inquiry-based learning process is based on a cycle:

1. A question is posed.
2. The student predicts, or hypothesizes what outcome is expected. This will be based on prior knowledge or preconceptions.
3. An experiment is performed and results are observed.
4. A theory or model is developed that will explain the results, in the student’s understanding.
5. The model is analyzed, to determine its effectiveness and scope.
6. The analysis of the theory leads to new questions, and cycle begins again; this time with knowledge informed by the process of the previous cycle.

As this cycle is repeated, students think not only about the question posed, but about the process itself. They refine their approach in subsequent cycles based on this reflection. It is clear that this learning process mirrors the scientific method, as it is understood today. Another similarity to science research is that the inquiry-based learning is often done in collaboration with other students. This allows for introduction of, and debate over, conflicting hypotheses during step two of the cycle. This debate can play a large role in the learning as it requires deeper reflection on the knowledge the hypothesis is based on. The importance of this reflection increases as the cycle continues (24, 25, 26).

It is common to see inquiry-based learning divided into the categories: open inquiry, guided inquiry, and structured inquiry. These vary by the amount of scaffolding provided for the inquiry process. With open inquiry, students are only provided with materials. They must formulate their own question to start the cycle, formulate their own hypothesis, design and execute their
own experiment, and arrive at their own conclusions and model. Guided inquiry provides both the materials and the question. Students must hypothesize and experiment and model without specific instruction. Guided inquiry will often prompt analysis of the students’ theories and a return to the start of the cycle with new questions based on the theories’ shortcomings. This is accomplished by the teacher’s use of open-ended questions; designed to promote ideas for new questions to probe or extensions of the students’ theories. In structured inquiry, only the results are left to the students. The question is posed and an experiment to determine the answer is provided. Students must execute the experiment and arrive at a conclusion (20, 24, 26, 27, 28, 29, 30).

2.2.2 Studio-Style Physics Instruction

In an effort to maximize the benefits of inquiry-based learning, many physics departments have launched projects that completely abandon traditional lecture and lab introductory physics instruction. These projects involve students working in small groups on activities that take them through the inquiry cycle until they arrive at an understanding of the concepts traditionally introduced in lectures. Typically all levels of inquiry are used, with most emphasis in guided inquiry. The instructors role in these settings becomes that of an enabler of the learning process, rather than that of an authority on the subject. The instructor will steer the direction of the students’ investigation with questions designed to promote students’ critical reflection on their theories, and analysis of their theories as they repeat the inquiry cycle. The activities are designed to make use of cognitive conflict as students are led to confrontations between experimental results and their own preconceptions. The starting questions of the activities are chosen to evoke initial predictions from students that follow common preconceptions, identified through research (23, 31, 32).

2.2.3 Interactive Lecture Demonstrations and Real-Time Physics

The Interactive Lecture Demonstrations (ILD) and Real-Time Physics (RTP) components of The Physics Suite make use of the inquiry approach to teaching and learning physics, but in a way that still allows classes to be taught in the traditional settings of the large lecture hall and separate physics lab. In a traditional lecture environment students play a passive role, which research has shown severely limits the amount of learning. The ILD method turns students into active participants by having them follow through the inquiry cycle, including collaboration with fellow students. ILD starts by posing a question on what the outcome of a physical demonstration relating to the topic currently being covered, or about to be covered in the lecture, will be. The students must individually record their predictions of the outcome. This is followed by discussion and debate of the predictions between students in small groups. The collaborative predictions are then recorded. The demonstration of the experiment is performed and results are observed. After this,
a class-wide discussion of the results, including analysis of both correct and incorrect predictions is conducted.

The physics lab class is collaborative, hands-on activity by definition. RTP increases the instructional effectiveness of the lab through the use of cognitive conflict and the inquiry cycle. The activities in the RTP manuals often start with an open inquiry structure; students are given a loosely defined question to investigate with the given materials. After this step, predictions are elicited on a more explicitly defined question, and then an experiment is performed. The results of the experiment are reported, with attention paid to the amount of agreement or disagreement between the actual results and the predicted results. This cycle is repeated with incremental increases in the amount of scaffolding provided. The process builds a strong base in the students’ conceptual understanding as well as developing a set of skills in conducting experiments and use of the equipment (21, 22, 32, 33, 34, 35, 36, 37).

2.3 STEM Retention Through a Learning Community: The Excel Programme

The UCF Physics Department has been involved with other projects designed to improve retention and performance in STEM majors at the university. An ambitious ongoing project, the Excel Programme, based in the Department of Electrical Engineering and Computer Science in the College of Engineering and Computer Science and involving the departments of Mathematics, Biology, Physics, and Chemistry from the College of Sciences. The program targets the most at-risk segment of the population of STEM students – students in the first two years of a STEM degree program – by providing extra academic support and opportunities and an enhanced peer-community environment.

The Excel programme was started in 2006 with the goal of improving the performance and retention within the major of STEM students at UCF. About 200 freshman with plans to major in STEM programs are admitted to Excel each Fall. They go through a specially designed calculus sequence as a group; either Pre-Calculus, Calculus I, Calculus II, or just Calculus I, Calculus II, depending on their performance on a placement test. The classes are taught only to Excel students and include an extra one-credit-hour recitation section. The Calculus courses are also taught in conjunction with a special one-credit-hour applications class. This class features a series of guest instructors from different STEM disciplines who outline how the current topic being covered in the Calculus class is applied within their field of research. This preview of real world uses for mathematical topics being covered in class gives a relevance to the learning that is not always apparent to first- and second year college students. Some students are required to start with the pre-calculus course based on their placement test score because it is the philosophy of the program that students must master the fundamentals and should not be placed in the class where they
will feel over their head. Students are also required to log a certain number of hours each week in an Excel-only learning lab. There are computers and study space and the lab is staffed with graduate assistant tutors, trained by the Excel faculty. The emphasis in the lab is on the pre-calculus/calculus sequence, but tutoring is also offered in physics, chemistry and biology (38, 39).

Another benefit of having students go through the exclusive calculus sequence together is that it builds a sense of community among them that is not always available to students in a large university setting such as UCF. This informal peer-support system can be very beneficial to students’ success. The community aspect of Excel is also encouraged by offering members access to on-campus housing reserved exclusively for students in the Excel programme, and Excel-sponsored social gatherings and outings scheduled regularly throughout the school-year (38, 39).

In their second year in the Excel programme, students are offered the opportunity to work in a paid internship in the research program of specially selected faculty from the STEM disciplines at UCF. The early experience in real research gives the students the upper hand as they continue into the upper-class levels of their discipline or, for some of the early participants, into graduate school (39).

The combination of specialized instruction, academic assistance, enhanced community and peer-support, and early opportunities for career-specific experience have proved successful for Excel. Excel students score almost 5% higher than control-group students on diagnostic tests evaluating learning in the calculus courses (38) and retention within the STEM majors at UCF has increased almost 20% since the start of the program. Initially funded for five years by NSF, the program will be continued by UCF due to its success (40).
3 METHODOLOGY

3.1 Physics in Films

Teaching physical science through popular media is an idea used in classrooms to teach from physical science (13) to psychology (14, 16). It has also been used in popular literature (41, 42). With UCF’s large student population, and the number of students going through the physical science course as a general requirement, Physics in Films has been able to specialize. The course doesn’t only teach science through the use of Hollywood blockbusters; it has been able to teach using specific genres of these blockbusters. Students are able to learn from a type of film that they have great interest in, and thus their engagement with the subject matter is maximized.

Using the films to teach physical principles requires careful selection of the scenes. The information necessary to make calculations of quantities such as momentum or potential energy must be available to the viewer; either explicitly or through some reasonable approximation. The use of these approximations to create tractable problems from complicated situations is an art frequently called “Fermi Problems”.

The active participation of students in the learning process is a necessary ingredient to ensure that engagement is maintained. The large lecture hall setting of the physical science courses makes this a challenge. To facilitate interaction between the students, and between the students and the instructor, electronic student response systems (ESRS) have been used in Physics in Films.

3.1.1 Different Film Genres Supply “Flavors” to Physics in Films

Hollywood has provided a wealth of examples that can be applied to the topics covered in a physical science course. Popular science fiction movies often include stunning visual demonstrations of fantastic situations that can be analyzed from a physical point of view, and continually improving special effects make these situations appear more realistic than ever before. Nevertheless, science-teaching opportunities are not limited to sci-fi. Action movies are full of excellent examples of kinematics and mechanics, and the increasingly popular comic book-inspired superhero movies combine the benefits of the action and sci-fi genres. Another bountiful resource, and one
that inspires some of the liveliest in-class debate, is the family of films that deal with the paranormal: ghosts, magic, zombies, or the afterlife. Because of the broad range of film genres that have scenes that provide excellent teachable moments but which appeal to slightly different audiences, Physics in Films has been adapted to different genres and/or themes, creating different “flavors” of physical science that each focus on the science as it appears in a particular movie type. These different flavors of Physics in Films are taught as different sections of the same physical science course. The list of flavors that have been developed is (43, 44, 45):

- **Action/Adventure**
- **SciFi**
- **Superheroes**
- **Modern Physics** (Movies that enable the teaching of topics from Modern Physics)
- **Astronomy**
- **Pseudoscience** (Movies that include pseudoscientific topics: paranormal or supernatural stories)
- **Metaphysics** (Movies that touch on questions of metaphysical content)

The data in this study is taken from four sections in three different flavors, taught by three different instructors: A Superheroes section, taught in Summer 2004; An Action section, from Summer 2005; and two Pseudoscience sections, one from each Summer semester.

### 3.1.2 Fermi Problems

For the physical principles involved in a scene to be clearly revealed, the action taking place on the screen must be translated into a relatively simple problem. A powerful tool in the translation of on-screen action to a solvable problem is an appropriate estimate of quantities involved and then their use in a calculation. The results should give an answer that is correct, at least in order of magnitude, without going through the possibly intimidating details of the exact calculation. This method is often called “back of the envelope” calculation or “Fermi calculation”, after the Nobel laureate Enrico Fermi, who was a master of the technique. Learning to use the Fermi calculation technique can give the students a real sense of empowerment. With it, they are able to logically analyze situations that initially seemed intractable. Although they may not become masters of the technique during the time they spend in the course, exposure to the method allows students to see a side of the scientific process of which they may not have been aware. The method of
repeated, increasingly accurate estimates of solutions to a problem too complex to solve directly is one of the most implemented tools of modern science. The hope is that students finishing the course will continue to practice the use of Fermi calculations as a method of critical thinking in their daily lives. The use of Fermi problems for teaching from Hollywood films requires careful selection of scenes. The scene should dramatically demonstrate a physical principle from the course curriculum. Necessary information to make the calculations must also be available from clues in the film. If a quantity that is necessary for the calculation is not available in the context of the film, it must be one that can be estimated based on general knowledge. Some examples of scenes used in class are the crashing of the alien spaceships in Independence Day, the cruise ship crashing into the pier in Speed II, and the rotating space station in 2001: A Space Odyssey. Fermi calculations show scientific inaccuracies in the first two films. The spaceships crash over every major city in the world with what would be the energy release of tens of thousands of atomic bombs, yet people celebrate this as a victory. The cruise ship’s deceleration, as calculated from reappearing shots of the ship’s speedometer over time, is only a tiny fraction of the acceleration due to gravity, yet people are dramatically hurled around the ship. On the other hand, the third film, 2001: A Space Odyssey, realistically portrays a rotating space station creating an artificial gravity similar to that experienced on the surface of earth.

3.1.3 Electronic Student Response Systems

Student response systems are interactive technologies that have recently become very popular. They allow teachers to pose questions to the entire class, often as part of a PowerPoint presentation. The students respond using electronic keypads. The answers are recorded, and the responses are immediately available for display, again in the PowerPoint presentation. Studies have shown that the use of student response systems as part of the classroom interaction increases student engagement and classroom discussion, leading to improved understanding of the subject matter.

From its inception, Physics in Films has made use of various electronic student response systems. The systems provide instant feedback from students as responses to questions posed by the instructor. This provides a means for real time assessment of student understanding. The statistical results of the students’ responses can be displayed in a PowerPoint presentation as soon as the responses are collected, with or without revealing the correct answer. Revealing the correct answer gives the students immediate feedback on their performance and comparison of their response with the class in general. Display of the class response statistics without the correct answer indicated allows the use of the system as a polling mechanism. The results are often used as an introduction to discussion in smaller groups. Students are invited to debate their answers and
views with their neighbors. After the discussion, the class is polled again, and the results are displayed, this time with the correct response indicated. Sometimes polls are taken before and after a certain topic is studied, showing any change of opinion on the topic after it has been investigated scientifically. As pointed out by Malcolm Montgomery of the University of Cincinnati (46), the anonymity of the electronic student response system is a big advantage over simply using a show of hands when polling students. When responses to questions are not anonymous, students tend to follow the first opinion expressed. When responses are gathered electronically and then displayed simultaneously, all are on equal ground. This brings a much larger range of views to any following discussion (46).

In addition to the benefits that the student response system brings to the classroom, it is also helpful with bookkeeping. The system provides a way to take attendance and measure participation during the course of the lecture. The grades for quizzes performed with the system are automatically logged, eliminating the need to record grades later.

3.1.4 Method of Evaluation

All sections of Physics in Films took tests at the beginning and the end of the semester that included the same sets of questions. After each question, the students were asked to rank their confidence in their own answer on a five point scale. The amount of improvement from pre-test to post-test is presented, as well as the shifts in the students level of confidence for their answer to each question. Also, interviews were conducted with student volunteers following their completion of the course and their opinions were elicited on various aspects of the course.

3.2 Implementation of The Physics Suite at U.C.F.

The set-up and basic method of instruction is described for each method of instruction in the lecture and lab sections of the introductory physics classes. The evaluation process is outlined, including the administration of concept evaluations, examination of class performance, and students’ feedback (47).

3.2.1 Introductory Physics classes at UCF, and changes made to implement The Physics Suite

The lecture sections of the introductory physics classes at UCF are taught in an auditorium-style lecture hall seating 80-120 students. Traditional format lectures are taught in a method determined by the instructor. Most are taught as straight lecture using either projected slides or blackboard/whiteboard. A few instructors have made occasional use of electronic student response systems (ESRS) to incorporate some active student participation into the format.
There are many innovative approaches to teaching introductory physics. One that has been demonstrated to effectively improve students’ conceptual learning is curriculum presented in *The Physics Suite* (22). Some elements of *The Physics Suite* apply readily to the large-scale approach to the teaching of the introductory classes at UCF, with little or no change to the scheduling format or the infrastructure used by the department. *Interactive Lecture Demonstrations* (48) can be used effectively in a large lecture hall setting, so they can be implemented in any of the sections scheduled at UCF. Similarly, *RealTime Physics* (49, 50, 51) is designed for use in a lab setting with groups of two to four students performing experiments using computers and probeware, much of which is already used in the UCF introductory physics labs. These elements of *The Physics Suite* bring physics education research-based curriculum into an existing large-scale physics instruction program while maintaining the department’s existing method of scheduling and class structure and making use of the department’s existing equipment.

The sections chosen for participation in *The Physics Suite* project used *Interactive Lecture Demonstrations* (ILD) during one lecture class each week. A demonstration relating to the current topic being addressed in the class is set up. Students are asked to make a prediction of what results will be seen during the demonstration. The predictions are recorded as a poll, using the ERS. Students are then encouraged to interact in small groups, discussing their predictions and explaining their reasoning. After the discussion interval, students are polled again and the results are displayed. The demonstration is then conducted and students can see the actual results. Finally, the physical principles involved are discussed, with participation both from students who had reasoned correctly and from some who had misconceptions. This approach of direct confrontation of preconceptions with actual demonstrations, requiring the students to thoroughly reason through the problem both before and after the demonstration has been shown to be an effective teaching method. It develops deeper understanding by connecting students’ intuition to the concepts addressed, and it is effective in changing flawed preconceptions (36, 52, 53, 54).

The lab component of the introductory classes is a separate, one credit-hour class. The classrooms are arranged for eight stations of four students each, and each station equipped with a computer and Pasco CI-6560 interface. The experiments used in the traditional format lab were largely written by former UCF professors and are published in-house. Most of the activities are centered around conducting measurements that are then used to confirm a theory outlined at the beginning of the lab, including any equations. The instructions assign which measurements to take, how many times to take each, and how to apply the results in the appropriate equations. The students present their results in a report composed outside of class and turned in the following meeting. The format of the report is determined by the instructor. Part of the focus of the manual is on experimental set-up and method, and there is some introduction of error analysis.
The lab sections using *RealTime Physics* (RTP) as their lab manual are set in the same rooms and make use of much of the same equipment as the traditional format labs. The RTP manual makes use of a guided-inquiry approach to the execution of the experiments. After a brief outline of the experimental set-up, the students are asked to make predictions of the results they expect to see. Like the ILDs in the lecture sections, this prediction step will target preconceptions and lead to discussion of the underlying principles among members of the lab group. For most activities, the data is plotted in real time, as the experiment takes place. The students are encouraged to make multiple runs of each experiment, watching the relation between the physical activity and the mathematical plot. The actual results are compared with the predictions made earlier. Questions are asked to get the students to think about the physical principles determining the experimental results. Some mathematical analysis is done with the graphs and data from the experiment to show relations between physical quantities.

An example of an activity performed during one of the one-dimensional motion labs from Physics I follows: A student holds a ball above a motion detector that is hooked to a computer. The ball is going to be thrown into the air directly above the motion detector and air resistance ignored so gravity is the only force considered. The students predict what will happen to velocity and acceleration for the ascent, turning point, and descent. Then the ball is thrown in the air so the motion detector can plot velocity versus time and acceleration versus time. Now students discuss the results and can see that for the ball even though velocity changes acceleration is constant. The plots of velocity and acceleration are compared, illustrating the mathematical relation between the quantities. Careful attention to the graphs also helps illustrate the vector nature of the quantities (55, 56, 57).

The lab report is completed within the lab class time, consisting of answering the questions posed during the activities. There is a brief homework following each lab, designed to reinforce concepts developed through the activities in the lab. Through the Fall 2007 semester, the first semester of the project, the homework was optional. Since then, the students have been required to turn this in at the start of the following lab. The emphasis of the RTP labs is on understanding the physical concepts addressed and interpreting the graphs of mathematical relations followed by the physical quantities (37, 58).

### 3.2.2 Method of evaluation

To evaluate the effectiveness of *The Physics Suite* method at UCF, all the students in the introductory physics classes were given a pre-test during the first meeting of the lab section, and a post test on the last day of the lab. The tests used are concept tests and the same tests were given to all students both times. The Physics I test is the *Force and Motion Concept Evaluation* and is included as
an appendix to the Thornton/Sokoloff article cited (35). The Physics II test is the Electric Circuits Concept Evaluation, also created by Sokoloff and Thornton. The students’ pre- and post-test scores were compared based on the percentage of material that they learned during the semester. The improvement score, normalized gain, calculates what percentage of the questions missed on the pre-test are answered correctly on the post-test.

The students in each semester registered for their lecture and lab classes without knowing if either would include a component of The Physics Suite, so their placement was random. A small number of students each semester take either the lab or lecture component alone. The students taking only the lecture component did not take the concept evaluation tests.

The scores from the pre- and post-tests were grouped into four categories: students taking an ILD lecture section and an RTP lab, students taking an ILD lecture section and a TF lab, students taking a TF lecture or no lecture and an RTP lab, students taking a TF lecture or no lecture and a TF lab. Students who missed either test due to add/drop of a class or an absence on either test day were not counted. Also, for any student who had taken a pre-test and switched sections and took it again the lower score was kept. These statistics were used to evaluate the effect of The Physics Suite elements on conceptual learning.

Student performance in the lecture component of the course, measured by grade, is compared between the different combinations of teaching formats. Since grading can vary widely between instructors, each instructor’s students are divided separately into those taking an RTP lab, those in a TF lab, and those with no lab at all. The class performance of each of these groups is compared. Some of the instructors taught the lecture using the ILD module, the rest were classified as TF. The percent of students successfully completing the lecture component of each course, defined as C or better, is also compared for the different methods.

Finally, student opinions were solicited. Interviews were conducted with student volunteers after two semesters, the Spring 2008 semester and the Spring 2009 semester. In the spring of 2008, twenty-eight students were interviewed, eight students from Physics I and twenty from Physics II. Six of the students were Physics II RTP students who had taken Physics I during the fall with the RTP method. A survey was given to all sections of the lab classes at the end of the Spring 2009 semester. Excerpts from the interviews and results from the survey are presented.
4 RESULTS FOR PHYSICS IN FILMS

An internal evaluation performed on several sections of Physics in Films shows a marked improvement of students’ understanding of the physical science topics presented through the course. Pre- and post-tests consisted of a series of questions addressing topics covered in the specific section (“flavors”) of the course. Following each topical question, the students were asked to rank their confidence in the answer chosen on a five point scale ranging from “Just Guessing” to “Very Confident”. Student mastery of the course material showed not only in the improved percentage of correct answers on the science questions, but also in the dramatic shift toward the higher end of the confidence scale on the post-test. Examples of specific questions are shown, both for class performance and for improved confidence. The number of students participating in the pre- and post-tests from each section is given in Table 4.1. Excerpts from focus group interviews with student volunteers are included at the end of the chapter (45).

<table>
<thead>
<tr>
<th>Physics in Films Numbers by Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
</tr>
<tr>
<td>Superheroes Summer 2004</td>
</tr>
<tr>
<td>Pseudoscience Summer 2004</td>
</tr>
<tr>
<td>Action Summer 2005</td>
</tr>
<tr>
<td>Pseudoscience Summer 2005</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*Table 4.1: The number of students in the sections of PiF used in the study.*

4.1 Pre-Test and Post-Test Results

All sections of Physics in Films took tests at the beginning and end of the semester that included the same set of questions. Comparisons are made between the percentage of correct answers on the pre-test with the percentage of correct answers on the post-test for each question, in each section. Cumulative results are compared for each section. The amount of improvement for each section is also calculated as a normalized gain using the percent of correct answers from the two tests and
the formula (20):

\[
\text{normalized gain} = \frac{\text{post-test score} - \text{pre-test score}}{\text{maximum score} - \text{pre-test score}} \times 100
\]

Figure 4.1 shows the percent of correct answers on the pre-test and post-test, as well as the normalized gain, for each of the four sections.

4.2 Examples of Class Performance on Specific Questions

The general goal of the physical science class and Physics in Films in particular, is to increase the scientific literacy of a population of students unlikely to pursue knowledge of the subject outside of the context of class. The following examples are illustrations of class performances on the pre-test and post-test for specific questions. The questions probe students’ understanding of some basic concepts, ideas, and principles of science and the scientific process.

4.2.1 Basic Physical Principles

Some questions go directly to students’ knowledge of basic physical principles. Figure 4.2 shows class pre-test and post-test answers to the question, “Which way does heat flow?” Figure 4.3 is
the answers to, “An object is thrown upward. After it has left the hand, the acceleration …”. These indicate many students have gained knowledge of the scientifically understood behaviors of energy transfer and of acceleration due to gravity near the Earth’s surface. Figure 4.4 shows students have attained knowledge of one property of light, so valuable to scientific understanding of the nature of space-time, through their answers to the question, “Which of the following speeds is not possible to achieve no matter how advanced our technology becomes?”. Knowledge of the accepted theory of the formation of most elements is probed by having students complete the statement, “All known elements on Earth were made …”. Responses are shown in Figure 4.5.

**Which Way Does Heat Flow?**

(A) From hotter to colder.
   Always.

(B) From colder to hotter.
   Always.

(C) It could be either A or B.
   Additional information must be given.

(D) It does not necessarily flow from one object to another.

![Figure 4.2: Students' Answers to Question on Heat Transfer](image)

An object is thrown upward. After it has left the hand, the acceleration …

(A) is zero.

(B) decreases.

(C) increases.

(D) is constant.

![Figure 4.3: Students' Answers to Question on Acceleration Due to Gravity](image)
Which of the following speeds is not possible to achieve no matter how advanced our technology becomes?

(A) 30,000.33333 Km/s
(B) 90,000.22222 Km/s
(C) 120,000.11111 Km/s
(D) 300,001 Km/s
(E) 299,999.99999 Km/s

---

Figure 4.4: Students’ Answers to a Question on the Universe’s Speed Limit

All known elements on Earth were made …

(A) on Earth by natural processes.
(B) inside comets.
(C) inside stars.
(D) on Mars and captured by Earth via its gravitational attraction.
(E) inside other planets.

---

Figure 4.5: Students’ Answers to a Question on the Origin of the Elements
4.2.2 Vocabulary

Other questions are simply on vocabulary. Students’ responses to “Which entry in the following list is not used as a unit of energy?” are shown in Figure 4.6. The units used for quantities in electricity are common in everyday life, yet many people have little understanding of what quantities are represented by what units. The students taking this course show an improved knowledge by their chosen answers, shown in Figure 4.7, to “Electric potential is measured in ______ and electric current is measured in ______.” At a deeper level, “Conservation of some physical quantity means that the quantity . . . ” probes students’ understanding of the concept of conservation, the starting point for solution of so many problems in physics. The responses are shown in Figure 4.8. Figure 4.9 then shows the students’ knowledge of what quantities obey conservation laws by their answers to, “For which quantity in the following list is there not a conservation law?”

Which entry in the following list is not used as a unit of energy?

(A) calorie
(B) Calorie
(C) Joule
(D) 1 ton of TNT
(E) 1 ton of methanol

Figure 4.6: Students’ Answers to a Question on Units Used for Energy
Electric potential is measured in _________ and electric current is measured in _________.

(A) Volts; Amperes
(B) Amperes; Volts
(C) Coulombs; Amperes
(D) Amperes; Coulombs
(E) Volts; Coulombs

Figure 4.7: Students’ Answers to a Question on the Vocabulary of Electric Circuits

Conservation of some physical quantity means that the quantity …

(A) cannot be used in any calculations.
(B) should not be wasted.
(C) remains the same at all times no matter what happens.
(D) can be used to accelerate the system.

Figure 4.8: Students’ Answers to Question on the Meaning of a Conserved Quantity
For which quantity in the following list is there not a conservation law?

(A) momentum
(B) force
(C) angular momentum
(D) energy
(E) none of the above

Figure 4.9: Students’ Answers to Question on Conserved Quantities
4.2.3 Understanding Physical Processes

As with the query on the concept of conservation, some questions look for a deeper understanding of physical processes. Figure 4.10 shows answers to “Friction exists because . . .” and an understanding of the underlying reason for a common experience of everyday life. “Electric current will flow if there is a(an) . . .” looks for a connection between the vocabulary of electric circuits and the physical meaning of the named quantities. Figure 4.11 shows the responses. An understanding of the fundamental physical quantities tagged with all the different units is illuminated by “Which of the following quantities is not a base quantity in SI units?” with responses shown in Figure 4.12. The question “The pressure due to fluids does not depend on the . . .”, with students’ responses shown in Figure 4.13, requires an understanding of how these fundamental quantities combine to cause a physical phenomenon; possibly even an understanding of the mathematical relation between the quantities.

**Friction exists because . . .**

(A) the surfaces of most objects are smooth.

(B) **the surfaces of all objects are rough.**

(C) matter may be either liquid or solid.

(D) molecules are made of atoms.

(E) objects move with high speed.

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![Figure 4.10: Students’ Answers to Question on Friction](image)

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25
Electric current will flow if there is a(an) …

(A) electric potential at a point.

(B) zero electric potential difference between two points.

(C) non-zero electric potential difference between two points.

(D) object which has gravitational potential energy.

Figure 4.11: Students’ Answers to a Question on Electric Potential and Current

Which of the following quantities is not a base quantity in SI units?

(A) length

(B) time

(C) mass

(D) momentum

Figure 4.12: Students’ Answers to a Question on the Basic Quantities and Their Units in SI
The pressure due to fluids does not depend on the ...

(A) acceleration of gravity.
(B) depth of the fluid.
(C) density of the fluid.
(D) width of the container that contains the fluid.

Figure 4.13: Students’ Answers to a Question on the Quantities That Influence Pressure
4.2.4 Making Calculations and Interpreting Mathematical Models

The target population of the physical science class is not expected to gain a deep understanding of the mathematics used in much of science and engineering. However, a basic grasp of simple principles, how they are applied, and how they serve to model the physical world is a large part of science literacy. One of the simplest and most common mathematical relations that appears in science is a proportionality. Figure 4.14 shows results for “Triple the net force on an object. Then . . . ” where students must remember, and understand, the direct proportionality of Newton’s second law. Looking at the post-test results, it seems that students have at least remebered which quantities appear in the equation, as the number of students selecting the answer involving momentum drops significantly. Slightly more complicated is Coulomb’s law, with its inverse-square relation, shown in Figure 4.15; responses to “If we double the distance between two charges, the electric force between them . . . ”. Notice that the most common mistake on the post-test is the choice that treats the relation as a direct proportionality between the force and the square of the distance—the students seem to have grasped a part of the relation. Vectors and the idea of independence of quantities in different directions, is a more sophisticated mathematical topic, but still within the scope of the course. Results from a question on projectile motion are shown in Figure 4.16: “Two tennis balls are projected horizontally from a tall building at the same instant, one with a speed of 100 miles per hour and the other with a speed of 50 miles per hour”, with the students asked to choose which ball will land first. There is no requirement to perform a calculation; choice of the correct answer only requires an understanding of the concept. Even more advanced math, such as Calculus, can be introduced through everyday examples of situations that require such treatment. Completion of the statement “The speedometer of your car measures . . . “, shown in Figure 4.17, familiarizes the idea of instantaneous rate of change.
Triple the net force on an object.
Then . . .

(A) its speed triples.
(B) its mass triples.
(C) its momentum triples.
(D) its acceleration triples.
(E) nothing happens unless the object is already moving.

Figure 4.14: Students’ Answers to a Question on the Newton’s Second Law

If we double the distance between two charges, the electric force between them . . .

(A) remains the same.
(B) doubles.
(C) becomes 4 times the original.
(D) becomes 9 times the original.
(E) none of the above

Figure 4.15: Students’ Answers to Question on Coulomb’s Law
Two tennis balls are projected horizontally from a tall building at the same instant, one with a speed of 100 miles per hour and the other with a speed of 50 miles per hour.

(A) The ball with the speed of 100 miles per hour will hit the ground first.

(B) The ball with the speed of 50 miles per hour will hit the ground first.

(C) Both balls will hit the ground simultaneously.

(D) There is not enough information to decide. For example, the height of the building is not given.

The speedometer of your car measures …

(A) the average speed of the car.

(B) the instantaneous speed of the car.

(C) the average acceleration of the car.

(D) the instantaneous acceleration of the car.

(E) the instantaneous speed of the car, except in dense traffic with often stops that measures the average acceleration of the car.

Figure 4.16: Students’ Answers to Question on Projectile Motion

Figure 4.17: Students’ Answers to a Question on Instrument Readings; Instantaneous and Average Quantities
4.2.5 Challenging Preconceptions

A big part of the problem with scientific literacy involves preconceptions, and Hollywood has played a large role in introducing, reinforcing and propagating many of these preconceptions. This is especially true in many science fiction and fantasy films, where, with Hollywood’s virtuosity with special effects and the popularity of a pseudoscientific treatment of some subject matter, the stories have become increasingly believable. Much of the Pseudoscience section of Physics in Films has been designed specifically to confront these preconceptions. The following two examples are illustrations. Figure 4.18 encourages students to think about what might happen to beings that had evolved in a completely different environment, should they ever visit the Earth; a topic usually ignored, or treated very briefly, in sci-fi films. The question shown in Figure 4.19 confronts some of the popular notions about ghosts, including that the presence of ghosts can be “measured” by temperature change – often portrayed with much scientific seriousness and state-of-the-art instrumentation by Hollywood. Finally, students make choices between both fantastic and mundane explanations for strange noises in the night, shown in Figure 4.20.

Choose the statement that is valid with certainty.

(A) If aliens visit Earth, it is certain that they will be peaceful.

(B) If aliens visit Earth, it is certain that they will be bloody killers.

(C) Aliens have visited Earth in the past and have helped with the evolution of life on the planet.

(D) If aliens visit Earth, they will face many challenges due to the different physiology of their bodies.

![Figure 4.18: Students’ Answers to Question on Extra-terrestrial Visitors](image)

Figure 4.18: Students’ Answers to Question on Extra-terrestrial Visitors
Which of the following properties has been proved to be a property of ghosts.

(A) To be invisible.
(B) To be transparent.
(C) To lower the temperature.
(D) To radiate microwaves.
(E) None of the above.

![Figure 4.19: Students’ Answers to Question on Ghosts](image)

Sounds heard during the night inside houses are due to...

(A) ghosts.
(B) poltergeists.
(C) uneven contraction and expansion of objects.
(D) structural defects in the building.
(E) insects crawling under furniture.

![Figure 4.20: Students’ Answers to a Question on Things That Go Bump In the Night](image)
4.3 Student Confidence Gains

Perhaps the most important reason to have the general public sufficiently literate in science is to reduce the susceptibility to false science. If people are not confident in their knowledge of science, they are less likely to challenge ideas or facts presented with a “scientific” argument. So increasing the students’ knowledge alone is not enough—they must also believe in their own ability to recognize honest science. The change in students’ confidence in their answers between the pre-test and post-test is recorded by having them rank their confidence in each answer on a five-point scale from a low of “Just Guessing” to a high of “Very Confident”. The normalized gain for students’ confidence is calculated similarly to the normalized gain presented above for the test performance. The confidence gain is calculated from the raw scores by assigning the confidence choices values from 1 for “Just Guessing” to 5 for “Very Confident”, then multiplying these values by the percent of students answering in each category. The resulting scores are used in the formula:

\[
\text{confidence gain} = \frac{\text{post-test confidence} - \text{pre-test confidence}}{\text{maximum confidence} - \text{pre-test confidence}} \times 100
\]

The confidence gain for each section, along with the score gain presented earlier, is shown in Figure 4.21.

The individual sections’ confidence scores for the pre- and post-tests are shown in the following figures: Figure 4.22 shows the Superheroes section from Summer 2004, Figure 4.23 shows the Pseudoscience section from Summer 2004, and Figures 4.24 and 4.25 show the gains for the Action and Pseudoscience sections from Summer 2005, respectively.
Figure 4.21: Gains In Performance Compared With Gains In Confidence - Normalized gain in performance compared with normalized gain in confidence for each of the four sections of Physics in Films

Figure 4.22: Shift of Student Confidence: Superheroes Section, Summer 2004 -
Figure 4.23: Shift of Student Confidence: Pseudoscience Section, Summer 2004

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just Guessing</td>
<td>29.71</td>
<td>0.93</td>
</tr>
<tr>
<td>Not Very Confident</td>
<td>13.23</td>
<td>1.06</td>
</tr>
<tr>
<td>Not Sure</td>
<td>25.85</td>
<td>9.26</td>
</tr>
<tr>
<td>Confident</td>
<td>17.99</td>
<td>20.37</td>
</tr>
<tr>
<td>Very Confident</td>
<td>13.00</td>
<td>68.39</td>
</tr>
</tbody>
</table>

Figure 4.24: Shift of Student Confidence: Action Section, Summer 2005

<table>
<thead>
<tr>
<th></th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Just Guessing</td>
<td>20.30</td>
<td>7.95</td>
</tr>
<tr>
<td>Not Very Confident</td>
<td>12.71</td>
<td>9.14</td>
</tr>
<tr>
<td>Not Sure</td>
<td>34.58</td>
<td>30.03</td>
</tr>
<tr>
<td>Confident</td>
<td>18.99</td>
<td>31.26</td>
</tr>
<tr>
<td>Very Confident</td>
<td>12.46</td>
<td>20.45</td>
</tr>
</tbody>
</table>
Figure 4.25: Shift of Student Confidence: Pseudoscience Section, Summer 2005 -

<table>
<thead>
<tr>
<th></th>
<th>Just Guessing</th>
<th>Not Very Confident</th>
<th>Not Sure</th>
<th>Confident</th>
<th>Very Confident</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-test</strong></td>
<td>26.35</td>
<td>17.39</td>
<td>25.83</td>
<td>17.30</td>
<td>8.26</td>
</tr>
<tr>
<td><strong>Post-test</strong></td>
<td>1.58</td>
<td>2.33</td>
<td>14.08</td>
<td>25.58</td>
<td>51.33</td>
</tr>
</tbody>
</table>
4.4 Examples of Class Confidence Gains for Specific Questions

As with the classes performance on specific questions shown above, students’ confidence in their answers varies with the depth and difficulty of the question.

4.4.1 Vocabulary

Post-test confidence is answers can be quite high on questions that require a simple definition, such as the meaning of the term “pseudoscience”, as shown in Figure 4.26, or the meaning of the term “conservation” in a physics context, Figure 4.27. The post-test scores are very good on both of these, the first shown here and the second shown in the previous section, so the increase in confidence is justified. Other examples, from questions presented earlier, are the students’ confidence in their responses on units used for energy, Figure 4.28, and electric circuit vocabulary, Figure 4.29. Both of these show a definite shift to the higher end of the confidence scale, but it is not as overwhelming as the two previous examples. A look back at the scores show that the improvement, although present, is not as dramatic either. So, even with rote learning of vocabulary there is a significant difference between topics in students’ success.
The term pseudoscience means …

(A) something that is scientific but is presented in a confusing way.

(B) scientific statements that have not been proved yet.

(C) scientific statements that have already been disproved.

(D) statements that are not scientific but are presented as scientific.

(E) all topics used in Hollywood movies.

Figure 4.26: Students’ Confidence in Answers to a Question on the Meaning of “Pseudoscience”
Figure 4.27: Students’ Confidence in Answers to a Question About the Meaning of “Conservation”
- The shift of students’ confidence in their answers to the question, “Conservation of some physical quantity means that the quantity . . .”. The responses are shown in Figure 4.8

Figure 4.28: Students’ Confidence in Answers to a Question About Units Used For Energy - The shift of students’ confidence in their answers to the question, “Which entry in the following list is not used as a unit of energy?”. The responses are shown in Figure 4.6
Figure 4.29: Students’ Confidence in Answers to a Question on Electrical Circuit Vocabulary - The shift of students’ confidence in their answers to the question, “Electric potential is measured in ________ and electric current is measured in ________”. The responses are shown in Figure 4.7
4.4.2 Facts and Basic Principles

Comparable to memorized vocabulary are questions that require knowledge of a specific fact, process, or event. Again, the confidence seems to follow the actual performance on the questions, with some variance by topic. Gains are strong, both in performance and confidence, for questions relating to astronomy and the search for other possible life-supporting planets as shown in Figures 4.30 and 4.31. Students also do well on questions regarding possible processes for the origin of life here on Earth, Figure 4.32. Also fairly high is students’ confidence in their knowledge, shown earlier, of the origins of the elements. The confidence results are shown in Figure 4.33. Although the percentage of students correctly answering the question on the speed of light as a limiting speed for anything to travel jumped from 46% to over 80%, the confidence gain was more tentative, as shown in Figure 4.34. And, when a fact relates to zombies, the students remember it clearly, Figure 4.35.
In search of intelligent extraterrestrial life, astronomers are looking for planets in other solar systems. Planets in general are hard to discover since …

(A) it is not known if they exist.
(B) they do not emit any light.
(C) the intelligent beings hide them from us with celestial camouflage.
(D) we probably look in the wrong part of the galaxy.
(E) they are bigger than their neighboring stars.

Figure 4.30: Students’ Confidence in Answers to a Question About Astronomers’ Search for Extrasolar Planets
Europa is a moon of Jupiter first discovered by Galileo. Today scientists believe that Europa may harbor life since …

(A) it has an atmosphere identical to Earth’s atmosphere.

(B) it has mountains and valleys.

(C) it seems that it has an ocean of salty water beneath its frozen surface.

(D) they have found meteorites from Europa that seem to contain bacteria.

(E) it has the same size as Earth.

Figure 4.31: Students’ Confidence in Answers to a Question on the Possible Hospitality of Europa to Life
Amino acids are the building blocks of life. Which of the following is not a proposed theory for their creation?

(A) They came to Earth on meteorites.

(B) They were already present when Earth was created.

(C) They were created inside the Sun and came to Earth through the solar wind.

(D) They were made in the Earth’s atmosphere by natural processes.

Figure 4.32: Students’ Confidence in Answers to a Question Relating to the Origin of Life on Earth
Figure 4.33: Students’ Confidence in Answers to a Question on the Creation of Elements - The shift of students’ confidence in their answers to the question, “All known elements on Earth were made ...”. The responses are shown in Figure 4.5

Figure 4.34: Students’ Confidence in Answers to a Question on the Universe’s Speed Limit - The shift of students’ confidence in their answers to the question, “Which of the following speeds is not possible to achieve no matter how advanced our technology becomes?”. The responses are shown in Figure 4.4
Which of the following is the best possible explanation for the effects of ‘zombification’?

(A) voodoo magic
(B) excess eating
(C) excess drinking
(D) genetic engineering
(E) tetrodotoxin

Figure 4.35: Students’ Confidence in Answers to a Question on Zombies
4.4.3 Understanding Concepts

The questions become more difficult as they demand a conceptual understanding. Figure 4.36 shows the class’s answers, and the confidence in those answers, to a question on methods of heat transfer, and Figure 4.37 shows the confidence levels for the question on the direction of heat transfer introduced earlier. Both show a fairly successful mastery of the concept, and a fairly high level of confidence in the new understanding. Another strong confidence shift is shown by students on the question addressing the fundamental quantities and their S.I. units; confidence shown in Figure 4.38. Unfortunately, not all the results are as positive. On the question that required an understanding of the relation between electric potential and current, where the improvement was positive but not overwhelming, the gain in confidence, Figure 4.39, is mediocre. A question on the use of banked curves in road design fairs even worse. Figure 4.40 shows that students actually did worse on the post-test than on the pre-test, while confidence rose slightly. Perhaps many of the students who were “Just Guessing” on the pre-test guessed right, and when most students were “Unsure” of their answers on the post-test their uncertainty was justified. However, there are more good results than bad. The students gained insight into the structure of the universe, shown by the responses they gave to a question about the fundamental forces, and their confidence in those responses, in Figure 4.41; and also by their confidence, Figure 4.42, in the understanding, shown earlier, of where conservation laws apply.
Which of the following is not a way of heat transfer?

(A) mixing  
(B) radiation  
(C) convection  
(D) conduction

Figure 4.36: Students’ Confidence in Answers to a Question on Different Methods of Heat Transfer
Figure 4.37: Students’ Confidence in Answers to a Question on the Direction of Heat Transfer - Which way does heat flow? The responses are shown in Figure 4.2

Figure 4.38: Students’ Confidence in Answers to a Question on Basic Quantities and Their Units in S.I. - Which of the following quantities is not a base quantity in the units of SI? The responses are shown in Figure 4.12
Electric current will flow if there is a . . . . The responses are shown in Figure 4.11
Roads are made with a slope around a turn to help cars have …

(A) more friction.

(B) less friction.

(C) more centripetal force.

(D) less centripetal force.

(E) less air resistance.

Figure 4.40: Students’ Confidence in Answers to a Question About Banked Curves and Centripetal Force
According to our present state of knowledge, in our universe there is (are) _______ of forces.

(A) only one kind
(B) two kinds
(C) four kinds
(D) eight kinds
(E) an infinite number

Figure 4.41: Students’ Confidence in Answers to a Question About the Fundamental Forces of the Universe
Figure 4.42: Students’ Confidence in Answers to a Question on Conserved Quantities - For which quantity in the following list is there not a conservation law? The responses are shown in Figure 4.9.
4.4.4 Applying Mathematical Ideas and Making Calculations

The most difficult questions require the understanding of a physical principle as well as the ability to interpret its mathematical expression, and possibly to make calculations. As expected with the group of students taking the physical science class, requiring calculations brings lower rates of success, and increased uncertainty in the answers given. Results and confidence ratings are shown for a simple metric unit conversion in the context of an everyday example, drug dosage, in Figure 4.43. Perhaps the context is a little too mundane to inspire interest, what seems to be a more challenging conversion, using light speed and time to measure distance, yields better results and higher confidence; shown in Figure 4.44. The students’ confidence in their efforts with the proportionality relations discussed earlier are shown: Figure 4.45 shows a significant shift to higher confidence on the post-test. Remember that the most common mistake on the post-test was to treat the force as directly proportional to the square of the distance, rather than inversely proportional. The students choosing that answer probably felt they were correctly identifying the relation. Although the results were similar for the question involving Newton’s second law, the confidence shift was less, Figure 4.46. Further evidence of the difficulty posed by questions that require some calculation is shown in Figure 4.47. The shift away from “Just Guessing” between the pre- and post-tests would seem to give some indication that many of the students grasp the concept of using the principle of conservation of momentum as starting point for the problem. However, the results for the answers and the fact that most are still “Unsure” of their answer show that they are largely unable to solve the problem. On a more positive note, the students’ confidence in their answers to the projectile motion question, which required no calculation–only an understanding of the independence of vertical and horizontal motion, is noticeably stronger on the post-test, Figure 4.48.
A milligram (mg) is a popular unit for drug dosage. It measures the mass of the drug taken. A milligram is equal to ...

(A) 1000 grams.
(B) 100 grams.
(C) 10 grams.
(D) 1/10 gram.
(E) none of the above.

Figure 4.43: Students’ Confidence in Answers to a Question Involving a Metric Unit Conversion
How much is a distance of 5 light seconds?
(A) 600,000 Km
(B) 900,000 Km
(C) 1,200,000 Km
(D) 1,500,000 Km
(E) none of the above

Figure 4.44: Students’ Confidence in Answers to a Question Involving Conversion of Light Seconds to Kilometers
Figure 4.45: Students’ Confidence in Answers to a Question Requiring a Calculation Using Coulomb’s Law - For which quantity in the following list is there not a conservation law? The responses are shown in Figure 4.15

![Bar Chart 1](image1.png)

Figure 4.46: Students’ Confidence in Answers to a Question Requiring a Calculation Using Newton’s Second Law - Triple the net force on an object. Then … The responses are shown in Figure 4.14

![Bar Chart 2](image2.png)
A gun of mass 10Kg fires a bullet of mass 0.1 Kg with a muzzle speed 200m/s. What is the final momentum of the gun?(All answers are in SI units)

(A) 2000  
(B) 200  
(C) 20  
(D) 10  
(E) We cannot find it since its speed is unknown.

Figure 4.47: Students’ Confidence in Answers Requiring a Calculation Using Conservation of Momentum
Figure 4.48: Students’ Confidence in Answers to a Question Requiring an Understanding of Projectile Motion - Two tennis balls are projected horizontally from a tall building at the same instant, one with speed 100 miles per hour and the other with speed 50 miles per hour. The results for responses to the question are shown in Figure 4.16.
4.4.5 Challenging Preconceptions and Recognizing Science

If students are to go into the world armed with an acceptable amount of science literacy, their confidence in their knowledge is as important as the knowledge itself. The insecurity of people with their own understanding of the physical workings of the world leads to susceptibility to pseudo-scientific portrayals and even superstitions. The first step toward science literacy is developing an understanding of what science actually is and being able to recognize the practice of actual science. Figure 4.49 shows a question on the scientific method and students confidence in their development of an understanding of what constitutes science. They show a growth in the ability to recognize where the practice of science takes place in Figure 4.50, a question on disciplines that use the scientific method. Extrasensory perception is an idea that is often discussed with terminology associated with science; even the name has a “scientific” ring to it. In Figure 4.51 students demonstrate that they understand what it would really mean to study ESP using science, and a growing belief in their own understanding. Figure 4.52 shows a statement regarding a magician’s performance. In the post-test, students demonstrate an ability to differentiate techniques the magician could use that would make use of real physical principles, understood through scientific study, from those the magician might have you believe he was using.
Which step is not part of the scientific method?

(A) Observing the phenomena.

(B) Introducing a hypothesis.

(C) Performing experiments to test the hypothesis.

(D) Accepting an idea that seems reasonable.

(E)
Which of the following disciplines does not use the scientific method to arrive at conclusions?

(A) psychology
(B) astronomy
(C) biology
(D) chemistry
(E) astrology

Figure 4.50: Students’ Confidence in Answers to a Question About Who Uses the Scientific Method
Choose the correct statement for extrasensory perception (ESP).

(A) If there is ESP, even if it is due to scientific mechanisms, it is impossible to be detected.

(B) ESP is a mystical property and thus cannot be studied by science.

(C) If there is ESP, then we should be able to devise a scientific experiment to detect it.

(D) It is known that ESP is due to special brain waves that only a few people can emit and receive.

(E) Science cannot make any claim for or against ESP.

![Figure 4.51: Students' Confidence in Answers Identifying a Scientific Statement on ESP](image)
Which of the following cannot explain magic tricks performed by magicians in front of an audience?

(A) optical illusions
(B) camouflage
(C) misdirection
(D) manipulation of geometry
(E) hypnosis

Figure 4.52: Students’ Confidence in Answers Identifying the Science Behind a Magician’s Show
4.5 Student Interviews

Several groups of students from different sections of Physics in Films were interviewed following their completion of the course. The interviews were conducted by an independent party, the Research Initiative for Teaching Effectiveness (RITE) office, which has been established by UCF to support faculty in formulating and implementing research on effective teaching practices in higher education. The students were asked questions about various aspects of their experience in *Physics in Films*, their views of the subject of science, and their previous experience in the physical science class. The following excerpts illustrate the students’ thoughts about the use of the films to convey science concepts in the class and their attitudes about movies after taking the class and the students’ feelings about the use of the electronic response system in the class.

4.5.1 The Use of Films as a Teaching Tool

These first excerpts from three group interviews show the students’ opinions on the effectiveness of the films as a method of communicating the science concepts. Along with several comments about the films keeping students’ attention better than lecture and watching movies a preferable form of homework, a couple of students mention that learning the concepts as illustrated in films makes them easier to remember.

1. **Group 1. Talk to me about the movies a little bit – did you feel like they helped the instruction at all? Was that of value to the class?**
   - It’s like, you know the class will watch movies, we’ll do our homework, we’ll come and discuss it and he talks about what happens in the movie and whether or not that’s physically possible, due to science and all that. So it helps you understand better.
   - I was more interested because I’d rather spend 2 hrs watching a movie than spend 2 hrs reading a textbook because then I can pull things from the movie instead of trying to go back and remember what I just read because … I just, it’s not as interesting.

2. **Group 2. Do you think it helps you understand the physics concepts he was talking about, using the movies?**
   - Well, yeah, especially if you’re a learner that learns more by demonstration instead of just reading a fact and trying to put it together. It helps a lot more to see it in the movie or to pull back from that instead of just reading the text.

3. **Group 3. How did you think the films worked in the class?**
   - Personally, I think it was so much better. Like, I’ve taken this class before, I took it in the spring and I failed it. And I took it with Professor [name omitted], and as far as I know, the class average in the class was a D. And I don’t think it’s even close to that right now. I mean, not to say I enjoy the subject of physics, I would never major in it in my life, but it’s a much easier course, and I’ve learned a lot more the way it’s taught with the films.
- Yeah, I liked it too, because like, it’s one thing for them to talk about a subject, but watching a movie kind of like reinforces information that he’s talking about. I mean, he could just talk to us and we can like, imagine, but if we’re watching, like, a movie, and actually see what he’s talking about, it makes it, like, better for us to understand. Like a visual.

4. Do you think, would you recommend this class using the films to teach it to other people?
- Definitely.
- Yeah, it’s very visual.

5. It’s better than not having the films?
- Yeah, I’ve heard like, I mean I know you took physics [looking at other student] but I’ve heard people just dread physics before, and like taking it now, telling people who’ve taken physics before, they’re like, jealous because it’s like, “I worked my behind off” and I’m not saying that this - it’s not a difficult course, you know what I’m saying, you learn, and it’s like easier to learn because of the visual and you know, the material given. I think it’s lot more effective.
- I’ve actually talked to people who haven’t taken this course yet – well actually someone’s who’s just transferring over - and I was telling them about this course and they actually said they were interested in taking it even though it wasn’t required for them. Just because they thought it was a cool course. So …
- And the teacher, he gives a lot of information … but you can keep a lot of information with you. You know, you can observe, because some teachers just talk and talk and talk and you get a lecture. And he gives a lot of information just with the demos, and the little videos that he has, you know, clips … and you know things like that, you know, demonstrations that he does.
- Yeah, it’s not just a lecture, you get to see movies that aren’t that boring – they’re normal movies and they’re nice so…

4.5.2 Watching Movies After Physics in Films
These three excerpts deal with students’ approach to watching films after taking the class. One concern has been that learning to watch more analytically will decrease the enjoyment of movies in the future. The students in these interviews did not seem to feel that they had lost anything.

1. Group 1. Do you find that you look at films differently now because of …
- I also, like, usually I just follow the storyline and don’t think twice, but now, when it comes to the paranormal and stuff like that, I’ll kind of think twice, I’ll be like “Wait a minute,” say “that doesn’t coincide with reality.” I mean, a lot of movies don’t, but I’m a little bit more skeptical now when I do watch a movie.

2. Is that a good thing or a bad thing?
- For me it’s a good thing, because when you watch a movie you believe everything, you know? And you’re like, you go with what they are telling you. And now you’re like … the movie is this … it doesn’t go with the beginning. And now you analyze this, and don’t get like, emotional.

3. You’re just thinking more about the movie?
4. You can’t just enjoy the movie now.

- Well you can though. You know, I enjoyed every movie I watched, even though I thought about it a little more now. It’s still, you know, the same movie. You just think about it differently.

5. Group 2. Do you find, since you’ve used movies this whole semester, like, do you look at movies differently now when you go to the movies to watch them? Did this class change how you watch movies?

- It shows you how fictional a lot of the movies are and how they come across as truth, but it’s really not.

6. Group 3. Do you think now that you’ve looked at films in a different way, does that affect the way you watch movies?

- Yes. Because it makes you think you look smarter now.

- Yeah, when you watch scary movies, you’re kind of not that scared because you know it could never happen. It’s pretty cool.

7. Is that a good thing or a bad thing?

- No, it’s a good thing. Because I used to get pretty scared. Yeah, and now I’m like, “Alright, cool.” Now it’s just entertaining, it’s not scary anymore.

8. So you don’t lose the entertainment in the movies?

- No, not at all.

4.5.3 Student Views on the Use of Electronic Response Systems in the Class

The anonymity in answering questions was appreciated. Some students felt the use of the system to keep an attendance record helped them keep up their attendance. Other students appreciated the extra credit offered for correct responses and used the questions as review for their tests. They also commented that putting some value on the responses made them take answering seriously. One group mentioned the use of the system to show changing class opinions on topics during the lecture. One student resented being interrupted and having to “think about” the material during the lecture. Although he may not have liked being forced to think during an 8:00 am lecture, his comments may actually be a favorable review for the system.

4.5.3.1 Anonymity

1. Did you think his using them to ask questions, did that help you at all in the class?

- It’s so much better than him just randomly picking someone because it’s just like, kind of anonymous, so you don’t feel really stupid if you get it wrong because nobody has any idea if you got it wrong.
4.5.3.2 Attendance

1. Did you think it was worthwhile to use that though? I mean he asked you questions in class?
   - It made me go to class.
   - It counts as attendance, so.
   - And it’s good for studying because you know those are like, kind of like, the questions that he’s gonna ask on the test. So it’s like, good to see.

4.5.3.3 Extra Credit and Test Review

1. The second ones(response system), once they worked, he used it for attendance, but also did he ask you questions?
   - I liked the questions and how you can get the extra credit if you do the questions, so it makes you want to stay there and actually do the questions.
   - And it helps with the midterm – there’s times I think I understand concepts and then I’ll get the question totally wrong, and he’ll re-explain it and I’ll understand it better.

2. Are the questions, they’re extra credit, or …
   - No, they’re part of the attendance grade and part of the grade, but if you answer – I think it’s 75% right, you get 5% extra credit – which I think is, it’s a big motivator to do it – stay the whole class.
   - It’s like the questions are taking attendance because if you answer a question then they know you’re there. And it also, it motivates you to think – because if it wasn’t for extra credit, and just for attendance, you know, I’m sure half the people wouldn’t really think about the question.
   - They’d just push a button.

4.5.3.4 Polling for Class Opinions

1. Now he – the way the keypad works is he actually gets the recording of all the students’ responses?
   - It comes up on a bar graph of the right answer, and how, like the percentage of who got it right.
   - I like how he showed the percentages, because it was interesting when like, he’d ask, “Do you believe in ghosts?” and then you’d see how many people in the class actually do believe in ghosts.
   - And then he’ll go through the lecture and he’ll ask the question again and see how it changes.

4.5.3.5 Keeping Attention

1. You didn’t like the keypads? No. Why?
   - I don’t know, I just didn’t really – I mean I kind of saw the point. But I was just, they were just kind of a burden because you’re just sitting there and the lecture’s flowing, you know, and you’re getting interested and then all of sudden you just kind of have to stop and answer a question and think about it, and then get back on to the lecture.
5 RESULTS FOR THE PHYSICS SUITE

5.1 Student Performance on Conceptual Inventory Evaluations

The students’ conceptual learning as measured by the performance on the Force and Motion Concept Evaluation (FMCE) and Electric Circuits Concept Evaluation (ECCE) pre- and post-tests is presented first. The comparison is made between students taking sections using either Interactive Lecture Demonstrations (ILD) in their lecture, RealTime Physics (RTP) in their lab, or both components of The Physics Suite (ILD & RTP) and those taking only traditional format classes (TF) in both their lecture and lab component (47). The formula used to calculate the normalized gain is (20):

\[
\text{normalized gain} = \frac{\text{post-test score} - \text{pre-test score}}{\text{maximum score} - \text{pre-test score}} \times 100
\]

Figures 5.1 and 5.2 show the two-year cumulative performance in Physics I (PHY2048) and Physics II (PHY2049) separately. The gains for all formats are higher in Physics I, with students taking both ILD and RTP components gaining over 50% compared to 19% for students having both components in the traditional
format. In Physics II, the gains are less for all formats, but students taking any component of *The Physics Suite* more than doubled their gain over the TF-only group.

The remaining figures for this section show the performance of students in the introductory classes by semester for the first two years of the project, from the most recent results back to the start of project. Note that in PHY2049 there are no students in the TF lab categories after the first semester of implementation. After positive results in the initial semester of the project, all sections of the Physics II lab component were switched to the RTP format.

The latest results from the Spring semester of 2009 are shown in Figure 5.3. Figure 5.4 shows the results from the Fall semester of 2008. Figure 5.5 shows the performance in the Spring of 2008. Finally, Figure 5.6 shows the Fall of 2007, the first semester of implementation.

For Physics I, the number of students in each category and for each semester is given in Table 5.1. The Physics II numbers are in Table 5.2. Fall 2007 was the only semester with traditional format labs in Physics II.

### Physics I Numbers by Semester

<table>
<thead>
<tr>
<th>Semester</th>
<th>ILD&amp;RTP</th>
<th>ILD&amp;TF</th>
<th>TF&amp;RTP</th>
<th>TF&amp;TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2007</td>
<td>26</td>
<td>57</td>
<td>72</td>
<td>270</td>
</tr>
<tr>
<td>Spring 2008</td>
<td>15</td>
<td>42</td>
<td>43</td>
<td>186</td>
</tr>
<tr>
<td>Fall 2008</td>
<td>19</td>
<td>49</td>
<td>60</td>
<td>104</td>
</tr>
<tr>
<td>Spring 2009</td>
<td>32</td>
<td>121</td>
<td>34</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td>92</td>
<td>269</td>
<td>209</td>
<td>680</td>
</tr>
</tbody>
</table>

*Table 5.1:* The number of students taking the FMCE, by semester.
Figure 5.3: FMCE & ECCE results for Physics I & II from Spring 2009

<table>
<thead>
<tr>
<th>Lecture &amp; Lab</th>
<th>PHY2048</th>
<th>PHY2049</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILD &amp; RTP</td>
<td>0.66</td>
<td>0.32</td>
</tr>
<tr>
<td>ILD &amp; TF</td>
<td>0.29</td>
<td>0.33</td>
</tr>
<tr>
<td>TF &amp; RTP</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>TF &amp; TF</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.4: FMCE & ECCE results for Physics I & II from Fall 2008

<table>
<thead>
<tr>
<th>Lecture &amp; Lab</th>
<th>PHY2048</th>
<th>PHY2049</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILD &amp; RTP</td>
<td>0.56</td>
<td>0.37</td>
</tr>
<tr>
<td>ILD &amp; TF</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>TF &amp; RTP</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>TF &amp; TF</td>
<td>0.20</td>
<td></td>
</tr>
</tbody>
</table>
Figure 5.5: FMCE & ECCE results for Physics I & II from Spring 2008.

Figure 5.6: FMCE & ECCE results for Physics I & II from Fall 2007.
### Physics II Numbers by Semester

<table>
<thead>
<tr>
<th>Semester</th>
<th>ILD&amp;RTP</th>
<th>ILD&amp;TF</th>
<th>TF&amp;RTP</th>
<th>TF&amp;TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2007</td>
<td>17</td>
<td>21</td>
<td>66</td>
<td>191</td>
</tr>
<tr>
<td>Spring 2008</td>
<td>15</td>
<td></td>
<td>141</td>
<td></td>
</tr>
<tr>
<td>Fall 2008</td>
<td>46</td>
<td></td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Spring 2009</td>
<td>78</td>
<td></td>
<td>210</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>156</td>
<td>21</td>
<td>627</td>
<td>191</td>
</tr>
</tbody>
</table>

*Table 5.2: The number of students taking the EECE, by semester.*
5.2 Effects on Class Performance

The conceptual gains of students taking part in classes making use of Interactive Lecture Demonstrations and Real-Time Physics are evident in the results of the FMCE and the ECCE. The transfer of these conceptual gains to improved performance in problem solving is an important goal of physics education. To try to gain some insight into the success of this transfer in the study at UCF, students performance in their physics lecture class is examined. Since grading can vary widely between different instructors, the performance of students is evaluated separately for each instructor. Only one instructor used both traditional and ILD instruction in lecture classes taught during the study, so the rest are investigated by the effect of the method of lab instruction on students’ performance. For both Physics I and Physics II the cumulative GPA of students taking a lab using RTP, a lab using TF, or no lab at all is shown for each instructor.

5.2.1 Effect of Lab Instruction Method on Lecture Performance

The concept inventory results suggest improved conceptual learning for students involved in sections implementing the elements of The Physics Suite. An important question follows: Does the improved conceptual understanding translate to improved performance in problem solving? To answer this question, students’ performance in their lecture classes is examined. The lecture class demands problem solving, on homeworks and tests, sustained throughout the semester. Since class grades depend largely on the instructors’ individual policies and philosophies, comparison directly would yield little insight. By comparing the grade performance of students taking different lab instruction methods with the conceptual gains of those same students the immediate effect of the those gains on class performance is investigated.

Figures 5.7 through 5.23 compare the cumulative GPA for each of the 17 instructors with the FMCE and ECCE gains of the students from each instructor’s class. For instructors 11 and 17, there is no data on the pre- to post-test gain, but the comparison of GPA between the lab instruction methods is presented.
Figure 5.7: Comparison of GPA and Gain Data for Instructor 1
Figure 5.8: Comparison of GPA and Gain Data for Instructor 2
Figure 5.9: Comparison of GPA and Gain Data for Instructor 3
Figure 5.10: Comparison of GPA and Gain Data for Instructor 4
Figure 5.11: Comparison of GPA and Gain Data for Instructor 5
Figure 5.12: Comparison of GPA and Gain Data for Instructor 6
Figure 5.13: Comparison of GPA and Gain Data for Instructor 7
Figure 5.14: Comparison of GPA and Gain Data for Instructor 8
Figure 5.15: Comparison of GPA and Gain Data for Instructor 9
Figure 5.16: Comparison of GPA and Gain Data for Instructor 10
Figure 5.17: GPA Data for Instructor 11 - No Gain Data
Figure 5.18: Comparison of GPA and Gain Data for Instructor 12
Figure 5.19: Comparison of GPA and Gain Data for Instructor 13
Figure 5.20: Comparison of GPA and Gain Data for Instructor 14
Figure 5.21: Comparison of GPA and Gain Data for Instructor 15
Figure 5.22: Comparison of GPA and Gain Data for Instructor 16
Figure 5.23: GPA Data for Instructor 17 - No Gain Data
5.2.2 Successful Course Completion

To see if there might be any immediate effect of retention within the major due to the different instruction method, a comparison is made between the different groups of the percentage of students successfully completing the course they are in at the time of the study. Most of the engineering majors require a C or better in the introductory physics classes to receive credit toward their degree and continue with their majors’ core classes. The results are in Figure 5.24.

![Figure 5.24: Percentage of ABC Grades]

Figure 5.24: Percentage of ABC Grades - Most of the engineering majors require at least a C in the introductory physics classes.

5.3 Student Interviews and Survey

The evaluation also involved student input. A survey was given to all students taking the post-test at the end of the Spring 2009 semester. The survey consisted of fifteen statements relating to the benefits of the lab component of the course, the correlation between the lab and lecture components, the recitation sessions conducted during the lab meeting time, and possible ways to maximize the benefit of the lab component. Students were asked to rank their agreement with each statement on a five-point scale: strongly agree, agree, neutral, disagree, or strongly disagree. The percent of students responding in each rank is shown, grouped by the combination of lecture/lab instruction method. Here the responses of students are shown for two statements that are key to both the motivation for, and the success of the implementation of The Physics Suite. They refer to the goal of challenging common preconceptions held by students of the introductory physics classes, which The Physics Suite curriculum is written specifically to address, and the goal of better coordinating the lab component topics with the lecture component topics chronologically during the semester. The results for all questions in the survey are shown in Appendix A.

Figures 5.25 and 5.26 show the responses to the statement, “The experiments performed in the lab have caused me to change my mind about how some physical process works.” The students who had
taken a RTP lab had a more positive response than those taking the traditional format lab. The strongest positive response came from students taking only the RTP lab, with no lecture component. Most of these students had taken the lecture component in a previous semester. The least positive of the RTP lab responses came from the students who also had an ILD lecture as their lecture component. This is the group that performed the highest on both the conceptual test and in the lecture component grade. The lower positive response may be due to the wording of the statement. These students may feel that their preconceptions were challenged during the ILD lecture as well as during the RTP lab experiments.

![Figure 5.25: Physics I Students’ Response To Survey](image)

**Figure 5.25: Physics I Students’ Response To Survey** - The experiments performed in the lab have caused me to change my mind about how some physical process works.

Figures 5.27 and 5.28 show the average of the responses to the statement, “There is a connection between the concepts addressed by the lab experiments and the theory covered in the lecture class.” Again, students have responded more positively if they had the RTP lab than if they had a TF lab.
Figure 5.26: Physics II Students’ Response To Survey - The experiments performed in the lab have caused me to change my mind about how some physical process works.

Figure 5.27: Physics I Students’ Response To Survey - There is a connection between the concepts addressed by the lab experiments and the theory covered in the lecture class.
Figure 5.28: Physics II Students' Response To Survey - There is a connection between the concepts addressed by the lab experiments and the theory covered in the lecture class.
Student volunteers were interviewed following the Spring 2008 semester. On major items such as: Do you like the format?; Have the experiments changed misconceptions?; and, Do the experiments help you learn physics?; the majority of students gave positive feedback. The interactive nature of the RTP labs was praised by a number of students. Many students claimed to have had preconceptions modified by conducting the experiments in the RTP lab. A question in the interview addressed the homework and most students had a positive response. It was an indication the homework was fulfilling its intended purpose. The interviews were conducted in a group setting. The responses have been paraphrased to accommodate grouping of like responses and the entire paraphrased transcript is available in Appendix B.
6 DISCUSSION

6.1 Physics in Films

Results from the pre- and post-tests show that students are definitely learning. There does seem to be a correlation between students’ interest in the subject matter and their grasp and retention of the ideas. This argues in favor of the course, which aims to connect the curriculum with subjects of interest to the students. The more specific the “flavors” can be made, and the more variety that can be offered each semester, the better will be the chance to reach the most students.

As expected, the more mathematics that a question requires, the lower the average score is on the question. This is particularly true for actual calculations; it seems that students are able to understand and even make use of some abstract mathematical relations in answering questions while even simple calculations cause scores to plummet. The scores on confidence would seem to support this. Confidence seems to rise or fall along with actual performance on questions, except on some examples where confidence would indicate students thought they knew how to approach a problem but calculations led to an incorrect answer. On the other hand, students seem to perform very well, and with a high level of confidence, on questions that required some understanding of fairly complicated concepts—as long as there was no actual mathematical execution required.

One of the main goals of the physical science course, and the main motivation for the creation of an alternative version, is to increase the science literacy of the students graduating from the university. To this end, the course appears to be a great success. Students understanding of what science is has improved through the course. Their attitude toward science has also improved greatly. This is in evidence in the large improvement of confidence rankings from pre- to post-test. Students leave the course with a sense of empowerment—that they can recognize and understand real science. Both of these come through in the interviews also. Students are grateful for the new understanding. The improved science literacy also shows in the scores on questions making direct challenges to many of the preconceptions students have coming into the course.

The best use of these results may be to inform the further development of Physics in Films. Identification of the topics that best resonate and then connection of the course curriculum with those topics should lead to the best results. Even further specialization of the sections may lead to higher student interest. Hollywood is quite cooperative with its love of sequels. It may be possible to create a section of the class devoted to one series of movies. Identification of the preconceptions that students hold most strongly coming into the class, and a search for more of these specific preconceptions would enhance students’ learning, as the direct confrontation of these preconceptions seems very effective.

The success of Physics in Films to this point has been encouraging. The popularity of the course has been steadily increasing as its reputation on campus grows. The course offers a very attractive alternative to the standard physical science class available to our target audience. Student performance in the class has been good, and student reaction to the class has been favorable. The hope is that the Physics in Films
method of covering the material has yielded a group of students with a deeper understanding and better retention of the ideas. The evidence so far suggests that the goal is being met. Further testing, for a direct comparison with the students taking the standard physical science class, is needed to confirm this. If the method is successful in improving the science literacy of an at risk population, it could be a valuable tool in creating a general public with a good exposure to science (45).

6.2 *The Physics Suite* at UCF

There is strong evidence, based on the results from the pre- to post-test gains on the FMCE and ECCE, that *The Physics Suite* elements implemented into the introductory physics classes at UCF have a positive effect on students’ conceptual learning. This is especially true when both the *Interactive Lecture Demonstrations* and *RealTime Physics* labs are used in conjunction. However, the investigation shows evidence that either component benefits student learning when used alone. This makes *The Physics Suite* a good option for a large-scale physics program with many different instructors. *RealTime Physics* as a stand-alone method for lab instruction pairs well with the lecture component of the course, whether or not the lecture instructor chooses to include *Interactive Lecture Demonstrations* as part of the course.

Despite the notable conceptual gains, students taking RTP did not show a benefit in their lecture class performance. There was also no measurable effect in the retention of students in the semester of their participation. The students that withdraw or fail often do not attend class, or do not put any effort into their studies of the subject. Even if the presentation of the material is improved, it does not have an effect on this group. Both actual class performance and retention in the program may be effected by the use of *The Physics Suite*, but the benefits are not apparent in the semester of participation. Some subsequent study of the participating students’ success later in their program of study must be made to determine this.

There is also evidence that the students themselves feel that the approach of *The Physics Suite* has positively impacted their learning. Responses to the survey questions and statements made during the interviews indicate a perception among the students that the inquiry-based activities of *RealTime Physics* and the active participation in lecture required in *Interactive Lecture Demonstrations* play a large role in helping them grasp the difficult material of the introductory physics classes (47).
All students in the introductory physics labs were given a survey at the time that they took the post-test at the end of the Spring 2009 semester. They were asked to rank their agreement with each statement on a five point scale from “Strongly Agree” to “Strongly Disagree”. The percentage of students replying in each category for each question is shown here. The results are shown in separate figures for Physics I and Physics II. The results are divided on each figure by the method of instruction each student had for their lecture and their lab.

![Bar graph for Physics I responses to Question 1](image1)

**Figure A.1: Physics I Responses to Survey Question 1** - Answering the questions in the lab report helps me understand the concept addressed in the lab.

![Bar graph for Physics II responses to Question 1](image2)

**Figure A.2: Physics II Responses to Survey Question 1** - Answering the questions in the lab report helps me understand the concept addressed in the lab.
Figure A.3: Physics I Responses to Survey Question 2 - There is a connection between the concepts addressed by the lab experiments and the theory covered in the lecture class.

Figure A.4: Physics II Responses to Survey Question 2 - There is a connection between the concepts addressed by the lab experiments and the theory covered in the lecture class.
Figure A.5: Physics I Responses to Survey Question 3 - The experiments are the correct difficulty level.

Figure A.6: Physics II Responses to Survey Question 3 - The experiments are the correct difficulty level.
Figure A.7: Physics I Responses to Survey Question 4 - The homework assigned in lab helps me understand the concepts from the lab.

Figure A.8: Physics II Responses to Survey Question 4 - The homework assigned in lab helps me understand the concepts from the lab.
Figure A.9: Physics I Responses to Survey Question 5 - The homework assignments are the correct level of difficulty.

Figure A.10: Physics II Responses to Survey Question 5 - The homework assignments are the correct level of difficulty.
Figure A.11: Physics I Responses to Survey Question 6 - The recitation problems are helpful with understanding the theory.

Figure A.12: Physics II Responses to Survey Question 6 - The recitation problems are helpful with understanding the theory.
Figure A.13: Physics I Responses to Survey Question 7 - The recitation problems are helpful with developing a problem-solving strategy.

Figure A.14: Physics II Responses to Survey Question 7 - The recitation problems are helpful with developing a problem-solving strategy.
Figure A.15: Physics I Responses to Survey Question 8 - The experiments performed in the lab have caused me to change my mind about how some physical process works.

Figure A.16: Physics II Responses to Survey Question 8 - The experiments performed in the lab have caused me to change my mind about how some physical process works.
Figure A.17: Physics I Responses to Survey Question 9 - The lab should include more information on the theory behind the concept.

Figure A.18: Physics II Responses to Survey Question 9 - The lab should include more information on the theory behind the concept.
Figure A.19: Physics I Responses to Survey Question 10 - The lecture class provides enough theory. The lab time is best spent with hands-on practice.

Figure A.20: Physics II Responses to Survey Question 10 - The lecture class provides enough theory. The lab time is best spent with hands-on practice.
Figure A.21: Physics I Responses to Survey Question 11 - I prefer to hear the theory in the lecture class, then do lab experiments to see it in practice.

Figure A.22: Physics II Responses to Survey Question 11 - I prefer to hear the theory in the lecture class, then do lab experiments to see it in practice.
Figure A.23: Physics I Responses to Survey Question 12 - I prefer to have hands-on experience with a concept in lab before I hear the theory in lecture.

Figure A.24: Physics II Responses to Survey Question 12 - I prefer to have hands-on experience with a concept in lab before I hear the theory in lecture.
Figure A.25: Physics I Responses to Survey Question 13 - The experiments in lab help me better understand the theory.

Figure A.26: Physics II Responses to Survey Question 13 - The experiments in lab help me better understand the theory.
Figure A.27: Physics I Responses to Survey Question 14 - The recitation is a valuable part of the lab.

Figure A.28: Physics II Responses to Survey Question 14 - The recitation is a valuable part of the lab.
Figure A.29: Physics I Responses to Survey Question 15 - The recitation is valuable, but it would be better to have it separate from the lab.

Figure A.30: Physics II Responses to Survey Question 15 - The recitation is valuable, but it would be better to have it separate from the lab.
The following is the paraphrased transcript of the student interviews. Numbers in parenthesis indicate the number of people responding with a duplicate answer. The question is in bold followed by the positive responses and then the negative responses.

1. Do you like this (overall) format as compared to a traditional lab format where you take all the data and later write a report, why?

   - Yes(16)
   - Much more interactive(3)
   - More effective because you forget when you try and write the report at home (2)
   - Traditional format not helpful because you only think about lab in that time period.
   - Method is good it is easier to remember and write up
   - Easy to follow/ lab helpful toward course
   - This is better/ Possible simulations would be good
   - This one is better/ Less out of class work/ Teamwork on the report
   - Helps to bounce ideas off for report
   - Somewhat, explains to a point that makes you find out a purpose
   - Much better/ Works well
   - Seems like less work but has much better grade
   - Good to answer questions as going through
   - Tedious to do lab report at home
   - Traditional format lab reports are tedious and unnecessary
   - Does more to reinforce

Negative Responses:

   - Like old format better. Makes it easier but would learn more writing at home
   - Has more work/ Pink book is monotonous so you don’t want to do it
   - Sometimes groups are too big so not everyone does work/ Can be redundant with extensions
   - Will this hurt undergraduate report writing skills?

2. Does doing the homework help and is it the correct difficulty level (most students took approx 30 minutes to do the homework)?

   - Yes (14)
   - Reinforces concepts (5)
   - Helps for the quiz (3)
   - Helps remember from one week to the next (2)
   - Different than the lecture
- Helps when the material is understood/ Helps for lecture/ Helps with concept
- Helps to a point
- Most help was going over homework

Negative Responses:
- No (3)
- Some questions are worded poorly so it’s not clear what is being asked (5)
- Hard to figure out from lab sometimes (4)
- Sometimes questions are too difficult (3)
- Sometimes just repeating same question (3)
- Not helping to learn material
- Not returned in time for the quiz
- Would help to go over main points of lab in summary so people know for homework
- Some questions are too easy

3. **Do the lab report questions help understand the material?**

- Yes (16)
- Helps understand
- Makes you stop and think
- Helps if you take your time to do it
- Like doing it as a group which helps clarify
- Observing then writing reinforces
- Seeing the result really helps with concept

Negative Responses:
- No (2)
- Sometimes not sure if result is correct due to no experience. This can lead to misconceptions or uncertainty (5)
- Questions redundant (3)
- Some questions poorly worded lead to confusion (2)
- Questions not preparing enough for quiz
- Need to be more in-depth on tougher concepts

4. **Do the experiments help you learn the material?**

- Yes (11)
- Sometimes (3)
- Helps to better visualize (3)
- Good for their purpose
- Better than other methods
- They work and get the concept across
- Would like to see more real life applications

**Negative Responses:**
- Tedious/ Asking same question/ Repetitive (5)
- Did not know if result was correct which left uncertain/incorrect (3)
- Just doing the lab to get done
- Like formulas more than the experiments

5. **Are the experiments the correct difficulty level?**
- Yes (14)
- Some good (2)
- Helps visualize
- At first too easy then it was good
- More complex would be confusing

**Negative Responses:**
- Trouble with directions not being clear (4)
- Explore harder material more in-depth (2)
- Some too easy (2)
- Labs too long (2)
- Did not know if experimental results were correct which left uncertain
- Some more difficult and not necessary
- More quality less quantity
- Can be boring

6. **Comments on the lab manual?**
- Good (2)
- Ok
- Straight forward/ Explains what you are doing well
- Pictures were good

**Negative Responses:**
- Redundant questions and sections of experiments (7)
- Ambiguous/ Unclear wording or instructions(5)
- Had to buy 2 and they are expensive (5)
- Put theory up front so you know if your results are correct (2)
- Sometimes felt like it was just doing busy work (2)
- Be more software specific
- More detailed steps
- Not using material in the homework

7. **Have the experiments changed any misconceptions you had or if you had no prior conception give you a good foundation?**

   - Yes (11)
   - Learned correct theory for foundation (6)
   - Reinforces more than corrects (5)
   - Helps apply theory (4)
   - Had prior experience so unknown

**Negative Responses:**

   - Not really (2)
   - Not interesting enough

8. **Overall has this method helped you learn physics?**

   - Yes (17)
   - Gained exposure to basics (2)
   - Helps to clarify/ reinforce (2)
   - Learned easier than traditional format
   - This is the reason I understand lecture

**Negative Responses:**

   - No
   - Sometimes no connection between lab and lecture (2)
   - Not really
   - Learned more from lecture

9. **What would you change about this format?**

   - Less busy work/ redundancy (7)
   - Questions on both homework and quiz. (6)
   - Show results so can verify if my results are correct (3)
   - Tie in more theory (2)
   - Go over quiz/ homework in class (2)
   - Get homework back then take quiz the following week. Missing the same
   - Provide user manuals for equipment
- Smaller groups
- No Pre-lab

10. **What worked really well for this format?**

- Group helps to understand/ members have different strengths (4)
- Equipment/ Software (4)
- GTAs (3)
- Homework (2)
- Pre-lab (2)
- Lab report format (2)
- Labs are good length
- Experiments
- Section breaks for experiments are good you learn one thing at a time
- Interactive format makes you think.
- Quiz on the homework

11. **What did not work for this format?**

- Predictions/Pre-Labs are a blind guess because of no exposure to material (3)
- Manual (2)
- Quizzes (2)
- Too long

12. **Would it be helpful to have more theory in the lab manual?**

- Yes (12)

*Negative Response*

- No (6)
- Don’t know if results are correct which leads to uncertainty / confusion (3)
- Need more for homework (3)
- Make more explicit
- More at beginning of lab
- Add more real world applications
- Easier to learn when seeing equations

13. **Does going over the quizzes/homework help?**

- Yes (24)
- No (2)
- Go over homework then take quiz
14. **How would you rate the overall work load?**
   - Good amount (23)
   - Too much for a one credit class (3)

15. **How is the equipment?**
   - Good (10)
   - No way to know if it is working and sometimes it didn’t (6)
   - Easy to use (5)
   - Needs user guides/ better instructions (2)

16. **Comments on the grading method.**
   - Weight lab report more (9)
   - Weight quizzes less (7)
   - Good (6)
   - Strict grading leads to poor quiz scores not accurately reflecting knowledge (2)
   - Weight homework more
   - Weight homework less
   - Weight individual problems on homework differently (More for harder)

17. **General comments:**
   - Dan is a great TA (5)
   - Possibility of other experiments maybe magnetism (2)
   - The lab is really helpful (2)
   - Sometimes need the lab and lecture to coincide better (2)
LIST OF REFERENCES


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[40] K. LEWIS. Three Join UCF’s Pegasus Professor Elite. UCF Newsroom news.ucf.edu. 10


