PHYSICS & SOCIETY
Interim Report

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1 Introduction

The National Science Foundation has made effort to address the problem of science illiteracy in American society. With statistical data and discussion in their biannual report, Science and Technology Indicator, they make their conclusions by two main standards, comparing the current poll data to past data and data from other countries, and comparing the data to preconceived standards for survival in an advancing technological age.

As compared with past data and data from other countries, "Americans appear to know as much or more about science, and they express as much or more optimism about technology." [1] However, considering current general standards for future survival of our society, the data is discomforting. From the issues of climate change to misconceptions about emerging technologies in biology and nanoscale physics, morality in science, and the speed of technological change, NSF believes the population is not well enough aware of these issues. In addition to a lack in knowledge, many Americans reject accepted scientific knowledge conflicting with their religious beliefs, and favor the addition of nonscientific material regarding human origins into the science class curriculum in public schools. [1]

In their book, *Unscientific America*, Mooney and Kirshenbaum attempt to identify the problems leading to a poor relationship between science and society. They believe science illiteracy is a huge issue for the future of our society and partly blame the misinformation and a lack of coverage through media sources and the internet. [2]

In our efforts to debunk pseudoscience, we think of a supporting excerpt from the writings of a distinguished mathematician and philosopher, W.K. Clifford:

> If a man, holding a belief which he was taught in childhood or persuaded of afterwards, keeps down and pushes away any doubts which arise about it in his mind, purposely avoids the reading of books and the company of men that call into question or discuss it, and regards as impious those questions which cannot easily be asked without disturbing it–the life of that man is one long sin against mankind. To sum up: it is wrong always, everywhere, and for anyone, to believe anything upon insufficient evidence. [3]

Unscientific America and similar books are able to indicate specific problems between the Scientific community and the general public. More-so, The National Science Foundation

rigorously and aggressively attempt to draw attention to this issue from other scientists, educators, and the government through their extensive biannual report. We intend to help our students in Central Florida understand the importance of science and critical thinking, encouraging those who support science as opposed to those who attack it.

2 Research

2.1 The Course

A brief description of the course is outlined, closely following several papers produced by the main *Physics in Films* Instructor, [5], [6], [7], [8].

In the summer of 2002 two professors began the *Physics in Films* version of the physical science course with goal of improving the scientific literacy of the thousands of non-science students who take the course at our institution each year. In the process of the continuing development of that program it has been discovered that general education students, who normally shudder at the thought of doing calculations of any kind, readily accept and learn to emulate the Fermi calculation approach to dealing with seemingly very difficult, if not impossible problems.

The project addresses the issue of how to instill in the broad spectrum of college and university students the enthusiasm and excitement of physics all physicists have experienced and continue to experience. We have thus proposed to accomplish this by adopting as a teaching vehicle a medium that the students have already accepted as a reection of todays culture, namely by using popular movies to illustrate both the basic principles and frontier discoveries of science. The targeted audience is science and non-science majors alike. The course created is more relevant and a more interesting substitute for the traditional Physical Science courses taught in nearly all colleges and universities.

Personal Response System

From the beginning all sections of Physics in Films have used a personal response system that enables each student to register their attendance and to record answers to questions asked in class by the instructor. The system provides immediate confirmation of answers, permits the students to change their answers, displays the correct answers, and provides a histogram of the class responses to questions so that students can compare themselves to the class as a whole.

Enrico Fermi Solutions

Fermi had an extraordinary ability to answer with reasonable accuracy any question posed to him, questions that would seem impossible to answer to an ordinary person. The classic example of such questions that is attributed to him is "How many piano tuners are there in the city of Chicago?" Asking this question, even of trained scientists, will initially create frustration and a feeling that the answer may be unattainable, at least without referring to the piano tuners union website. However, upon second, more careful thought, one discovers that the question can be split into a series of simpler questions which admit approximate

answers leading eventually to an approximate (but very reasonable) answer to the original question. "Fermi problems" thus have a very distinct profile: they always seem vague with very little or no information given, but they admit dissection into a set of simpler questions that lead to the final answer. Once understood, Fermi problems become a source of limitless fun. An answer found is a blast of excitement and joy.

Pseudoscience

An idea or theory is called pseudoscience if it contradicts accepted scientic data, but is presented as scientic. Note that a mistake or error in presenting scientic data does not signal pseudoscience. It is the intentional misrepresentation of facts or unveried claims that justify the label. For our purposes the authors categorize as pseudoscientic those movies that are based on topics or phenomena that contradict scientic facts. There are many such films that might be used, but a group was chosen that most students had already seen or knew about. (See Figure 1.) *Physics in Films: Pseudoscience* was first taught in the summer 2003 term.

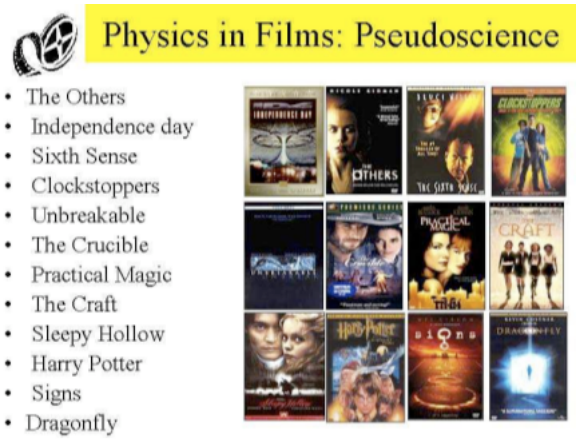

Figure 1: Films with Pseudoscientific content. [6]

Among all sections, *Pseudoscience* was especially praised by the students. Contrary to passive attendance in the traditional course, the class was full of passionate discussions driven by scenes in popular movies such as Sixth Sense, The Others, and Dragonfly. Almost every single person in the class (of 90 students) would participate in the discussions and defend his/her positions. These discussions often were passionate and quite heated. Eventually, scientific analysis was presented by the instructors who always maintained a skeptic attitude on any extraordinary topic requiring extraordinary proof, thus explaining how the scientific method works and what is acceptable and what unacceptable in science. Amazingly, a fraction of the students (not always the same students in all topics) did not always agree with the rational explanations; often their decisions were influenced by personal fears and biases or emotions. Their thinking at times revealed the introduction of arbitrary assumptions and acceptance of anecdotal statements.

2.2 Research Goals

The main focus of our research will deal with the *Physics in Films: Pseudoscience* course, and the analysis of the student's belief or non-belief in pseudoscience and their understanding of science relative to the scientific method. I have collected data from the Summer A course in 2007, 2008, and 2009. This data, including student performance, polls, essays, and interviews, is what we will use to analyze how the students feel about this course, and their understanding of the so called Fermi Problems, critical thinking, inquiry skills and the scientific method.

With the knowledge gained from this research, we intend to structure our teaching to attack more effectively false ideas, improve on the way we promote critical thinking. It is our belief that this understanding is important for science and non-science majors alike to ultimately improve our society. In addition, we hope to transfer these methods to all levels of education. In particular, these practices will be implemented in my own teaching environments.

2.3 Past Research

During the Summer term of 2008, we started on the project to analyze the past two summer courses on Pseudoscience. We have found that students were having trouble accepting ideas that may seem to contradict their religious beliefs. If the student believed in spirits, then it was hard for them to accept that ghosts may not exist. Another issue we are dealing with is the teaching of critical thinking skills. This is a tough concept for the students to understand. The professor uses the idea of Fermi problems to express the action of estimating the implications of certain statements to decide whether they are valid statements, or pseudoscientific statements. It was also found that certain topics, such as astrology, do not need as much focus, because students are already understanding the flaws. Conversely, other topics like critical thinking and quantum mechanics will have to be mentioned more. This was part of participation in an REU at UCF, and resulted in a final report for NSF. I have presented on this research during the American Association of Physics Teachers Winter and Summer Meetings, bringing this topic to discussion amongst fellow scientists and educators.

3 Current Research and Data

In previous *Physics in Films* courses since 2002, it has been the focus to teach physical science through the avenue of Action/Sci-Fi films, and these courses have been very successful compared to the standard Physical Science class. The second focus was on promoting science literacy among non-science majors, and this focus has slowly helped develop the course and change to *Physics in Films: Pseudoscience*. The practice of science is a means by which to seek "consensus under communally agreed criteria for judging evidence" [4]. As one criterion for my analysis of this data, I hold to the assumption that something is a "scientific" claim if it stands trial through the Scientific Method, or is in the process of being tested with a reasonably predicted outcome. Science not being perfect, there exists the possibility that a widely accepted scientific claim could be disproved and, thus, would no longer be a proper claim. A claim that does not adhere to the criterion I plan to follow, while still assuming

the title of "scientific," I will consider "pseudoscientific;" not testable or would fail if tested. Strict acknowledgment of the Scientific Method will be evident in my analysis. It was important that this course, before expanding on pseudoscience, could teach the physical science curriculum. Collecting the data from 2007 and 2008 (Figure 2), we see that the course was very effective at pushing the physical science concepts and increasing student confidence in the subject (Figure 3), in some cases better than the older *Physics in Films* courses. [9] The following sections are new topics discussed and focused on in *Physics in Films: Pseudoscience* in 2007 and 2008.

Figure 2: Average scores for pre- and post-tests evaluating the students' knowledge of the course content. Summer semesters 2007 and 2008.

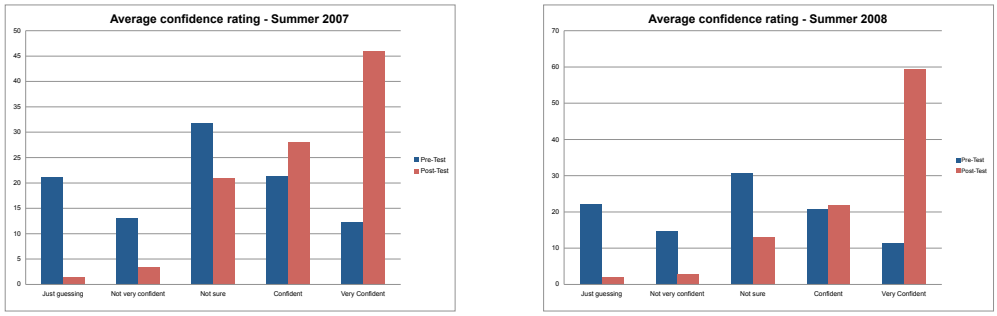

Figure 3: Confidence levels for pre- and post-tests. 2007 and 2008.

3.1 Fermi Problems

We believe there is a major lack in critical thinking skills in the students, with correlation to the rest of society and the heart of our problem. Students are expected to understand the nature of Fermi problems. This teaches them to understand the importance of critical thinking and estimation. It is important for the students to understand the technique of estimating approximate quantities of a previously intimidating problem simply with the knowledge they already have.

Students are asked questions throughout the course through polls, quizzes, and one essay to discuss what they understand about Fermi Problems. We analyze these answers to understand their critical thinking abilities. In Figure 4 are several examples of questions showing the students' ability to estimate and use reason to explain a particular phenomena. This concept helps students to recognize what is reasonable in movies, and understand false statements made by popular pseudoscientists.

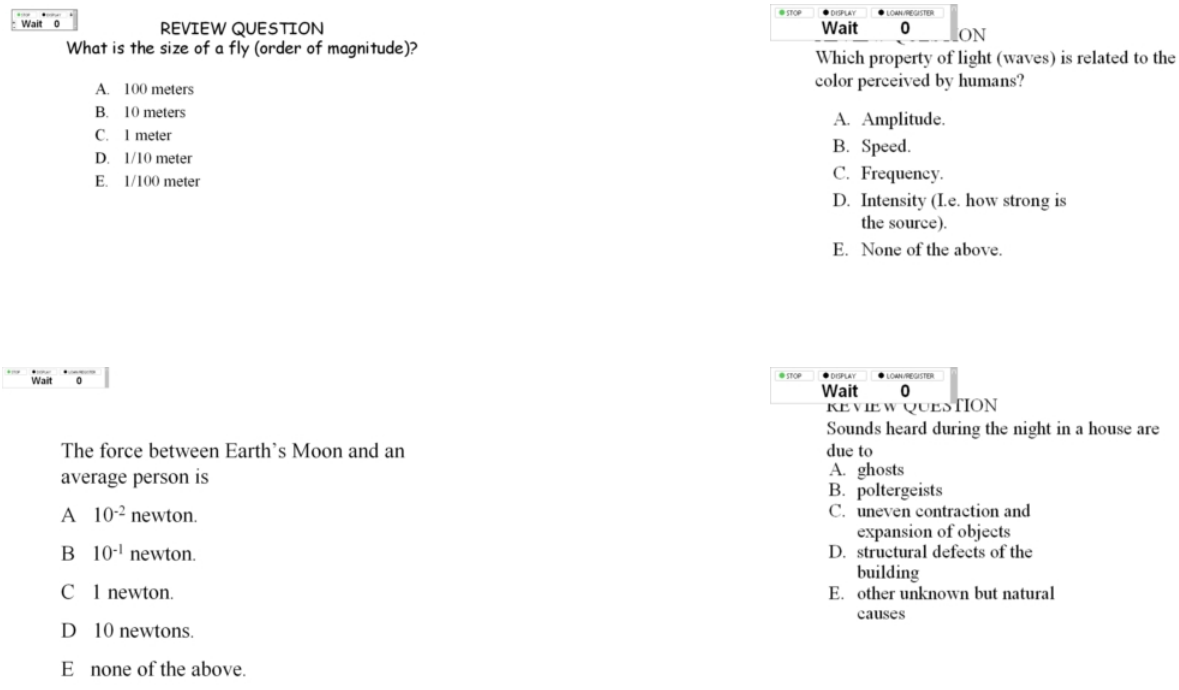

Figure 4: Examples of poll questions on estimation and basic reasoning.

3.2 Quantum Mechanics

There has been a recent increase in the use of Quantum Mechanics by people who make their money on different types of self help books, movies and seminars. While self help and positive thinking — the main topics of the teachings — are understandable and welcome, their physical explanations are very wrong, misleading, and ultimately detrimental to the society. Figure 5 is a question asking the students if they understand the word "Technobabble," a word coined to mean words which sound scientific to those who don't know any better,

but are in fact nonsense. "Quantum Flapdoodle," coined by Murray Gelmann, identifies nonsensical statements specifically in Quantum Mechanics. If students can identify such nonsense, they will not fall victim to such popular movies.

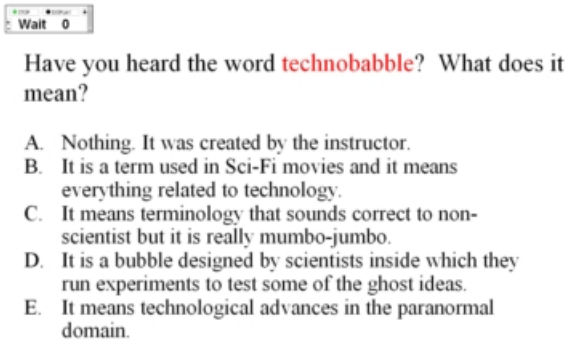

Figure 5: Example of poll question identifying misused information, and words claiming to be scientific.

Students watch two Documentaries, *The Secret* and *What the Bleep Do We Know*. They are asked to write a paper analyzing what they believe to be true from the given information. They are also asked their understanding of Quantum Mechanics, of which the movies include false usage of the concepts. We do not expect a high level of understanding of Quantum Mechanics, as these are non science majors. However, the teacher includes an explanation into the curriculum about the basic nature of this theory what can and cannot be explained by our current knowledge of Quantum Mechanics.

3.3 Magic and the Paranormal

Students watch several movies about supernatural or magical events and provide papers with their opinions of the existence of each. The claims and occurrences in these movies are singled out and discussed in class. While not all beliefs are questioned (especially religious ones), the students understand scientific claims from others. We define a scientific claim to be one which follows the scientific method, or shows reasonable intent to do so. Even some scientific claims could sound unreasonable at times, but when looked at closely — logically and mathematically — they withstand the tests, and eventually are proven with experiment, or thrown out.

Evaluating the students' understanding through their papers, as well as accounts of personal experiences, we have found that students who have had parents or grandparents experience such a paranormal event as ghost sightings, psychic readings, or spiritual healing, they are more likely to refuse our scientific explanation of the event. We posted poll

questions to see if they understand simple details regarding everyday events that may seem supernatural. [Figure 6] Instances such as unexplained sounds in a house or feelings of deja vu were brought into question by these polls. Because of the superstitions and religious or cultural beliefs students have, certain topics are difficult to grasp.

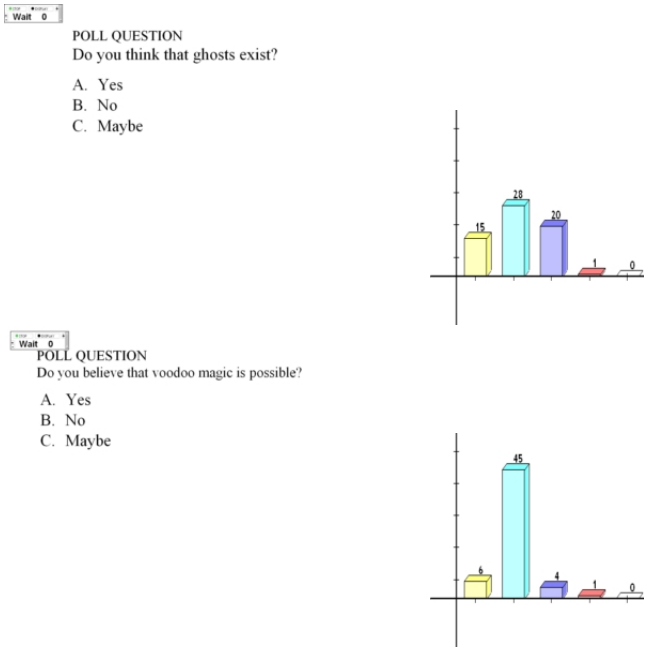

Figure 6: Some questions about students' belief in the paranormal

In March, the SPS chapter at UCF was able to bring Dr. David Willey to campus to explore the myth and science of firewalking. [10] His lecture was warmly welcomed by the students, showing that while people claim to have supernatural powers, usually it is an ability anyone can have with practice. His video will be used to help the students recognize the difference between paranormal claims and scientific explanation.

3.4 Interviews and Qualitative Data

After each Summer A course, interviews took place to gauge the students' feelings on the noted pseudoscientific topics and the class itself. Students were asked a variety of questions including NSF survey questions from basic scientific facts to whether or not they believe in specific paranormal claims. The data gathered from essays and interviews was used to focus on student attitudes toward each topic.

Over the last three summers the *Physics in Films* course has maintained an underlying theme of promoting science literacy by specifically addressing scientific illiteracy. This last summer of 2009, he changed the course slightly to reflect a mix of the *Physics in Films* strategies over the years since it's development in 2002. I have taken data from this summer course in the same way as the *Pseudoscience* courses during 2007 and 2008. This data will serve to judge our development in the course and compare the students' knowledge to the two previous semesters.

We have also formed a survey from the interview questions to give to students in the course, *Physics for Scientists and Engineers*. This will allow us to judge the attitudes and knowledge of those students going into scientific fields as compared to those non-science majors in the physical science course.

3.5 Budget

Using the funds provided to me from the Fellowship in Physics and Society, I have purchased the following items:

- One Hundred Essential Things You Didn't Know You Didn't Know
  John D. Barrow $10.00

- How To Think Straight About Psychology (8th Edition)
  Keith Stanovich $30.99

- Debunked!: ESP, Telekinesis, and Other Pseudoscience
  Georges Charpak $16.50

- Unscientific America: How Scientific Illiteracy Threatens Our Future
  Chris Mooney, Sheril Kirshenbaum $10.00

- The Power of Critical Thinking
  Lewis Vaughn $34.50

- The Paranormal and the Politics of Truth: A Sociological Account
  Jeremy Northcote $29.90

- Physics for Future Presidents
  Richard A. Muller $20.99

- Sony Digital Voice Recorder
  $59.99

This funding has also contributed to my attendance at the AAPT Summer Meeting in Ann Arbor, MI July 25-29.

3.6 Budget table

Item	Cost	Total
Salary	Summer Support	$1500
Travel	Flight to Michigan	$170
Books	Noted Above	$152.88
Other Materials	Digital Voice Recorder	$59.99
Total spent		$1882.87

4 Future Work

Visit Schools

In September I plan to share my data and information with students at the local high schools. I will be discussing pseudoscience and explaining exactly why certain claims cannot be true according to our scientific knowledge. I will push the importance of critical thinking by using history, science, and statistics, much like the *Physics in Films* course.

Publish

When the analysis is finished, a paper will be submitted for publishing in a Physics Education Journal. It will consist of the consolidated data collected this summer comparing the *Pseudoscience* class to older *Physics in Films* course data as well as to the new course this past Summer of 2009. The effectiveness of this method of teaching will be fully evaluated and recommended for further implementation in the University of Central Florida and several local high schools. We hope this information will help other researchers and educators to become more active in similar projects debunking pseudoscience.

Expand Research

Collaborating with an education researcher, we will be applying for an NSF grant to further fund more research. We plan to extend this research into high schools to better understand the causes of science illiteracy and lack of critical thinking skills in students and the general public.

5 Conclusions and Discussion

While we have come far in our work to debunk pseudoscience, preliminary results are showing that this latest course was not as effective at promoting science literacy as the previous two summers. The main reason for this is lack of time for further explanation and sufficient coverage of each topic. To adapt these curriculum methods into a fall or spring semester, or a high school class could prove most effective. This being so, we have still received much positive feedback for the class overall. The professor is continuing to update his course to teach physical concepts and try to encourage critical thinking as a way of combating pseudoscientific claims — deciding what is reasonable based on current knowledge in science and technology.

Acknowledgements

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