CINEMA AS A TOOL FOR SCIENCE LITERACY

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1 INTRODUCTION

Surveys conducted by the National Science Foundation (NSF) have thoroughly documented a severe decline in the understanding of and interest in science among people of all ages in the United States (NSF, 2002). About 50 percent of the people do not know that Earth takes one year to complete an orbit around the sun, that electrons are smaller than atoms, and that early humans did not live at the same time as the dinosaurs. These examples of faulty knowledge of physical sciences surely extend to life, social and literary sciences and are mirrored in other nations.

This paper summarizes an ambitious project embarked upon by the authors at the University of Central Florida (UCF) to improve public understanding of the basic principles of physical science, topics often included in the general education programs of many universities and colleges (Efthimiou & Llewellyn, 2003). This new approach, *Physics in Films*, uses popular movies to illustrate the principles of physical science, analyzing individual scenes against the background of the fundamental physical laws of mechanics, electricity, optics, and so on.

While still not a mature project, *Physics in Films* has been successful and has become a topic of wide discussion, both among UCF students and the physics education community (APS News, 2003; Chow, 2003; Graham, 2002; Grayson, 2002; Priore, 2003). Only a few similar projects have been tried earlier (Dennis 2002; Dubeck et al., 1994; Rogers, 2002). None has approached the scope of the *Physics in Films* project.

2 DESCRIPTION OF THE PROJECT

2.1 Genesis of the Physics in Films Project

It is our experience that students in general think that physics is difficult, hence boring, and without much relevance in their daily lives. The authors, who regularly teach physical science for non-science majors, searched for a way to instill in these students the enthusiasm and excitement that all physicists experience. After much discussion and review of existing resources (Dennis, 2002; Dubeck, 1994; Rogers, 2002), the proposal was made to accomplish

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this goal by adopting as a teaching vehicle a medium that students had already accepted as a reflection of today's culture. The vehicle chosen was the use of popular movies to illustrate both the basic principles and frontier discoveries of science and also to motivate students in becoming more critical observers of their world. By using popular movies as the actual mode of instruction, the intent was to provide a course in physical science that was more relevant to their daily lives and to begin to correct the many misconceptions they held about science.

2.2 Summer 2002: Action/Adventure Movies

During the summer 2002 *Physics in Films* was offered for the first time. Principles of physics were discussed using scene clips from nine popular action/adventure movies. For example, the law of gravitation as (mis)used in "Independence Day," conservation of momentum in "Tango & Cash," speed and acceleration in "Speed 2" and so on.

Figure 1 shows the nine movies used that first summer. Students were required to watch the films at home and turn in a brief, written analysis of the physics principle illustrated in each of three scenes of their own choosing (homework!). In class, five to ten percent of the class (of 90 students) were called upon each day to orally present their analysis of one scene to the class. Both the written and oral analyses became part of their grade in the course.

Figure 1: Summer 2002: Action/Adventure/SciFi Movies.

An Example: Armageddon. As an example of how a movie clip is used in illustrating a physical principle, consider "Armageddon" (starring Bruce Willis). A huge, errant asteroid the size of Texas is on a collision course with Earth. (There are no known asteroids that large.) A team of oil well drillers is dispatched via a pair of space shuttles to intercept the asteroid, drill a hole in it at the right place, lower a large nuclear bomb into the hole, and subsequently blow the asteroid into two large pieces. The transverse velocities imparted to the two pieces by the explosion, when added to their (undiminished) velocities toward Earth, are to cause the pieces to just miss Earth, thereby averting worldwide disaster. After showing the clip, the analysis uses conservation of energy, conservation of momentum, vector addition, and the law of gravity to assess how physically realistic the solution in the film (and in such a future event) might be. The overall situation is depicted in Figure 2.

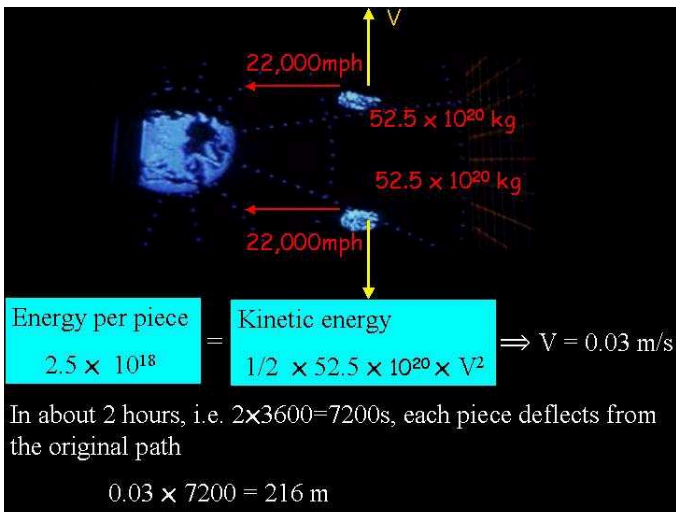

Figure 2: Asteroid Pieces Approach Earth

Using numbers provided in the film, the students are introduced to the idea of making reasonable approximations. For example, the asteroid is the size of Texas, so Texas is assumed to be a square whose surface area equals that of the state. Then the asteroid is approximated as a cube, each of whose sides equals the surface area of the state. Multiplying the volume of the cube by the average density of Earth gives us a decent estimate of the mass of the asteroid.

Assuming the nuclear bomb to be equal to 100,000 Hiroshima bombs provided an estimate of the energy available for the job (a modern nuclear warhead equals about 1,000 Hiroshima bombs). Assuming all of that energy became kinetic energy equally divided between the two pieces of the asteroid (i.e., ignoring the energy needed to break the asteroid into two pieces), we can readily compute the distance the pieces have moved perpendicular to their original direction of motion by the time they reach Earth. As noted in the diagram, that distance is only a bit over 200 meters for each piece.

The students are astonished. Instead of being hit by one Texas-size asteroid, Earth will be hit by two half-Texas-size asteroids about 400 meters apart! This discussion concludes with an explanation of what is realistically possible and why the government has an ongoing project to detect and track space objects approaching Earth or in Earth-crossing orbits around the sun.

2.3 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.

Attendance records and responses to quiz questions, both of which contribute to the final grade, are recorded automatically by an in-class computer. The system also provides a means of recording student opinions regarding various aspects of the course, information that is helpful in improving the presentations. For example, Figure 3 contains two tables showing student responses to the use of the system itself. (SA=strongly agree, A=agree, N=no opinion, D=disagree, SD=strongly disagree.) Shown, too, in the picture are a few communication pads like the ones used by individual students.

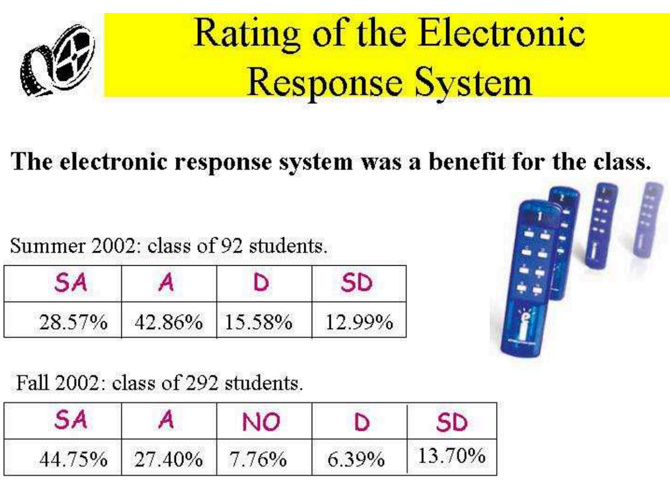

Figure 3: Rating the Electronic Response System

2.4 Development of Flavors

After *Physics in Films* had been given for three terms to four sections with a combined enrollment of about 800, the improved performance of the students relative to the traditional physical science course together with their enthusiasm regarding the *Physics in Films* approach motivated the authors to explore new directions for developing the course further. The original syllabus included movies selected to span the entire topical range of the traditional physical science course. No special attention was given to the genre or theme of the films used. The films eventually used, like those in Figure 1 for the first term, were action/adventure and science fiction films. Encouraged by the students' enthusiasm, the authors considered possible variations of the course that would accommodate the curiosity of every student and satisfy the needs of every instructor. It was decided to create versions (packages)—nicknamed "flavors"—whereby each flavor used films of a particular genre or theme. Plans have been developed to create the following flavors: Action/Adventure, Science Fiction, Superhero, Modern Physics, Astronomy, Pseudoscience, and Metaphysics. During the summer and fall 2003 terms the Superhero and Pseudoscience flavors were given for the first time.

2.5 Physics in Films: Superheroes

Part of the motivation for offering the Superheroes flavor came from a course given by Jim Kakalios at the University of Minnesota-Twin Cities (Feder, 2002). He has taught a successful course in physical science based on superhero comic books. The *Physics in Films: Superheroes* flavor complements Kakalios' approach, substituting motion and 'real' action for static images. It was first taught in the summer 2003 term using the films shown in Figure 4.

Figure 4: Physics In Films: Superheroes Films

When the course was in progress, two of the films ("The Hulk" and "X2") were not yet available on disk or tape, so the students had to go to the theaters, but no one complained.

In fact, the whole class approved!

The topical content of *Physics in Films* originally closely followed that of traditional physical science courses. The textbook was "Fantastic Voyages" (Dubeck et al., 1994). While somewhat 'lighter' than a typical physical science textbook, it uses some (rather old) movies as illustrations and is the only such text available. In *Physics in Films: Superheroes* classes however, the authors deviated somewhat from the traditional path and added some decidedly non-traditional books. They were "The Science of Superheroes" (Gresh & Weinberg, 2002), "The Science of Superman" (Woolverton, 2003), and "The Science of XMen" (Yaco & Haber, 2000), all illustrated in Figure 5. Stocked in the trade book sections of the bookstores, they are replete with applications of the concepts of physical science. The authors of these books frequently use physical laws in an effort to make the powers of the superheroes plausible to the lay reader. In so doing they provide fertile ground for lively discussions.

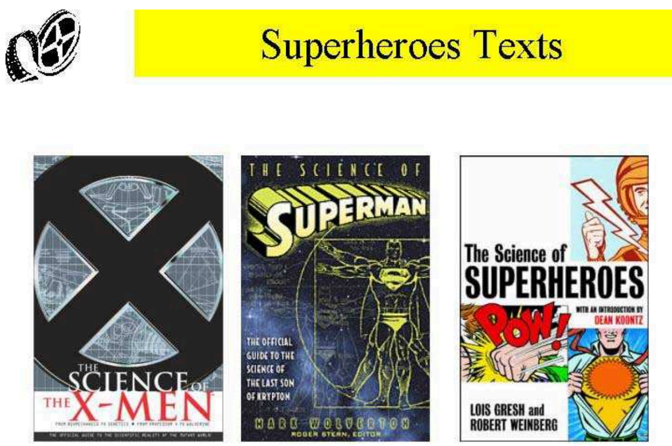

Figure 5: *Physics In Films: Superheroes* books.

***An Example: "Spiderman**."* As an illustration of a superhero film used in the course consider "Spiderman" (starring Tobey McGuire) and a specific scene. The scene is where the Green Goblin is standing on one of the towers of the Queensboro Bridge in New York simultaneously holding Mary Jane (MJ) suspended over the river with his left hand and the broken cable holding the Roosevelt Island cable car filled with children with his right hand. This one scene provides for discussions in equilibrium of forces, torque, friction, and free fall. Considering the latter, the Green Goblin presents Spiderman, who is crouched on the bridge superstructure, with a dilemma by allowing both MJ and the cable car to fall. Which will Spiderman save?

Timing events directly from the film clip, students see that it takes Spiderman 14 seconds to decide and start after MJ first, saving her, then saving the children in the cable car. It looks great in the film! But when the instructor leads the students through analysis of MJ's fall they discover that in those 14 seconds she would fall a distance $d = \frac{1}{2} \quad g \quad t^2$ where $g = 9.8$ m/s^2 and $t = 14$ s. Thus, d = 960 meters and the Queensboro Bridge is only 106 meters above the water! Once again, the students are astonished! Even assuming that the director implies 'slow motion' effects as he presents the events, we can estimate that Spiderman cannot react and catch MJ in less than 5 seconds. This would give a free-fall length of 122.5 meters, still more than the height of the bridge.

2.6 Physics in Films: Pseudoscience

An idea or theory is called pseudoscience if it contradicts accepted scientific data, but is presented as scientific. Note that a mistake or error in presenting scientific data does not signal pseudoscience. It is the intentional misrepresentation of facts or unverified claims that justify the label. For our purposes the authors categorize as pseudoscientific those movies that are based on topics or phenomena that contradict scientific 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 6.) *Physics in Films: Pseudoscience* was first taught in the summer 2003 term.

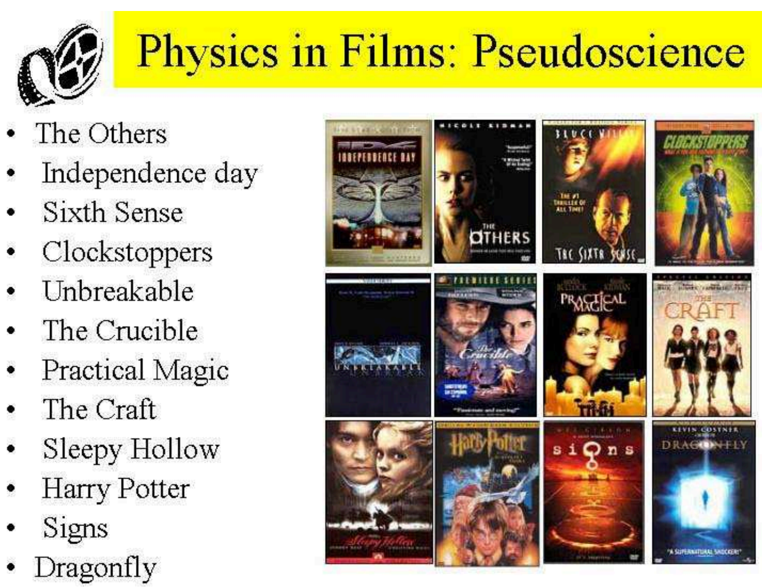

Figure 6: Films used in Physics in Films: Pseudoscience

The topics covered and related to pseudoscience included, among others:

- Universality of physical laws – magic
- Time – time reversal, time stopping

- Strength of materials – unbreakability
- Chemical reactions – zombies
- Fundamental interactions – ghosts
- Intelligent life in the universe – alien visitors to Earth, alien abductions

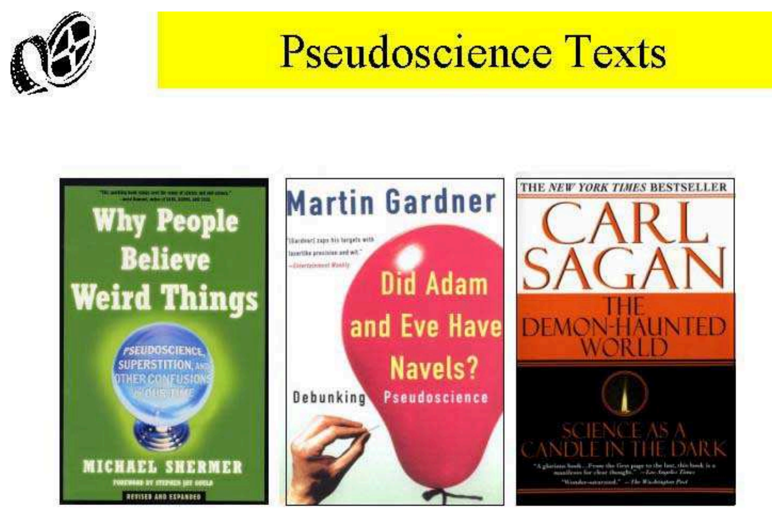

Figure 7: Bookss used in *Physics in Films: Pseudoscience*.

An Example: The Sixth Sense. Among the topics discussed in physical science are the related concepts of temperature and heat transfer via conduction, convection, and radiation. "The Sixth Sense" (starring Bruce Willis) is concerned with ghosts. The movie tells us that ghosts like low temperatures, although why that should be is not made clear. In the scene where the young hero goes to the bathroom during the night, a sudden drop in temperature is clearly shown. We have been told that this heralds the appearance of a ghost, and indeed one appears.

As it happens, a scientific study of this presumed phenomenon has been done (Frood, 2003). The Haunted Gallery of Hampton Court Palace near London, UK, is reported by many visitors to be haunted by the ghost of Catherine Howard (fifth wife of Henry VIII, executed in 1542). Air motion and thermal detectors were deployed in the Gallery and some 400 visitors were asked about their experiences during the visit. More than half felt sudden drops in temperature, some sensed ghostly presence, and several reported seeing Elizabethan figures. The study (Frood, 2003) revealed many poorly sealed hidden doorways that admitted columns of colder exterior air. In two locations the temperature of the localized draft was only 36^o F!

A Course Book Display. The UCF campus bookstore cooperated by installing a prominent display 'island' featuring the *Physics in Film: Superheroes* and *Physics in Film: Pseudoscience* courses (Figure 8). The display attracted student attention and (the authors suspect) increased sales of the displayed books, as well.

Figure 8: UCF Bookstore display for *Physics in Films*.

3 ASSESSMENT AND FINDINGS

As of this writing, the *Physics in Films* alternative to the traditional Physical Science course has been offered at UCF since the summer 2002 term to a total of nine sections enrolling, collectively, about 1600 students. During that time the authors have collected data regarding student evaluations of the course and their performance on exams. In that same time period there have been seven sections of Physical Science taught in the standard way, enrolling about 2000 students. Some of the more interesting results and comparisons are presented in this section.

3.1 Examination Results

Even though students may embrace a new idea enthusiastically, that does not mean their performance will necessarily improve relative to the traditional course (where most of them really struggle). In fact, student performance on individual exams and overall is improved in the *Physics in Films* sections when compared with those in traditional Physical Science sections. Table 1 shows the exam scores distribution for two classes of about the same size (295 students each), covering the same topics, and taught by the same instructor. The results are obviously dramatically different!

Instructional Mode	Exam 1	Exam 2	Exam 3	Final Exam
Traditional Class average percent	49.3	65.3	58.2	59.4
Physics in Films Class average percent	4.9	67.7	75.7	72.8

Table 1: Comparison of Exam Results for large enrollment sections. The sections were taught by the same instructor on the same material.

3.2 Student Evaluations and Opinions

Since Physics in Films was first offered, considerable data has been collected regarding student opinions and evaluations of the course and the various flavors taught to date. This section summarizes some of the more interesting of those data.

Term	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
Summer 2002 92 students	77.9%	10.4%	n/a	9.1%	2.6%
Fall 2002 292 students	56.9%	26.6%	6.9%	4.1%	5.5%

Table 2: Responses to the Statement: *Physics in films should be developed further since it is more interesting than the standard physical science course.*

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
60%	32%	5%	1%	2%

Table 3: Response to the statement: *I think I learned something from this class (Physics in Films: Superheroes).*

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
68%	25%	5%	2%	0%

Table 4: Responses to the statement: *I would recommend to my friends that they take this course (Physics in Films: Pseudoscience).*

However, changing the public's overall perception of science is not easy. More and longer term efforts reaching a much broader audience will be needed. As Table 6 suggests, fear

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
42%	42%	16%	0%	0%

Table 5: Responses to the statement: *The topics selected from the movies for physics analysis were interesting.*

and unreasonable dislike of science are deeply rooted in the minds of students and others, as the NSF surveys cited in the introduction to this paper makes clear.

Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
25%	26%	8%	18%	23%

Table 6: Responses to the statement: *I do not like science and I do not want to read anything about science once I have finished this course.*

4 CONCLUSIONS AND RECOMMENDATIONS

It appears clear from the information and data presented herein that the *Physics in Films* alternative to the more traditional Physical Science course captures student interest and improves their performance. Approximately half of the students who enroll in Physical Science at UCF now take the *Physics in Films* version, a further testament to the success of the approach.

4.1 The Future

The authors will certainly continue their work at UCF in further developing the *Physics in Films* concept. However, it may be argued that will not be enough. As Table 6 and the NSF surveys have made clear, changing public perceptions of science will be neither easy nor quickly accomplished.

It is the goal of the authors to increase the awareness of science and to show that an understanding of basic physical science can be both enriching and rewarding. To this end they are working toward the development of ‘packaged’ *Physics in Films* flavors that can be readily transferred to other institutions. They are also writing a new physical science textbook designed to support the *Physics in Films* mode of teaching. In addition, they have begun to explore the application of the concept to the creation or enhancement of general education courses in many other disciplines. The following list presents several possibilities together with a few examples of films that include material for each discipline.

- **Mathematics in Films:** *Pi, Good Will Hunting, Pay it Forward, Contact*

- **Astronomy/Astrophysics in Films:** *Armageddon, Deep Impact, Contact*
- **Biology in Films:** *Spiderman, The Hulk, Planet of the Apes, Jurassic Park*
- **Chemistry in Films:** *Flubber, Year of the Comet*
- **Engineering in Films**: *Armageddon, The Bridge on the River Kwai*
- **Archeology/Anthropology in Films:** *Indiana Jones trilogy, Jurassic Park*
- **Computers in Films**: *The Net, Independence Day, War Games*
- **Philosophy in Films:** *Blade Runner, Matrix, Terminator trilogy, Ghost*
- **History in Films**: *Braveheart, Patriot, The Man in the Iron Mask*
- **Law in Films**: *Erin Brockovich, The Firm, Legally Blond, Primal Fear*
- **Forensic Science in Films:** *Jennifer 8, Murder by the Numbers, Bone Collector*

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