"Physics in Films"
A New Approach to Teaching Science

C. Efthimiou[1] and R. Llewellyn[2]
Physics Department
University of Central Florida
Orlando, FL 32816

Abstract

Over the past year and a half we have developed an innovative approach to the teaching of *Physical Science*, a general education course typically found in the curricula of nearly every college and university. The new approach uses popular movies to illustrate the principles of physical science, analyzing individual scenes against the background of the fundamental physical laws. The impact of being able to understand *why*, in reality, the scene could or could not have occurred as depicted in the film, what the director got right and what he got wrong, has excited student interest enormously in a course that, when taught in the traditional mode, is usually considered to be 'too hard and boring'. The performance of students on exams reflected the increased attention to and retention of basic physical concepts, a result that was a primary goal of the '*Physics in Films*' approach. Following the first offering of the revitalization of the Physical Science course, in which action and sci-fi films were the primary source of the scene clips used in class, the instructors have demonstrated the versatility of the approach by building variations of the course around other genres, as well —*Physics in Films: Superheroes* and *Physics in Films: Pseudoscience*. A parallel approach to the general education course in astronomy is currently being discussed; many others are in our thoughts.

Keywords: Physics, Physical Science, Films, General Education, Science Literacy, Multimedia

BACKGROUND

It is well documented that interest and understanding of science among people of all ages in the United States has declined severely and currently stands at an alarmingly low level. According to surveys conducted by the National Science Foundation (NSF 2002) over many years, about 50 percent of the people do not know that Earth takes one year to go 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 physics surely extend to other sciences and are mirrored in other nations. This trend is due in

[1]costas@physics.ucf.edu
[2]ral@physics.ucf.edu

part to a changing society that encourages new generations to adopt a more materialistic ideology and a disrespect, even distrust of scientific knowledge. Even though the luxury of technology we currently enjoy is due in large measure to science, our society has chosen to forget that, tacitly assuming that such progress is a natural phenomenon that occurs automatically and about which one need not worry.

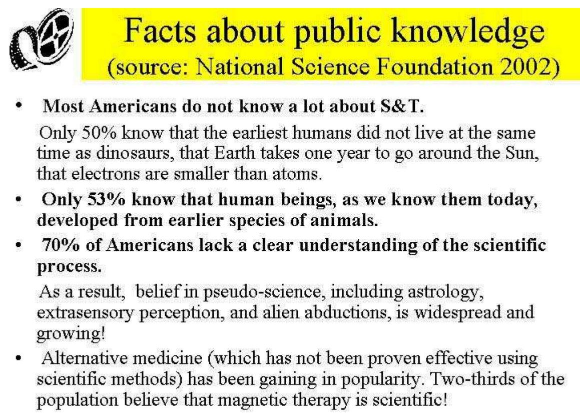

Figure 1: Some facts about science literacy in USA.

THE CORE IDEA AND THE FIRST IMPLEMENTATION

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 reflection of today's culture, namely by using popular movies to illustrate both the basic principles and frontier discoveries of science (Efthimiou & Llewellyn 2003). The targeted audience is science and non-science majors alike. The course we have created is more relevant and, frankly, a more interesting substitute for the traditional Physical Science courses taught in nearly all colleges and universities. If this effort proves to be as successful as our early results suggest that it will be, an appropriate version for majors in other science disciplines is a definite option for the future.

Summer 2002: Action and Sci-Fi Movies!

During the initial offering of the course in Summer 2002 we discussed the principles of physics using scene clips from popular action and sci-fi movies. For example, the law of gravitation as (mis)used in *Independence Day*, conservation of momentum in *Tango and Cash*, speed and acceleration in *Speed 2*, and so on. Figure 2 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) 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 2: Action and Sci-Fi films used in the original approach of the *Physics In Films* variation of the *Physical Science* course.

Based on the data collected so far and on discussions among the several physical science instructors and hundreds of physical science students at our institution (physical science enrollment: 2600 students per year), we have had an overwhelming success (APS News 2003, Chow 2003, Graham 2002, Grayson 2002, Priore 2003). Our experiences thus far reveal a strong tendency by the students to participate enthusiastically in discussions of physical science, if the topic under discussion is familiar from TV shows or movies. Not only may such a course be widely emulated and serve to educate our society, but it may also help correct misconceptions of science that popular movies and TV series have created, misconceptions that we feel have contributed to the public mistrust of science.

Example—*Speed 2*

In *Speed 2* (starring Sandra Bullock) there is a scene where a large cruise ship crashes into the waterfront of a busy resort town, hitting other boats, docks, the shoreline, and ultimately buildings. As the ship approaches the shore and hits various things, it begins to decelerate and people and objects onboard are thrown violently toward the bow, two men on the bridge even thrown through the windows onto the forward deck. All of the mayhem is seemingly in agreement with the audience's 'gut' feeling of what would happen as a consequence of the deceleration of the ship. However, throughout the scene we are given frequent views of the ship's digital speedometer on the bridge. Since the crashing of

	time		speed in knots	speed in m/s	deceleration
1	1:36:59	62s	10.5	5.25	0.0024 m/s²
2	1:38:01	32s	10.2	5.10	0.0094 m/s²
3	1:38:33	56s	9.6	4.80	0.0206 m/s²
4	1:39:27	120s	7.3	3.65	0.0017 m/s²
5	1:41:27	46s	6.9	3.45	0.0272 m/s²
6	1:42:13	96s	5.3	2.65	0.0172 m/s²
7	1:43:49	16s	2.0	1.00	0.0219 m/s²
8	1:44:05	15s	1.3	0.65	0.0433 m/s²
9	1:44:20		0	0	

Figure 3: The deceleration of the cruise ship according to the director's data in *Speed 2* as it crashes on the port.

the ship is shown in real time, by simply noting the time of each speed reading as the ship approaches the shore and finally comes to a stop, we can directly compute the deceleration, using the simple formula:

$$deceleration = \frac{speed\,change}{time\,change}\ .$$

The table in figure 3 shows the results of such a calculation based on the director's data. The numbers in the second column are clock times (according to the DVD timer) at which speeds (in knots) were read from the ship's meter. The numbers in the third column (lined up with the horizontal lines) are the seconds between successive readings. The fourth column converts the speeds into meters per second (1 knot is about a half meter per second) and the right-hand column shows the corresponding decelerations in meters per second square (m/s^2). Comparing the decelerations in the last column with the acceleration of gravity, about 10 m/s^2, we see that the ship's deceleration was actually quite low. To understand how low, think about the deceleration you would experience in bringing your car, travelling at 30 miles per hour, to a gentle stop (that is, applying the brakes for about 10 seconds) at a red traffic signal; this acceleration would be about 1.33 m/s^2, or more than 30 times the greatest deceleration 0.0433 m/s^{2}of the table. At this point the students are amazed! The ship certainly has an enormous amount of kinetic energy and that energy is dissipated in the collisions, but the widespread tumbling about of things and people on the ship would not have occurred. Indeed, a passenger who happened to be asleep in a bunk might not have even noticed the collision. The concept of impulse can also be discussed with the aid of this scene. The forces that people and objects on the ship experience during the collision are quite low because (1) the ship is not going very fast to begin with (hence, momenta are not large) and (2) the collision takes place over a very long time, more than 10 minutes.

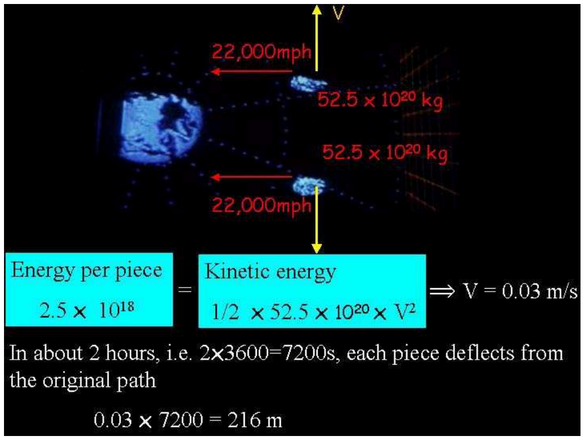

Figure 4: Summary of the calculation for the deflection of the asteroid fragments in *Armageddon*.

Example—*Armageddon*

In *Armageddon* (starring Bruce Willis) a huge, errant asteroid the size of Texas is on a collision course with Earth. 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. Analysis of this situation uses conservation of energy, conservation of momentum, vector addition, and the law of gravity. A summary of the overall situation is depicted in the diagram of figure 4.

Using numbers provided in the film, we introduce the students to the idea of making reasonable approximations. For example, the asteroid is, we are told, the size of Texas, so we assume Texas is a square whose surface area equals that of the state, then approximate the asteroid 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 bomb as being equal to 100,000 Hiroshima bombs provided an estimate of the energy available for the job. Then, 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, the deflection for each piece is only a bit over 200 meters. Once again the students are astonished. Instead of being hit by one Texas-size asteroid, Earth will be hit by two half-Texas-size asteroids few city-blocks apart! We then wind up this discussion 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.

BEYOND ACTION AND SCI-FI MOVIES

After the pilot course was very successfully tested in four sections (with total enrollment of 800 students), the authors were motivated to develop the course further and to explore new directions. The original pilot course included movies that were selected to span the entire topical range of the standard *Physical Science* course. In the selection of the movies no attention was paid to the genre or the theme of the movie; eventually all the movies used were action, adventure, and science fiction films.

Encouraged by the enthusiasm of the students, the authors decided to take the project to the next level by considering possible extensions of the course that would accommodate the curiosity of every student and would satisfy the needs of every instructor. Thus, we decided to create versions (packages) —nicknamed *flavors*—of the course whereby each flavor used a particular genre or theme of movies. As a result, plans were developed to create the following flavors, each using films with a well defined theme:

Figure 5: Superheroes films used in the superhero approach of the *Physics In Films* variation of the *Physical Science* course.

1. **Action/Adventure** that would use action and adventure movies;
2. **Sci-Fi** that would use science fiction movies;
3. **Superhero** that would use superhero movies;
4. **Modern Physics** that would use movies that enable the teaching of topics from Modern Physics;

5. **Astronomy** that would use movies that contain topics related to astronomy;
6. **Pseudoscience** that would use movies including topics from pseudoscientific;
7. **Metaphysics** that would use movies that touch on questions of metaphysical content.

The instructors started building the *Superhero* and *Pseudoscience* flavors in Summer 2003 and the coming summer will finish their development. In figures 5 and 6, the reader sees the movies used so far.

Example–*Superman II*

In *Superman, the movie* the audience learns that before the planet Krypton exploded, three criminals were sealed in a container and sent to the Phantom Zone (an extraordinary prison) for eternity. All of them (on Earth) would possess incredible powers exactly equal to those of Superman. In *Superman II,* extraordinary conditions, of course, allow them to escape and arrive at Earth where they terrorize the humans. During their trip towards Earth, they stop on the Moon. There they become aware of their incredible powers and we witness a discussion among them on their newly found powers. As real as this scene seems to the audience, it could never have taken place. Human voice is a sound wave that is created by vibrations of the vocal cords generating density variations in the air inside the larynx. Sound waves can be created only inside materials (such as the air of Earth's atmosphere) since they are really changes in the density of the material. The Moon, however, has no atmosphere; there is no material whose density can be affected to create sound waves. Therefore, sound on the surface of the Moon (without the use of sophisticated electronic equipment) is impossible. As has humorously been said, "in the vacuum of space, no one can hear you scream".

Example—*Sixth Sense*

The Sixth Sense is a film concerned with ghosts. A child has the ability to see and communicate with ghosts. The movie consistently tells the viewer that ghosts like low temperatures, although why that should be is not explained. In a scene where the young hero goes to the bathroom during the night, the director clearly and distinctly shows a sudden drop in the room temperature, so that one expects the appearance of a ghost; and indeed one appears.

To get a hint concerning the possibility that the appearance of ghosts is heralded by a sudden drop in temperature, we shall look at a case studied by scientists (BBC News 2001, Frood 2003). In Hampton Court Palace near London, UK, there is a well-known Haunted Gallery. It is said that The Gallery is stalked by the spirit of Catherine Howard. Many visitors to the room have described strange phenomena in the gallery such as hearing screams and seeing apparitions. Due to many reports of such occurrences, a team of 'ghost-busting' psychologists, led by Dr Richard Wiseman of Hertfordshire University was called

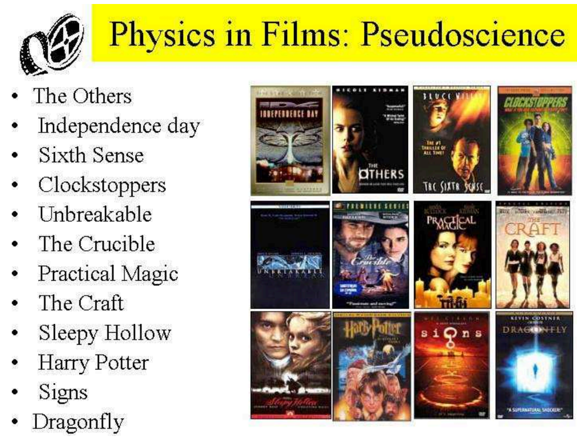

Figure 6: Films with pseudoscientific content used in the pseudoscience approach of the *Physics In Films* variation of the *Physical Science* course.

to investigate. The team installed thermal cameras and air movement detectors in the gallery, following which about 400 palace visitors were asked if they could feel a "presence" in the gallery. The response was quite amazing: more than half reported sudden drops in temperature and some said they sensed a ghostly presence. Several people claimed to have seen Elizabethan figures. However, the team discovered that the experiences could be simply explained by the gallery's numerous concealed old doors. These exits are far from draught-proof and the combination of air currents which they admit cause sudden changes in the room's temperature. In two particular spots, the temperature of the gallery plummeted down to 36^o F. "You do, literally, walk into a column of cold air sometimes," said Dr Wiseman. Convection is one of the three ways heat propagates; the other two are conduction and radiation. Convection appears in fluids that have a non-uniform distribution of temperature. As a result, currents inside the fluid will be such as to attempt to restore a uniform temperature. These currents are stronger when the non-uniformity is greater. In the case of the gallery rooms, the convection currents would be felt as cold drafts, similar to those experienced by someone who opens the door of a refrigerator a hot day in summer.

THE RESULTS

Student interest and performance in the *Physical Science* course have both increased dramatically compared with the traditional teaching mode, which we still use in some sections. In figures 7 and 8 we give an example of the several measures of student interest that we have used, including student opinions of the electronic personal response system used in class to answer quiz questions and to take attendance (both of which contribute to the final grade).

Class Evaluation

The instructors should develop this course further since it is more interesting than the standard physical science course.

Summer 2002: class of 92 students.

SA	A	D	SD
77.92%	10.39%	9.09%	2.60%

Fall 2002: class of 292 students.

SA	A	NO	D	SD
56.88%	26.61%	6.88%	4.13%	5.50%

Figure 7: One of the many class evaluation questions given to students. Notice that students strongly support the further development of the course. (SA=strongly approve, A=approve, NO=no opinion, D=disapprove, SD=strongly disapprove.) Statistics to other questions is similar.

The exam scores distribution in two classes of about the same size (295 students each) taught by the same instructor, one in traditional lecture mode, the other *Physics in Films* mode and covering the same topics are quite dramatically different, as the table below illustrates.

Rating of the Electronic Response System

The electronic response system was a benefit for the class.

Summer 2002: class of 92 students.

SA	A	D	SD
28.57%	42.86%	15.58%	12.99%

Fall 2002: class of 292 students.

SA	A	NO	D	SD
44.75%	27.40%	7.76%	6.39%	13.70%

Figure 8: The class is using a personal response system in order to obtain real-time data on the class state of knowledge. Although the students at the beginning of the class complain about the use of the system (since it increases their expenses for the course and forces them to attend the lectures), by the end of the course are very enthusiastic about it.

Fall 2002 Traditional mode			
Exam 1	Exam 2	Exam 3	Final
49.3	65.3	58.2	59.4

Fall 2003 'Physics in Films' mode			
Exam 1	Exam 2	Exam 3	Final
74.9	67.7	75.7	72.8

Table 1: Exam averages (100 being the maximum score)of two large sections of *Physical Science* taught by the same instructor.

THE FUTURE

Our goal is to increase awareness of science and to demonstrate that understanding some physics can be exciting and rewarding when presented in the context of an enjoyable activity. Our presentation has illustrated in detail exactly how the movies are used as a vehicle for learning physical science. In class clips from the films are integrated with lecture materials, quizzes, demonstrations, and slides so as to enhance both student attention and retention. We have given two sample scene analyses and comparative statistics of student reactions and performance. This new technique can be extended to many other disciplines, as the following list (with some suggested films) illustrates.

1. ***Math in Films***: Pi, Good Will Hunting, Pay it Forward, A Beautiful Mind
2. ***Biology in Films***: Spiderman, Planet of the Apes, Fly, Hollow Man
3. ***Engineering in Films***: Armageddon, The Bridge on River Kwai, Space Cowboys
4. ***Archeology in Films***: Indiana Jones: Raiders of the Lost Ark, The Mummy, The Relic
5. ***Computers in Films***: Independence Day, The Net, Swordfish
6. ***Philosophy in Films***: Matrix, Terminator, Blade Runner
7. ***History in Films***: Patriot, Braveheart, Gladiator, Elizabeth
8. ***Law in Films***: Legally Blonde, Erin Brockovich, The Firm, The Rainmaker
9. ***Forensic Science in Films***: Murder by the Numbers, Bone Collector, Torso, Jennifer 8
10. ***Psychology in Movies***: Don't Say a Word, Control, Final Analysis, Primal Fear

The authors are in the process of preparing a self-contained physical science course, complete with textbook and a CD-ROM with all scene analyses and slides we use, that can be handed to an instructor ready-to-go.

References

APS News (2003). *Physics in films*. `http://www.aps.org/apsnews/0303/030 306.html`.

BBC News (2001, March 29) *Palace Ghost Laid to Rest*. BBC News on-line. Retrieved 3/14/2003 from `http://news.bbc.co.uk/1/hi/uk/124936 6.stm`.

Chow, L. (2003). *Cinema as physics lesson*. Physics Today, 56, 15. `http://www.physicstoday.org/vol-56/i ss-5/p15a.html`.

Efthimiou, C. E. & Llewellyn, R. A. (2003). *Physical science: A revitalization of the traditional course by avatars of Hollywood in the physics classroom.* `http://www.arXiv.org/physics/0303005`.

Frood, A. (2003, May 21) *Ghosts 'all in the mind'*. BBC News on-line. Retrieved 1/6/04 from `http://news.bbc.co.uk/1/hi/sci/tech/ 3044607.stm`.

Graham, A. (2002). *A little bit of Hollywood, a lot of physics*. Retrieved 1/6/03 from `http://www.ucffuture.com/main.cfm?in include=detail&storyid=287529`.

Grayson, C. (2002). *Students play games, watch movies, raise grades*. Retrieved 1/6/04 from `http://www.ucffuture.com/main.cfm?in clude=detail&storyid=328832`.

NSF (2002). *Science & engineering indicators 2002*. Retrieved 1/6/04 from `http://www.nsf.gov/sbe/srs/seind02`.

Priore, T. (2003). *With great power comes a physical explanation: Action films teach students the laws of physics*. Retrieved 1/6/04 from `http://www.ucffuture.com/main.cfm?in clude=detail&storyid=436180`.