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Author(s): Michael Barnett, Heather Wagner, Anne Gatling, Janice Anderson, Meredith Houle and Alan Kafka

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The Impact of Science Fiction Film on Student Understanding of Science

Michael Barnett,[1,4] Heather Wagner,[2] Anne Gatling,[1] Janice Anderson,[1] Meredith Houle,[1] and Alan Kafka[3]

Researchers who have investigated the public understanding of science have argued that fictional cinema and television has proven to be particularly effective at blurring the distinction between fact and fiction. The rationale for this study lies in the notion that to teach science effectively, educators need to understand how popular culture influences their students' perception and understanding of science. Using naturalistic research methods in a diverse middle school we found that students who watched a popular science fiction film, *The Core*, had a number of misunderstandings of earth science concepts when compared to students who did not watch the movie. We found that a single viewing of a science fiction film can negatively impact student ideas regarding scientific phenomena. Specifically, we found that the film leveraged the scientific authority of the main character, coupled with scientifically correct explanations of *some* basic earth science, to create a series of plausible, albeit unscientific, ideas that made sense to students.

KEY WORDS: earth science; films; science in popular culture; student misconceptions.

"We have been charged by our funders to develop exhibits and learning experiences about nanotechnology so we can educate the public before the public learns about nanotechnology from science fiction movies."

> – Ioannis Miaoulis, President of the Boston Museum of Science, Introductory Comments at the Science Education for a Thriving Democracy Symposium in honor of TERC's 40th anniversary year, November 19, 2005

[1]Department of Teacher Education, Lynch School of Education, Boston College, Chestnut Hill, 024467, MA, USA.
[2]Framingham High School, Framingham, MA, USA.
[3]Department of Geology and Geophysics, Boston College, Chestnut Hill, MA, USA.
[4]To whom correspondence should be addressed; e-mail: barnetge@bc.edu

INTRODUCTION

The science education historian George Deboer, identified nine major goals of science teaching that would advance the development of a scientifically literate citizenry. He noted that one of the major aspects of scientific literacy was the ability to understand reports and discussions of science that appear in the popular media (DeBoer, 2000, p. 592). Unfortunately, as implied in the quote that starts this paper, for the average citizen, it is becoming more and more difficult to distinguish fact from fiction in an increasing visual society. According to the National Science Foundation (2000) the blurring of fact and fiction by visual media has corroded the public's critical thinking skills and has hindered the development of a scientific literate citizenry. This concern was further expounded upon by Helga Nowotny (2005), the chair of the European Research Advisory Board, in which she noted that the past few years has

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seen an increasing proliferation of images and symbols via hi-tech-driven media entertainment that is deliberately designed and intended to meet the public imagination about science but all too often creates misunderstandings regarding the nature of science and leads to a blurring between fact and fiction. The National Science Foundation (NSF) has also noted that today's fictional portrayal of science is harmful to the public understanding of science. According to the NSF's *Science and Engineering Indicators—2000* (National Science Foundation, 2000), fictional media have corroded the public's critical thinking skills and have hindered scientific literacy:

> The amount of information now available can be overwhelming and seems to be increasing exponentially. This has led to "information pollution," which includes the presentation of fiction as fact. Thus, being able to distinguish fact from fiction has become just as important as knowing what is true and what is not (National Science Foundation, 2000, pp. 8–31).

Dhingra (2003) noted that research studies are needed that explore the means by which visual entertainment influences students' understanding of science because education and entertainment often overlap which further merges fact and fiction. Yet, to date, very few studies have examined the impact of popular culture films on student understanding of scientific concepts. Studies that examine the impact of television and movies are particularly needed when one considers that the typical American, aged 10–22, spends an average of 3 h per week watching movies and 8 h per week watching television shows (Roberts *et al.*, 1999). These statistics indicated that there are ample opportunities for students to view "film science" which may or may not be based upon reality. Therefore, the rationale for this study lies in the notion that to teach science effectively, educators need to understand how popular culture influences their students' understanding of science.

ANALYTIC FRAMEWORK: SCIENCE AND FILM THEORY

Researchers who have investigated the public understanding of science have argued that fictional cinema and television is particularly effective at blurring the distinction between fact and fiction (Frank, 2003). This blurring is especially evident for natural phenomena that have never actually been directly witnessed (e.g. dinosaurs in *Jurassic Park*). For example, Black (2002) has argued that film needs to be recognized as a literalist medium whose nature is to make things explicit and present objects or phenomena in ways that are evidentiary based which not only reflect reality but appear to be realistic. What constitutes a realistic image has proven to be one of great debate to film scholars, however, and Prince (1996) has suggested that in visual media, there are two standards of reality, referentially real or perceptually real. These two standards can be used to describe any filmed image, and they characterize the audience's relationship to that image. A scene in a film is 'referentially' either real or unreal—that is, it depicts events that actually occur or exist, or ones that are imagined (Kirby, 2003a). The same scene is also either 'perceptually' real or unreal, meaning that it appears to be real or appears to be a fantasy (or to lack significant real-world elements). A perceptually realistic image is one that structurally corresponds to the viewer's audiovisual experience of three-dimensional space. Such images display a set of cues that organize the display of light, color, texture, movement, and sound in ways that correspond with the viewer's own understanding of these phenomena in daily life. Further, the images are also usually supported by reasonable sounding dialogue that attempts to explain the images on the screen. Because of this, unreal images may be referentially fictional but perceptually realistic. The important point here is that filmmakers design images, even unreal images, to correspond to 'cues' with which viewers normally interact. Familiarity with these cues compels the audience to perceive unreal images as realistic.

To make his point (Prince, 1993) uses *Jurassic Park* as an example of how film-makers create perceptually realistic images using digital technology: No one has seen a living dinosaur. Even paleontologists can only hazard guesses about how such creatures might have moved, let alone how they behaved. Yet the dinosaurs created at Industrial Light and Magic have a palpable reality about them which is due to the extremely detailed and realistic looking texture mapping, motion animation, and integration with live action carried out via high quality digital imaging.

Film scholars have argued that the point of fictional visual media is not to devise "accurate/educational" communications about science, but to produce images of science that are entertaining (Logan, 2001). Despite this argument, film research suggests that movies and television viewing experiences often lead to a changed perception or understanding of science or a scientific phenomena (Frank, 2003) despite the fact that audience members are aware that they are watching entertainment. The research base has shown that movies do have an impact on citizens' conceptions of science by either encouraging excitement, instilling fear about science and technology, or by leading to the development of stereotypes of science and scientists (Cavanaugh and Cavanaugh, 1996; Long and Steinke, 1996). Movies also have an impact by increasing the public's belief in paranormal phenomena (Sparks, 1998; Sparks *et al.*, 1997), and by propagating a masculine view of science (Steinke, 1999). These findings are not particularly new, as nearly 20 years ago, Gerbner (1987) conducted an extensive analysis of television shows and found that 7 out of every 10 programs on television between 1973 and 1983 contained images of science and technology. More importantly, Gerbner found that individuals who frequently watched television were more likely than infrequent viewers to lack confidence in the scientific community, believe that science is dangerous, be mistrustful of scientists, and believe that a career in science is undesirable.

Film scholars suggest the reason for visual media's impact on its audience members is that today's visual fictional depictions of science in film and television encompass more than just entertainment and focus on the production and presentation of an image of science, whether or not the science has anything to do with real science (Kirby, 2003b). Research on the production of modern science fiction visual media reveals that film makers strive to ensure that their depictions of scientific phenomena have a basis in reality, and that the images put forth in the film or television show appear as realistic and plausible as possible (Kirby, 2003b). In fact, it is film's ability to create plausible scientific phenomena that captures the imagination of the audience because they make people wonder whether what they have seen on screen is possible (Rose, 2003). In fact, to achieve plausibility many film makers design images, even unreal images, to correspond to 'cues' with which viewers normally interact. Familiarity with these purposively chosen cues compels the audience to perceive unreal images as realistic. *Jurassic Park* is an example of how film-makers create realistic images through the use of everyday cues coupled with digital technology (Prince, 1993). In *Jurassic Park* the viewer sees unreal animals (i.e., dinosaurs) that match the movement, appearance, and sounds of animals with which audience members have interacted. As a result of the "realism" of such images audience members tend to perceive these images as realistic even though they are not actually real (Frank, 2003). Then these "unreal" images have plausibility and explanatory power which can influence their ideas and understandings of scientific phenomena (Cavanaugh and Cavanaugh, 1996; Dubeck *et al.*, 2004). Therefore, given filmmakers intent of creating "realistic scientific images" it stands to reason that modern popular films may have impact on student understanding of scientific concepts. To date, however, there have been few, if any, studies that examine the impact of popular film on student understanding. (We could not find a single empirical study in the ERIC database that examined the impact of popular film on student understanding.) Therefore, the purpose of this work was to examine the potential impact of a popular science fiction film, *The Core*, on student understanding of earth science concepts.

Student (Mis)Understandings of Earth Science Concepts

During the past three decades, the educational research community has accumulated a wealth of knowledge regarding student understanding of scientific concepts. For example, Pfundt and Duit (2004) misconceptions bibliographical research database lists 5956 studies that have examined student understanding of scientific concepts. These studies have found that from an early age children strive to understand the natural world and in the process develop their own theories and mental models to explain their experiences and observations. In general, these studies have reported that students' theories and models are contrary and in conflict with currently accepted theories and models of the scientific community.

In terms of earth science education there have been a number of studies that have examined student understanding of earth science related concepts (Bailey and Slater, 2003; Barrow and Haskins, 1993, 1996; DeLaugter *et al.*, 1998; Gobert and Clement, 1999; Maria, 1993; Schoon, 1992; Sneider and Pulos, 1983; Vosniadou and Brewer, 1992). In general these studies have found that students do not understand the interior structure of the Earth, the direction of gravity at various points on the Earth, and how mountains and volcanoes form. Research has also found that students and adults do not understand the theory of plate tectonics and/or the causes for earthquakes, and that they believe that earthquakes are caused by either unrelated natural phenomena (such as changes in the weather) or by supernatural forces. For example, Tsai (2001) interviewed 52 5th grade students in Taiwan after the island experienced an earthquake and found that the students (1) believed that supernatural forces caused earthquakes, (2) relied upon cultural myths to describe the underlying causes of earthquakes, or (3) believed that a radical change in gravity was the cause for earthquakes. Tsai also found that students obtained their information about earthquakes from a variety of sources including television news, newspapers, their friends, their parents, and movies. Similarly, Ross and Shuell (1993) investigated children from kindergarten through sixth grade in New York and Utah regarding their beliefs about the characteristics and causes of earthquakes. Ross and Shuell (1993) found that students had a wide array of causal reasoning regarding earthquakes including: that the core gets too hot and hits the surface of the Earth; that the Earth is letting out air like a sneeze; and that earthquakes are caused by the wind, thunder and rain, or by mountains. Similarly, Barrow and Haskins (1993) interviewed 186 college students who were enrolled in an introductory geology course. Barrow and Haskins found the that students (1) generally identified volcanoes with earthquakes, (2) believed that earthquakes only occurred along plate boundaries, with no chance of intra-plate earthquakes, (3) lacked a broad understanding of the theory of plate tectonics, and (4) obtained much of their information about earthquakes through television news reports, newspapers, and movies.

METHODS

Study Context and Participants

This study was conducted in a medium-sized urban/suburban middle school called Chamberlain Middle School (pseudonym). Chamberlain has 700 students and a diverse student body. The student body makeup is 30% Latino, 10% African-American, 10% Asian-American (Indian and Vietnamese primarily), 40% Caucasian, and 10% Eastern European. In addition, 17% of the student population has been identified as students who require special needs or care. This study occurred in one 8th grade science teachers' classroom, Mrs. Kennedy (pseudonym), who taught 82 students distributed across five classrooms. All students experienced the same 4-week curriculum unit on Earth Science that included lessons on the Earth's interior structure, Earth's magnetic field, earthquakes, and plate tectonics. This Earth science unit followed a 4-week unit on the Solar system where the students learned about the Sun, other planets and their magnetic fields, orbits, and other planetary interiors. At the end of the unit the teacher showed three of her classes *The Core* while the other two classes finished their portfolios of the Earth Science Unit.

Data Collection

The students were interviewed prior to the beginning of their unit on the Earth, and once more following the completion of the unit. The interview questions were the same prior to and following the course. The interview protocol was semi-structured, consisting of questions that covered a wide range of earth science concepts typically covered in middle school earth science classes (see Table I). The questions were derived from the previously reviewed misconception research (Barrow and Haskins, 1993, 1996; Maria, 1993) and from consultation with geophysicists and middle school earth science teachers.

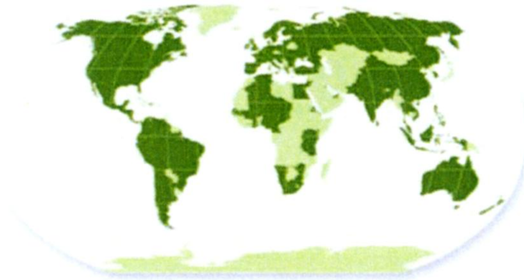
We pilot-tested the interview protocol with a small set of students ($N = 8$) to evaluate whether the questions were understandable by the students, appropriately phrased to elicit student understandings, and whether the interview could be easily completed within a single 45 min period. The final interview protocol consisted of 10 questions. The interviews were digitally audio recorded and on average ranged from 20 to 30 min. Throughout the interview, the interviewer asked probing questions to elicit student ideas. The students were also provided pen and paper for drawings that they were asked to create as a part of the interview process. We also collected and examined student papers, journals, and homework assignments and used these documents to triangulate with our interview data.

The post-interviews were digitally audio taped and conducted 2 weeks following the completion of the unit (including watching *The Core*). The post-interviews typically lasted 20–30 min and the students were asked to express their understandings either verbally or by drawing on provided paper. In total we post-interviewed 38 students (including 22 who watched *The Core*) with the average interview lasting approximately 30 min. Of the 38 students who were post-interviewed only two had seen *The Core* prior to watching it in their respective class.

In addition to the interview data we administered a pre–post, multiple choice, content test based upon Libarkin and colleagues' (2005) earth science diagnostic exam (see Table II). The questions were the

Table I. Illustrative Interview Questions

1. You have probably heard about earthquakes on the news. Can you describe for me in your own words what an earthquake is? How many earthquakes do you think happen each year? Why so many? Why so few? Why did you think that?
2. Here is a picture of the Earth. Could show me (mark or circle) where you think earthquakes are most likely to happen? Why? How do you know earthquakes happen there? Could you draw where you think earthquakes are most common?



3. Lets imagine that you cut the Earth in half. What do you think the inside of the Earth will look like? Can you draw what you think the Earth's inside looks like *(give them the paper to draw on)*? How do you know the interior of the Earth looks like that? How do you think scientists know what the interior of the Earth looks like?
4. Could you label and describe what each part of your Earth is made of? How do you know that?
   a. What is the purpose of the Earth's magnetic field? Why? How do you know?
   b What do think causes the Earth's magnetic field? Why do you think that? How do you know?

same on the pre-test and the post-tests. The pre–post content exam had 19 questions that asked students about the structure of the interior of the Earth, the reason for earthquakes, the reason for the Earth's magnetic field, and about the theory of plate tectonics.

Data Analysis

We assessed student conceptual understanding by extensive listening to the audio files, analysis and coding of the interviews, and scoring the student responses by a rubric ranging from a score of 0 to 4. Specifically, we gave each interview response a score and recorded a brief description of why the interview was given that score. In addition, to this description we included keys words, phrases, or whole sentences that illustrated the student response. It was these phrases (which served as the initial overarching high level coding structure) that were reduced by our research team by revisiting and discussing the interview results, in light of the other supporting data. By using this strategy were could then search our database for key words or phrases that were illustrative of our emerging themes and transcribe sections of interviews for a more detailed analysis to confirm or disconfirm our ideas. This process continued until we arrived at the three themes that are discussed below.

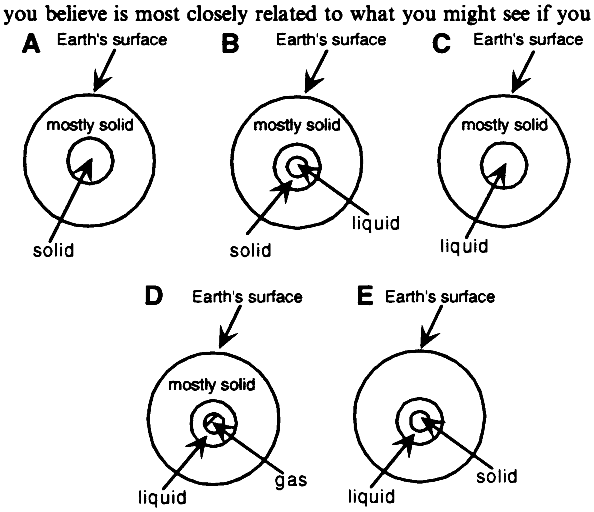
The rubric used to score the interview responses was based upon the categorization scheme used by a number of researchers (Barnett and Morran, 2002; Muthukrishna *et al.*, 1993; Simpson and Marek, 1988) where a score of 1 means the students were confused and tried to piece together their fragmented understandings into a coherent whole. A score of 4 represents a complete understanding of the concepts that the questions were addressing. Both the pre- and post-interview responses were scored using a rubric adapted to the question of interest. Multiple raters scored the interviews and the rubric went through iterative development until we had obtained an inter-rater reliability of 0.80. While examining the student responses we also re-examined the drawings students created during their interviews, as well as examining student journal and homework assignments which included their reflections on both the unit and the science as depicted in *The Core.*

RESULTS

We found that the two groups (those who watched *The Core* versus those who did not watch *The Core*) did not exhibit any statistically significant differences on any question on the pre-test. We also found that overall the two groups did not perform significantly different on the post exam with the exception of three questions which are presented in Table III. In short, the students who watched *The Core* had a larger tendency to think that the inner core of the Earth was a liquid rather than a solid. For example, on the question that asked the students about the center of the Earth 32 students answered the question correctly while another 20 said the center of the Earth

Table II. Illustrative Content Exam Questions

1. Some people believe that they have evidence that can prove whether the very center of the Earth is a solid, liquid, or gas. Which of the following is an accurate statement about the innermost part of the Earth?
   (A) The very center of the Earth is mostly made up of gases
   (B) The very center of the Earth is mostly made up of liquids
   (C) The very center of the Earth is mostly made up of solids
   (D) Scientists do not have enough evidence yet to indicate whether gases, liquids, or solids make up most of the very center of the Earth
2. The Earth probably has a magnetic field because of:
   (A) Changes in the composition of the Earth's crust
   (B) Gravity
   (C) Liquid metal moving inside the Earth
   (D) The Earth's revolution around the Sun
   (E) None of the above, the Earth does not have a magnetic field
3. Which of the following figures do you believe is most closely related to what you might see if you could cut the Earth in half?



was a liquid. We also found that the students who did not watch *The Core* also were unable to articulate explanations regarding the causes of the Earth's magnetic field, whereas, students who watched *The Core* could not articulate a more scientifically sophisticated response. The differences on these specific questions between the two groups led us to further investigate student understandings through clinical interviews. In our analysis we were surprised to find how much the students who watched *The Core* used examples and ideas that were expressed in the movie to explain their ideas. Our surprise was not so much in that the students used examples from *The Core* but rather the percentage of students and the apparent confidence that they had in their responses when they utilized ideas and examples from the movie. In our analysis of the interviews and other documents we identified three major themes that described the impact of the movie on student scientific ideas. These themes are (1) misunderstandings built upon plausi-

Table III. Quantitative Results for Post Tests: Number of Correct Responses

Question	*The Core* (N = 50)	Did not watch Core (N = 32)	t-value
Some people believe that they have evidence that can prove whether the very center of the Earth is a solid, liquid, or gas...	32 (64%)	30 (94%)	2.3*
The Earth probably has a magnetic field because of...	47 (94%)	26 (81%)	0.4
Which of the following figures do you believe is most closely related to what you might see if you could cut the Earth in half...	37 (74%)	29 (91%)	1.8**

*$p < 0.05$, **$p < 0.10$.

bility, (2) scientific authority of the main character, and (3) movie images appear to be more memorable than hands-on in class experiences. These three themes are discussed in more detail below.

Misunderstanding Built Upon Plausibility

During the pre-interviews the students in both groups had little understanding of the Earth's magnetic field. The students who articulated a response generally believed that the Earth's magnetic field was caused by some object inside the Earth (most likely a magnet) and that the spinning of the Earth had something to do with the formation of the Earth's magnetic field. In the post interviews the students understanding of the magnetic field was significantly improved from the pre-interviews, however there were some interesting differences in the students who had watched *The Core* as compared to those who did not watch *The Core* (see Table IV).

The students who watched *The Core* were significantly outperformed on the question of the role of the Earth's magnetic field. In particular, students often stated and in many cases described exact scenes from *The Core* in their interview response. For example, in one scene, the hero (Dr. Keyes, a geophysicist) is describing to another scientist (Dr. Zimsky) and a group of military leaders what will happen to the Earth if the Earth's magnetic field vanished. In this scene the hero argues (rather convincingly) that the Earth would be burnt to a cinder without its magnetic field by microwave radiation. During his soliloquy Dr. Keyes correctly explains the structure of the Earth by using a peach to represent the Earth's interior and how the Earth's magnetic field is generated. Following this presentation Dr. Keyes sprays the contents of an aerosol can onto a lit match which creates a mini-flamethrower and burns the peach to a crisp to demonstrate the effect of the Sun's microwaves on the Earth without a magnetic field. Needless to say this scene ended in a rather dramatic moment and the content and dialogue of the scene seemed to stay with students. For instance, the following interview exchange is illustrative of students' ideas who watched *The Core*:

> Interviewer: Could you explain to me what the inside of the Earth looks like.
> Student: Sure, the very inside is solid, then right outside of that is liquid, then we get solid again at the mantle. We live on the crust. The crust and the mantle are all rock.
> Interviewer: Great. Now could you explain for me what the Earth's magnetic field does?
> Student: It keeps the Earth safe from microwaves.
> Interviewer: Microwaves? How does the Earth's magnetic field keep us safe from microwaves?
> Student: Umm, not sure, but I know that if the Earth's magnetic field wasn't there the microwaves would get through the atmosphere and cause a lot of damage.
> Interviewer: How do you know that the microwaves will get through the atmosphere?
> Student: Umm, well I don't know for sure. The movie did show it happening.
> Interviewer: Tell me about the movie scene. Why do you think it is right?
> Student: Well, I don't know really. It just seemed right. The guy in the movie seemed to really know what he was talking about, you know. I do know what the inside of the Earth looks like and he got that right so I guess I thought that was right too.

This interview excerpt shows that the student believed that the Earth's magnetic field protected the Earth from microwave radiation. Further, when probed why the Earth's magnetic field is a shield

Table IV. Interview Results: Post-Interviews

Question	*The Core* ($N = 20$)	Did not watch Core ($N = 18$)	t-value
Lets imagine that you cut the Earth in half. What do you think the inside of the Earth will look like?	$M = 3.2$	$M = 3.5$	1.0
What is the purpose of the Earth's magnetic field? Why? How do you know?	$M = 2.3$	$M = 3.5$	3.4*
What do think causes the Earth's magnetic field? Why do you think that? How do you know?	$M = 3.9$	$M = 3.0$	2.8*
Could you label and describe what each part of your Earth is made of? How do you know that?	$M = 2.9$	$M = 3.4$	2.0**

*$p < 0.05$, **$p < 0.10$.

against microwave radiation the student cannot articulate a response without referring back to the movie that he had seen during class. In studying the student exams and portfolios we also found numerous examples of students using scenes and dialogue from *The Core* to make their point. For example, one student described a special effect scene from *The Core*:

> The Earth's magnetic field prevents beams of microwaves from breaking through the atmosphere and causing damage to the Earth...

We speculate that the reason the students tended to believe the science as described in *The Core* was because *The Core* had (1) a respectable geophysicist (professor at a university and shown teaching in his class) as the main character who was making the claims, (2) the main character had established credibility in that he explained the interior structure of the Earth correctly early in the movie, and (3) the argument put forth made sense because the science in the scene was ground in real-world experience (all the students knew that microwaves were used to cook their food). The arguments in *The Core* also made sense to the students because the main character in the movie explained science correctly that the students understood or had seen in class. This fact allowed the movie to anchor forthcoming ideas onto a kernel of scientific accuracy which yielded a set of plausible and realistic ideas that the students could grasp. This latter idea is illustrated well by the following interview excerpt from a student who was asked why she felt that the movie presented plausible science:

> Student: It all made sense. He explained the inside of the Earth right. He was a college professor. It all seemed to make sense. I thought that the burning down of the Golden Gate Bridge was probably wrong, but I don't know what would happen if a beam of microwaves hit it. I know for certain that it would get hot because microwaves heat things up.

This student felt that some of the science was probably wrong but still believed that the movie was mostly right and when specifically asked she uses the fact that the main character was a scientist and explained the science that she knew correctly.

Scientific Authority of the Main Character

The issue of scientific authority was a common theme among the students who had watched *The Core* compared to those who had not watched *The Core*. Students would often state that they believed the scientist in the movie because he was a professor, and he could explain all the science in the movie in a way that made sense to them. This was expressed well by a student in one of her journal entries when asked to consider what was correct science and incorrect science in *The Core*:

> Dr. Keyes, who was a geology professor, was able to explain much of the science and it all sounded right to me and he figured out the problem and others believed him. So I think much of the science early in the movie was correct....

This same student continued to explain how Dr. Keyes who was an expert in geophysics made statements that were correct, and as such she felt that much of the science was correct. However, she did recognize that some of the science content was not correct, but could not articulate why and tended to accept the science until she had a better explanation for the events in the movie:

> ...I think it [the science] was, or could be mostly right. Some of it was a little strange. I don't think scientists know how to dig through rock that easily or else we would have heard about it on the news or read about it in our book or Mrs. Kennedy would have told us about it. I also always thought that the aurora was caused by the magnetic field someway but in the movie they were caused by something else [in the movie the aurora was caused by high altitude static discharge]. It sounded right but I am not sure.

Other students in their interviews and journals noted that Dr. Keyes was a science professor and that to become a science professor it is necessary to really understand science. This sentiment was expressed by one student during an interview:

> Student: I didn't believe all the science in *The Core* but most of it was good. Dr. Keyes explained the inside of the Earth right.
> Interviewer: Why did you think he was right? Dr. Keyes?
> Student: Well he was a scientist, like you I guess. He also was a teacher and teachers know everything. Well usually they do.

Movie Images are More Memorable than Hands-on Science Experiences

As a part of the instructional unit the students created a scale model of the inside of the Earth, labeled the layers and included a few facts about each layer (i.e. temperature, pressure, and composition within each layer). The teacher also had the students crack open a hard-boiled egg and compare the inside of the egg to their model of the Earth, and led a discussion on whether the egg is a good model for the Earth's interior. The students were asked to compare the egg model to their constructed scale model and to what scientists currently believe the Earth's interior looks like. The students generally found this set of activities to be fun and they also felt that they learned a lot from the activity as noted in one student's portfolio:

> My favorite activity was the egg activity. I liked it because it really helped me to see what the Earth looked like inside. The center being *The Core* that is dense with the very inside being solid and the surrounding part being liquid and the outer white part being the mantle and the shell being the crust. I know it is not really like that but it is similar to the egg. I liked that lab.

On the post-interview, however, the same student responded to the question about the Earth's interior in the following way:

> Interviewer: So can you describe for me what the inside of the Earth looks like?
> Student: Sure. The inside of the Earth looks like a set of balls around one another. It is like a peach. The inside is the seed which is hard so that is *The Core*. Then as you start to head out it gets softer and softer till you reach the surface.
> Interviewer: Can you tell me what each layer is made out of?
> Student: Sure. The very inside is mostly rock and iron and is very hot. The next layer is mostly liquid though it probably has big chunks of rock or maybe diamonds or something like that.
> Interviewer: Why diamonds?
> Student: The pressure is very high there and that is how diamonds are formed, under high pressure.
> Interviewer: Have you read or seen somewhere that there might be Diamonds in the Earth?
> Student: Ummm, oh yeah in the movie that Mrs. Kennedy showed us. They ran into diamonds because they could see through them.

In the previous excerpt the student noted that she liked the scale and egg activity but when probed during the interview she remembered the scenes from the movie and used the movie scene, rather than what she had done or learned during class, as the basis of her explanation.

The premise of *The Core* is that Earth's magnetic field has disappeared and early in the movie it was necessary for the main character to explain why the Earth's magnetic field has stopped. The character accurately described that the Earth's magnetic field is generated by the Earth's outer core because it is a spinning liquid which generates a magnetic field. Within the previous instructional unit the teacher had discussed that the Earth's magnetic field was due to the spinning of the Earth and had discussed the difference between Venus and the Earth in that the Venus spins very slowly and has a very weak magnetic field despite being roughly the same size and a similar internal composition as the Earth. However, this is a rather abstract concept and it is not surprising that these middle school students had difficulty in understanding it. Nonetheless, in the state that Mrs. Kennedy teaches, middle school students are expected to know why the Earth's magnetic field exists and be able to explain the underlying scientific mechanisms that drive the Earth's magnetic field. In analyzing the interviews the students who had seen *The Core* did significantly better than the students who did not watch *The Core* in explaining why the Earth's has a magnetic field (see Table IV). For instance, Becky (a student in *The Core* group) articulated:

> Interviewer: So what causes the magnetic field?
> Becky: Well... Hmm, wait... I got it. It has to do with *The Core*, the outer core. It is a liquid metal and it has a lot of electrons. Electrons are what make electric current. And electric current makes a magnetic field. Bingo!
> Interviewer: How do you know that an electric current makes a magnetic field?
> Becky: Oh, Mrs. Kennedy showed us a something about earlier this year.
> Interviewer: Anywhere else?
> Becky: Oh, the movie also! That was the problem in the movie, *The Core*, the Earth's core had stopped spinning so not more current, so no more magnetic field and bad things happen to the planet.
> Interviewer: Did you do anything in class about the interior of the Earth?
> Becky: Oh, yea (smiling) we made that big model of the Earth and it also had a liquid core.

Here the student does not fully understand what causes the magnetic field but she does remember that the basic components of the Earth's magnetic field origins. Again, this student calls upon *The Core* as the initial way in which she remembers the reason for the magnetic field even though during class she had seen numerous visualizations, diagrams and pictures regarding how the Earth's outer core produces the magnetic field and even constructed a model of the Earth's interior in her class. One could argue that this outcome could have been the result of the timing of the post-interviews which were 2 weeks after the class had seen *The Core*, particularly given that in the interviews 19 of the 22 students who were asked the same question referenced the movie in their response. Yet, the movie dialogue and scenes were overwhelmingly what the students referenced and recalled during the post-interviews rather than their classroom experiences and as such we feel that watching of *The Core* did have a significant impact on student ideas and what they remembered about the Earth.

DISCUSSION

To date, nearly all research on the impact of film on science understanding has primarily examined how students and the general public perceive science as presented on film and how films represent the doing of science. The study presented here took a different approach and examined how a popular science fiction film can influence student understandings and ideas about Earth science content. We found that a single viewing of a popular science fiction film can have a great influence on student ideas and conceptual understanding of scientific concepts. Specifically, we found that the authority and credibility of the main character had a substantial influence on students' acceptance of the science as presented in *The Core*. To achieve credibility, the film spent considerable amount of time establishing the scientific authority of the main character by showing him in a scientific lab, teaching a college level geophysics class, and explaining scientific content that the students believed was correct. Further the film constructed plausible scientific explanations by building either unscientific or scientifically questionable claims upon scientifically reasonable explanations. For example, nearly all students have grown up with microwave ovens and they are aware that microwaves heat objects; therefore it was reasonable to most students that the microwaves as depicted in *The Core* would cause severe sunburns and destroy the Golden Gate Bridge by rapidly increasing its temperature.

The film also had the main characters engage in scientifically sounding dialogue, which at times was correct, to provide a foundation upon which they could construct the credibility of future "scientific" explanations. Once the students had "bought in" that the main character ideas and explanations were correct then they were more willing to accept the future science in the movie as being plausible. Thus, a noteworthy finding of this study is that movies that build upon a foundation of reasonably accurate science and then proceeds to more fictionalized science appears to be more likely to lead students to accept that the ideas presented in the movie as being scientifically reasonable. In other words, a film's attention to scientific detail appears necessary to root a plot or idea in reality but it appears that the plausibility of those ideas has significant potential to influence students' ideas about scientific concepts.

We were rather surprised at the influence that the film had on students' ideas regarding the Earth and other earth science concepts. The students had completed nearly 8 weeks of instruction on astronomy and Earth science before watching the film and yet during the interviews a majority of students referred back to scenes and dialogue in the 2-h movie. This implies that as science educators we need to pay more attention to how scientific ideas are being presented in today's science fiction films as such representations can have a significant impact on students' ideas.

To understand why watching a single film may have a significant impact on student ideas it is important to examine how educational theorists and researchers believe students come to understand a scientific concept. Vosniadou (1991) have suggested that as children develop and are exposed to scientific explanations of these phenomena they move from intuitive mental models based on their experience and showing no influence from adult scientific models to synthetic models that are a combination of intuitive and scientific views. Some children then develop scientific models after exposure to current scientific views either incidentally outside of school or through formal instruction, but retain the intuitive and synthetic models that the science education community characterizes as misconceptions well into adulthood. Vosniadou's theoretical perspective is particularly salient when considering how films represent scientific concepts and ideas. Namely, films introduce scientific ideas in an intuitive manner. The reason for this is so the audience can easily grasp the idea presented in the film. This is important to filmmakers because if the audience struggles to understand a point or an important aspect of the film it detracts from the movie experience which impacts the profitability of a film. Nonetheless, if science fiction films present scientific ideas that match or support students' intuitive ideas it is likely that students' existing ideas will be perceived as being quite plausible and more likely be adopted as a reasonable scientific explanation of a particular phenomenon. To understand why the film's idea may be adopted it is worthwhile to examine how conceptual change occurs.

The Conceptual Change Model is a widely accepted way to explain how learners adopt new understandings of phenomena. There are two major components to the Conceptual Change Model (CCM) model (see Vosniadou, 1991 for a more detailed discussion). The first of these components is the conditions that need to be met in order for a person to adopt a new understanding. According to CCM three conditions must be met before a learner will adopt a new understanding (i.e. conception); he or she has to (a) become dissatisfied with their existing conception, (b) find the new conception intelligible, and (c) find the new conception plausible, and fruitful. The second component of the CCM is described as the status of the new conception. A conception has status when it meets any of the aforementioned conditions, however, the more conditions that the new conception meets the higher the status the new conception obtains, and hence, a higher probability of being adopted. As we have seen, images of science and scientific phenomena in movies are designed to be both credible and plausible. Further, given that film and television images are visually appealing, easily understood, and appear to be supported by scientific authorities (e.g. NASA) through the use of science consultants they have a high potential to achieve high status in the minds of students. Thus when students are watching a film they may recognize an image of a phenomenon or dialogue about a concept that appears to agree with their intuitive mental model and as such they may decide that the image is plausible. Further given film's ability to create a convincing argument, the idea may be integrated into students existing views and become a significant part of their explanation for a particular scientific phenomenon. This effect may also be due to a similar phenomenon that has been observed regarding the impact of fiction and non-fiction text on particular beliefs. For example, Slater (1990) found that fiction labels may produce more impact on subsequent beliefs than do non-fiction labels when what is viewed is unfamiliar. Slater argued that unfamiliar text requires additional cognitive load which can inhibit critical analysis and in turn lead to skewed understandings. In his study with undergraduates, Slater found that text messages that were labeled as fiction had a greater impact on readers' beliefs than non-fiction text. Thus the blurred distinction between fiction and non-fiction in science fiction film could be due to the fact that students find fictional depictions, particularly as presented in film, more understandable that those presented in a non-fiction and a non-fictional form (i.e. textbook).

We acknowledge that this work has several limitations. First, as in all small-scale studies, the findings are not necessarily representative of the population at large. Further, in order to make more generalized claims regarding the impact of popular science fiction films on student ideas we need to interview students who have seen several science fiction films and compare those interviews to students who have not viewed science fiction films. However, this study does point out that a single film can have significant impact on students' ideas and that further research would shed light on exactly how much science fiction films can impact student ideas. Second, the post-interviews were conducted shortly after the students watched *The Core* and as such the film may have had a larger influence over student ideas than if the post interviews were conducted a few weeks later. Third, the students had already experienced considerable instruction on the topics in the movie and as such the information that the students learned during the units may have served as the foundation upon which the movie could build plausible arguments. Thus, in future research related to this area it may be wise to allow a subset of students to watch a film, interview them, and then observe whether the film impacts their discussion or ideas as they proceed through their instructional activities.

INSTRUCTIONAL IMPLICATIONS

As noted by Rose (2003) popular science fiction films are widely accessible and generally acknowledged to have some impact on public opinion of science. Attempts to evaluate this relationship have focused largely on how the public perceives science, rather than whether film can impact understanding of science concepts. Our findings suggests that popular science film can have a substantial impact on students' scientific ideas and as such it is important that teachers and science educators be aware of the ideas that are presented in popular movies as they may be a significant source of student misconceptions.

Science fiction films have the capacity to capture the attention and imagination of students and research has shown that the general public's interest in science often increases when exposed to science on television and on film. Therefore, rather than avoiding showing science fiction films in schools it may be a better strategy to engage students in the critique of a science fiction films. Such an approach may engage the students in reflecting not only on the science as presented in the movie but also on their own ideas and how their own ideas compare to those presented in the movie. To do this effectively, however, as science and teacher educators it is important that we provide teachers with the skills and experiences necessary for evaluating the science as presented in movies. Based upon this work we have instituted a new project within our introductory science courses for our pre-service teachers. Namely, we ask our students to choose from a list of movies and evaluate the scientific accuracy and plausibility of the science as presented in the particular movie. We feel that such experiences may enable future teachers to support their students in critically evaluating both good and bad science when exposed to it in the popular media and help their students to do the same.

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