Reaching Nonscience Students Through Science Fiction

Donald A. Smith, Guilford College, Greensboro, NC

In 2006 I had the chance to design a physics course for students not majoring in scientific fields. I chose to shape the course around science fiction, not as a source for quantitative problems but as a means for conveying important physics concepts. I hoped that, by encountering these concepts in narratives, students with little or no science or math training might become more comfortable with them. I also thought the stories might provide the ideas with a context that would enable students to remember them more clearly than if they were reading a physics textbook.

I am hardly the first person to use science fiction to teach science. Isaac Asimov suggested in 1968 that sci-fi stories might be useful for conveying scientific ideas in the classroom.[1] Many other authors have enthusiastically expanded on this suggestion. For example, Tom Southworth describes how he incorporated sci-fi stories to teach modern physics to high school students,[2] and Marta Dark uses sci-fi movies to teach introductory physics at Spelman College.[3]

The topic provides a tool for public outreach as well, as evidenced by many books and websites. Perhaps the most well-known is Lawrence Krauss' *The Physics of Star Trek*,[4] which started a whole series of *The Physics of* … books. Phil Plait's *Bad Astronomy*[5] is mostly concerned with astronomy and physics mistakes in nonfictional media, but he uses a chapter to chide science fiction movies. Most recently, two books published in the fall of 2007 use Hollywood for pedagogy: Tom Rogers' *Insultingly Stupid Movie Physics*[6] and Adam Wiener's *Don't Try This at Home: The Physics of Hollywood Movies.*[7]

The approach of many of these works is to use a science fiction movie or story as a word problem and show how one can calculate what really should have happened. For example, Dark analyzes the film "Armageddon"'s depiction of a narrowly averted asteroid impact on the Earth in terms of conservation of momentum and kinematics.[3] My approach was closer to that described by Dubeck et al.: to use the stories as a way of connecting with and inspiring students who have avoided classes in science.[8] My students were majoring in subjects like theater studies, religious studies, history, and music, and the last thing they wanted to do was calculate anything.

To construct the course, I first generated a list of physics concepts of which I wished all nonscientists had a basic understanding. The final list included, among others: the character of physical law, space, time, gravity, and the subatomic world (a combination of quantum mechanics and the standard model of particle physics). I then found short stories, novels, television shows, and movies that I hoped would convey these ideas in memorable ways, either by presenting them well or by getting them spectacularly wrong. I found it challenging to find stories that made the understanding of a physical concept the core of the narrative rather than using the physics idea as the backdrop for a character drama.

Law

To begin the course we read Tom Godwin's "The Cold Equations,"[9] in which an innocent stowaway

DOI: 10.1119/1.3116843

must be jettisoned into space because there is not enough fuel to land with her extra mass on board. This proved a great story for drawing students into the course because nearly everyone found the dilemma compelling, despite (or perhaps because of) the contrived situation. This story framed a wonderful discussion of the differences between physical law and societal law, and it allowed us to examine how scientific laws are constructed. On the final exam, the majority of students correctly described scientific law as descriptive and societal law as proscriptive.

Space

Edwin Abbott's *Flatland*[10] was an eye-opening experience for many students who had never given much thought to what space *is* or how to define a dimension. The lives of Abbott's two-dimensional beings and the way their experience is extrapolated down to one or zero dimensions, as well as up to three, gave the students a way to think about what a fourth (spatial) dimension might be.

This led us to talk about curved spaces, and the *Flatland* paradigm of arguing up from lower dimensions allowed me to follow a similar path in moving from circles to spheres to higher-order curved spaces. Although math phobia was a serious obstacle for these students, they knew the Pythagorean theorem. I had them measure the sides of triangles on spheres and on stretched fabric so they could see for themselves that the theorem does not hold in curved spaces. I then introduced the idea of a metric and worked my way into general relativity.

To complement *Flatland*, we read Nelson Bond's, "The Monster from Nowhere."[11] *Flatland* presents A. Square's contact with a sphere as a mystical experience: the extrapolation to higher dimensions leads ultimately to God. In Bond's tale, the higher-dimensional beings are dangerous and perhaps even hostile. This story aroused strong feelings in the students and led to a lively discussion of whether scientific exploration is always justified or whether some questions are better left unasked.

Time

The first few pages of H.G. Wells' *The Time Machine* provide a wonderful description of Aristotelian time.[12] Most students found this concept familiar, especially after our work with *Flatland*. Some, however, were dissatisfied, pointing out that just because you can plot height versus time does not make time a dimension like height. You can, after all, plot pressure versus time and nobody calls pressure the fourth dimension. This discussion served us well when we explored the implications of special relativity; the students already saw that time is a different kind of dimension than space.

Wells' description of the future also enabled me to introduce the ideas of extrapolation and prediction, and we compared his vision of the end of the world with the predictions of current models of stellar evolution. We deepened our study of predicting future behavior with Alfred Bester's "The Push of a Finger"[13] and Ray Bradbury's "A Sound of Thunder."[14] Both stories examine small changes that lead to drastically different scenarios. However, Bester envisions a kind of Gaussian curve of probable futures. He starts from the premise that if you could feed a computer ("The Prognosticator") enough information about the present, you could predict what would follow arbitrarily far into the future. Bradbury, on the other hand, anticipates Lorentz's s*ensitive dependence on initial conditions.*[15] Bradbury's time traveler steps on a butterfly in the Cretaceous and returns to a much different 20th-century world. The butterfly effect has become a cliché, but few students had read the original story or understood what the butterfly actually represents in terms of approximation and modeling. Most thought that the butterfly *causes* the hurricane! These stories allowed me to correct that common misconception and get them thinking about the limitations of prediction in complex systems.

We explored paradoxes involving time travel and how they derive from the ways authors imagine time. For example, in Philip K. Dick's short story "Paycheck,"[16] items from the future allow the main character to survive crises in the present. The events in the story form a closed loop: although the main character seems to take action and make choices, the author does not imply that events could have occurred differently. In contrast, the film adaptation (also called "Paycheck")[17] explicitly states that the characters' choices avoid an "alternate future" in which the world is destroyed. Same basic plotline, very different visions of how time works.

George Gamow's stories of Mr. Tomkins[18] whimsically embody the bizarre implications of special relativity. They enabled us to undermine Wells' definition of time and develop a more sophisticated understanding of the dependence of time on the observer's frame of reference. Unfortunately, Gamow also made the most explicit use of mathematics, and the students' fear prevented them from engaging with the ideas as much as I hoped they would.

We closed our examination of time by reading Alan Lightman's *Einstein's Dreams*,[19] which presents a series of different visions of time: some are exaggerations of the implications of relativity, some are imaginative (e.g., time as a sense), and others are psychological (e.g., time as perception). This book enabled us to discuss what we think of time from both a scientific and a personal perspective. It evoked wonder in the students; many said it made them think about time in new ways.

Gravity

With an image of curved space in mind, we used Jules Verne's *From the Earth to the Moon*[20] to look at orbital mechanics and consider what it would take to launch a projectile into orbit. We compared Verne's 19th-century vision of how to get to the Moon with the Apollo program, 100 years later, to show the difference rocketry made. We looked at the Moon project from a physics point of view as well as a political/social enterprise and found Verne astoundingly prescient. For instance, it was striking to see the similarities between Barbican's speech that launched Verne's Moon project and John F. Kennedy's speech at Rice University that announced the Apollo program.

We then used Larry Niven's "Neutron Star"[21] to explore the concept of tides. In this story, a pilot must survive a hyperbolic fly-by of a neutron star, which had mysteriously destroyed previous pilots. The plot hinges on the idea that a species from a moonless planet would not have predicted the existence of tidal forces. The students felt a species with enough understanding of physics to develop interstellar travel would have realized what a strong gravitational field would do. Isaac Asimov's "Nightfall"[22] provided a way to look at the many-body problem and the complexity of orbits. Both Niven and Asimov gave us the chance to reflect on the impact of environmental conditions on the development of science and our own understanding of the universe.

The Subatomic World

Mr. Tompkins' dreams provide vivid examples of how bizarre particle properties like tunneling and interference would seem if macroscopic objects like cars and tigers exhibited them.[18] Students found these ideas fascinating, but in the final exam, very few retained the idea of probabilistic interference. The question on tunneling also was missed more often than not.

Isaac Asimov's *The Gods Themselves*[23] was not much more helpful. Here, switching atoms with another universe in which the strong force is stronger solves an energy crisis: stable atoms there decay here and release energy once the atoms come to equilibrium with our universe. Students resonated with this story as an environmentalist metaphor but had a harder time connecting to the ideas for which I chose the story: entropy, equilibrium, radioactive decay, and the standard model of particles and forces.

The *X-Files* episode "Soft Light"[24] was more fun. It also showed the students they had indeed progressed in their understanding. As we watched, I asked them to call out when they heard a mistake in the script, and we stopped to discuss each error. It took almost 90 minutes to complete the 45-minute show. Groans filled the room when they heard dialogue like

> ***DAVEY:*** [He was] researching dark matter, quantum particles, neutrinos, gluons, mesons, quarks ...
>
> ***SCULLY:*** (with sage-like understanding) Subatomic particles.
>
> ***DAVEY:*** The mysteries of the universe. Theoretically, the very building blocks of reality.
>
> ***SCULLY:*** Except no one knows if they truly exist.

One student blurted out, "Quarks aren't dark matter!" They were startled to realize that just two weeks before the lines would have sounded like plausible gobbledygook.

Conclusions

The course was successful at raising enthusiasm in students who thought they had little interest in physics. Despite the fact that students were highly resistant to exploring *any* mathematics (the negative comments in the course evaluations all expressed the same concern: "too much math"), there were many comments in the evaluations like "It made physics fun" or "It made me see physics in a whole new light." Because of this course, 18 students will go off into other fields with tales of how exciting, fun, and thought-provoking physics is. One student even decided to switch majors from music to physics. What more could I have wanted?

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PACS codes: 01.40.Di, 01.75.+m

Don Smith *is in his fourth year as an assistant professor. He received his PhD in physics from MIT in 1999, and then he worked as a lecturer and an NSF Fellow at the University of Michigan. He teaches physics, astronomy, and liberal arts courses such as "Science Through Science Fiction" and "Magic, Science, and Religion."*

Guilford College, Guilford College, 5800 W. Friendly Ave., Greensboro, NC 27410; dsmith4@guilford.edu, http://www.guilford.edu/physics/dasmith