Deliberating Over Science Curricula: A 'Mundane' Solution

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A problem?

Physics, and science in general, has been relatively successful at educating its undergraduates in very particular ways. As a result of taking a one-year general physics course, a student should be able to solve problems relating to how things fall, how the temperature and pressure of a gas are related, and how electric current produces magnetic forces. In some cases, students might also be able to show how such problems can be applied to the "real life" applications of a laboratory. These students learn such skills because these are presumed to be a forerunner to other skills that allow them to be successful scientists, engineers, doctors, and the like.

Let me say at the outset that the traditional physics curriculum is not bad. It is this tradition that has produced most all of our scientists, and as a result, all of our scientific discoveries and the windfalls from such. Yet, not all who take physics become scientists, not to mention physicists. What are the rest of these students getting from a physics course? Many students take a physics course only to fulfill some college requirement, assuming that they will not use physics (at least as it exists in the given classroom) in their everyday lives. Even those students who take an "introductory" physics course that is aimed at conceptual understandings of physics rather than the problem solving of physics might wonder what the purpose of this curriculum really is. And so, I propose that herein there exists a problem: We typically teach physics and other science courses aimed at a general populous in ways very similar to those that are used to teach our budding scientists. Yet, not everyone (thankfully) wants to *be* a scientist. So, why are we teaching science to everyone else? And, what should they be getting out of a general science education?

The purpose of this piece is to disseminate my own characterization of this problem, and my own solution to it. First, we must consider *why* we should be teaching physics (or any science) in the first place, especially to non-science majors. We might consider the idea of creating a "scientifically literate" society. This is the goal of many science educators and the standards set for science education. According to the American Association for the Advancement of Science (AAAS),

> *Science education . . . should help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital.*[1]

This is a tall order – even for us physicists! If we concede that students in a general education setting are not coming to understand physics in the same way that physicists understand it, then we should have alternate goals. Yet, these alternatives should carefully thought out. How is it that we can teach physics in such a way that our students "participate thoughtfully" in "a society that is open, decent, and vital"? Arguably, memorizing Newton's three laws of motion or being able to demonstrate the conservation of energy of a falling rock does not directly translate to such goals.

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[1] American Association for the Advancement of Science (AAAS) (1990). *Science For All Americans: Project 2061*. New York: Oxford University Press. p. xiii.

The current scene

As I interpret it, general education physics courses typically fit into one of three different categories, though undoubtedly there exist many other less common curricular innovations. Perhaps the most prominent of these is a curriculum I call "conceptual physics." Such courses are taught with the idea that physics concepts are themselves at the heart of what a student should be motivated by and that which should be learned. Many texts focus on this; the classic *Conceptual Physics*[2] by Paul Hewitt is a well used and well written example. The idea is that in order to become an active member of a greater society, there are certain concepts that one must be familiar with. Energy conservation, forces, nuclear reactions, etc., are all topics that apply to discussions made on local, national, and worldwide levels, thus justifying the curriculum. Another curriculum, which I call "applied physics," tries to focus on similar concepts, but with a slightly different angle. Instead of motivating the content from the concepts (e.g., forces) themselves, the curriculum revolves around applications of these concepts (e.g., how a crane stays upright). Again, the concepts at hand are culturally relevant, and such relevance can immediately be brought to light by such a curriculum. Many texts[3] and course proposals[4] motivate topics in this way, though in many cases one sees that they directly parallel the conceptual physics curriculum.

In honors programs and in some smaller colleges with which I am familiar, a general education physics course takes on a different flavor. These courses are often taught to show physics in a grander scheme, be it historical, social, or personal. Here at Weber State, a colleague, Dr. Brad Carroll, teaches a course called *Physics and the Plays of Tom Stoppard*[5]. Robert March writes a text called *Physics for Poets*[6]. While each of these and many others are very specialized and unique, they generally all try to show connections between literature/theater and science, such as in Dr. Carroll's course, or perhaps between history and science, such as in March's classic text. While physics concepts are still focused on in such courses, they are seen in a greater context: Where did these laws/theories come from, and what do they mean to me and my everyday life?

All of these curricula could be shown to help one become scientifically literate in one aspect or another, assuming that a course is taught well and a student is attentive. But, we seem to have gotten ourselves stuck in a rut, for it is difficult to think of exceptions to these molds. In considering this, I started to sense a great void in the current selection of curriculum alternatives.

As we teach science in most courses, we do a good job of teaching what science currently "knows," but we do little to demonstrate what science is really all about. Science is not a book of knowledge sitting on someone's shelf. Science is a way of knowing – a way of understanding and interpreting the world – but by no means is it the only way. Science is exciting and powerful in that it can wonder, ask questions, and then work to answer such questions. Even when certain answers are ascertained, we find in the history of science

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[2]Hewitt, P. G. (1998). *Conceptual Physics*. (8th ed.). Reading, MA: Addison-Wesley.

[3]Bloomfield, L. A. (1997). *How Things Work: The Physics of Everyday Life*. New York: John Wiley & Sons.

[4]Bloomfield, L. A. (1997). How things work: A physics course for non-scientists. *The Physics Teacher, 35*(7), 439-442.

[5]For this course's description visit its web site, http://physics.weber.edu/carroll/honors/

[6]March, R. H. (1996). *Physics For Poets*. (4th ed.). New York: McGraw-Hill.

that they often turn out to be wrong; the Sun used to go around the Earth, according to the authoritative and popular view of centuries past. Yet, the scientific process gives us a means, both as individuals and as a society, to evaluate all that we think we know in light of new evidence and creative thinking. Rather than being a static set of known rules, facts, and mechanisms, science is a pursuit for understanding these things in a very particular and useful way.

Unfortunately, when an instructor is presenting problems, definitions, equations, and the like on the chalk board, she is not presenting this view of science. Instead, she is only portraying the most current "facts" of science, perhaps hoping that science's other aspects will be implicitly revealed. The explicit emphasis remains, however, on the solving of problems and the presentation of science as a static set of knowns. And, while these are likely very useful and applicable, they do not represent the totality of science. How then, are we helping the majority of our students to become scientifically literate?

The premise of mundane physics

In response to this question, I developed a course called *Physics of the Mundane*[7]. The intent of this course is to give non-science students an opportunity to actually do science in an everyday setting. Thus, the "mundane" part of the title is not meant to imply that the course is inherently boring, but that it focuses on situations and materials that we often take for granted. Science, after all, does not, and should not, limit itself to the study of black holes or objects which travel close to the speed of light.

Physics of the Mundane has three basics aims. The first of these is to give students an exposure to science that actually shows them how it works. As members of some greater, democratic society, it is important that we understand how science functions, what it can do, and what its limitations are. Second, students should come to understand how a scientific way of knowing can inform and be used in their everyday lives. Third, I wished to re-expose students to a sense of wonder about their surroundings. Perhaps Carl Sagan said it best:

> *Except for children (who don't know enough not to ask the important questions), few of us spend much time wondering why Nature is the way it is; where the Cosmos came from, or whether it was always here; if time will one day flow backward, and effects precede causes; or whether there are ultimate limits to what humans can know.*[8]

We probably too often assume that there are not any important or interesting questions to pose on the mundane level. This course tries to counter that misconception. At the same time that all of this is (hopefully) going on, students are learning some physics. Yet, this kind of course could be taught with any of the sciences. It is important to note that the science content is less emphasized than the process of science in general.

To achieve these aims, the course is set up around a full semester of investigations. (See appendix A.) Instead of me presenting these topics in the typical lecture format, students break into small research groups

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[7]For a look at the syllabus and an outline of the course, the reader is invited to visit the web site, http://physics.weber.edu/johnston/mundane.htm

[8]Sagan, C. (1996). *The Demon-Haunted World: Science as a Candle in the Dark*. New York: Ballantine Books. p. 321.

to address the problems and concepts for the day. Armed with notebooks and instruments fit for their investigations (tape measures, beakers, stopwatches, etc.), these non-science students act as scientists, poking at the natural world in ways that will gradually reveal relevant information about how it operates. These class sessions differ from typical laboratories in that there is generally no prescribed set of steps or known answer which they are required to derive. Instead, just as in a real science context, what the students face is mysterious and nebulous, and they must not only attempt to find an "answer," but must also figure out how to try to converge on such an answer. The point is to make the students realize that they can be, and in fact are, scientists in an everyday situation.

One of the strangest days of the course is our first class session. After a general introduction to the course and each other, I give each student a bottle of soap solution for blowing soap bubbles. With a partner and a variety of bubble blowing instruments, the students are simply told to record everything they observe about the bubbles in their notebooks. Due to the combination of this being the first day of class and the fact that these students are accustomed to sitting comfortably in chairs as a lecture or discussion takes place, the members of the class look genuinely confused with such a mundane task. For the first fifteen minutes or so, students look at each other and their bubbles and wonder if this is really what they are supposed to be doing. After some time, however, students begin to realize that the bubbles have much more to them than just soap. There exist symmetries, colors, fluid flows, pattern formations, and optical effects, all of which commonly go unnoticed. The students are asked to pose questions regarding their observations, and propose ways in which such questions could be pursued. This question asking is an important, but often overlooked, part of the scientific endeavor.

Gradually, students get used to the course format and continue to pursue and peruse the natural world through scientific investigations. While we cover many typical physics concepts, there is a special emphasis given (especially in the first two weeks) to how we collect evidence, test hypotheses in light of such evidence, and how we can begin to make sense of it all. We conduct ourselves as scientifically as possible as we drop objects from the roof of a six story building, roll bowling balls down hallways, make eye-droppers rise and fall in bottles of water according to our commands, make scraps of holiday bulbs glow, utilize gelatin as a means of bending light, and eventually return to the study of soap bubbles more closely. Using the bubbles at the end of the course brings to light just what these students learn during this class. While they are observing the same soap bubbles, they still tend to discover new observations and questions that never occurred to them fifteen weeks previous. Their comfort level with the process of science and the wonder of nature is significantly more pronounced.

In addition to these daily activities, there are three other important aspects to the course. First, I occasionally set aside half of a class period to further explain physics concepts and the history and process of science. While this was not part of my original idealized view of this curriculum, it became apparent that students like, and sometimes need, some background in physics, since it is generally altogether unfamiliar. I fill these discussions with demonstrations of experiments and recountings of how Galileo or some other predecessor might have gone about his scientific investigations. In my own experience, and in considering the experiences of others, it seems that our students appreciate and benefit from an occasional change of pace. These sessions give the students a break from their experiments and help to guide their own thinking, making them more comfortable in their own investigations. My only reservation in this is that I could be leading them too much, not allowing them to discover something for themselves. However, I must also realize that every good scientist is armed with a background of scientific knowledge that helps to organize one's thinking.

Another aspect of the curriculum is in discussions. Every four class sessions, students are given a detailed schedule of events to come (see appendix B), including problems they are to work on as they pursue their investigations, and assigned readings. The readings for the course deal not only with physics content, but more primarily with the assumptions and practices of science. These readings are the focus of students' written responses and our subsequent in-class discussions. Thus, we not only do science, but we also have the opportunity to reflect on what we are doing in contrast to what other scientists do. We consider the basic philosophical assumptions of science, and deliberate on the purpose of science. Such considerations are spawned by the writings of the likes of Popper, Kuhn, Sagan, Hawking, Feynman, and many others.

Finally, in addition to pursuing the investigations that I assign, students are required to propose and pursue a research project of their own. These projects contributed to 20% of each student's final grade, and are presented to the rest of the class during the final exam week. It is perhaps in these projects that I get to see how scientifically sophisticated these students can become. Students study and characterize the motion of persons on amusement park swings, the ability of a pickle to glow, the accelerations of a car, the causes and effects in different gymnastics tumbles, etc. The list goes on and on. What is remarkable is that the vast majority of these students have no aspirations to be scientists, nor do they take many other science courses. Yet, they have the ability to design and conduct their own research projects which are of personal interest and of high quality.

Conclusion

Physics of the Mundane is an enjoyable and fulfilling course for me to teach. In developing and instructing it, I am constantly reminded of the power (and limitations) of science, as well as the fascinating wonders of nature that tend to go unnoticed in our everyday lives. While I am fairly sure that the biggest beneficiary of this course is myself, students have responded very positively to the course; and, I am impressed with what they seem to come away from it as reflected in their assignments, discussions, and projects.

However, I cannot get away with writing this synopsis without stating that there are (and aren't there always?) drawbacks to this course format and focus. The most notable of these is the fact that there is no possibility for a class of this nature to be taught to a large number of students. In my case, I have no more than twenty students in a class, and even these numbers can, at times, seem too large. In other classes in which I teach to enrollments of 100 students, I must teach in a much different, less student-active, way. My own personal feeling is that we should be trying to teach to smaller audiences anyway, despite the current trends to make classrooms extend electronically. I believe that there is great value in creating the personal interactions that a small class can provide, though admittedly such small class populations can be hard to come by and justify. I am fortunate that my department has granted me the freedom to develop and teach such a course. (I suspect that other instructors might not be as fortunate.)

I should also note that this is an incredibly work intensive course for an instructor. I put a great deal of preparation into student experiments, making early morning trips to the store for dry ice, communicating advance arrangements with the campus bowling alley, and putting together supplies for model rockets. So, even though such preparation is relatively enjoyable (especially in comparison to grading), it is time consuming.

In closing, I should say that I do not think that this class, *Physics of the Mundane*, is *the* way to teach science. Rather, I think that this is one potentially fruitful alternative. As I mentioned before, we have historically done a good job of educating students who will eventually choose science careers. However, this kind of education is not necessarily the type which benefits all of our students, especially those with no intention of becoming scientists. I offer my mundane alternative as simply an alternative – there certainly should exist many others. In any case, however, we should be quite deliberate in considering exactly why we are teaching the way we are, taking into account the students in our courses and their needs, as well as the needs of society in general. I can only hope that my course demonstrates such a deliberateness.

Appendix A: Course schedule

	Tuesday	Thursday
Week I:	**“Why are you here?” Fun with bubbles.**	**Madness of stirring hot chocolate. The swinging pendulum.**
Week II:	**The runaway bowling ball: Analysis of motion**	**Debriefing and discussion.** ***The purpose of science.***
Week III:	**Motion, the easy way.**	**Dropping stuff (in the spirit of Galileo and Letterman).**
Week IV:	**(The ups and downs of) Elevator physics.**	**Debriefing and discussion.** ***The methods of science.***
Week V:	**A brief history of forces and intro to Newton’s laboratory.**	**Rocketry.**
Week VI:	**Environmental physics.**	**Debriefing and discussion.** ***The nature of laws and theory.***
Week VII:	**Conservation of energy. Bouncy (and no so bouncy) balls.**	**Mad bicyclists.**
Week VIII:	**The physics of bowling.**	**Debriefing and discussion.** ***Contexts for unraveling and discovering.***
Week IX:	**Hot, cold and all the in-betweens.**	**A candle in the water.**
Week X:	**The magic and mystery of *Orbitz™*.**	**Debriefing and discussion.** ***Normal science vs. revolutionary science.***
Week XI:	**The Cartesian diver.**	**Getting a charge out of physics: Intro to electricity.**
Week XII:	**Charge in motion, magnetism, and the dance of induction.**	**Debriefing and discussion.** ***Science vs. other ways-of-knowing.***
Week XIII:	**The music of physics.**	***NO CLASS*** **(Thanksgiving Holiday)**
Week XIV:	**Light and optics: Fun with gelatin and lasers.**	**Debriefing and discussion.** ***Science education: Why and how?***
Week XV:	**Return of the bubbles . . .**	**Final debriefing. Begin presentation of research projects.**

Appendix B: A week in the life of a mundane physicist.

Assigned Readings:

Hatton & Plouffe[9]: pp 60-62 (Wynn), 63-67 (Hawking).
March[10]: Ch. 3-4 (pp 30-50).
Feynman (handout): "The Law of Gravitation: an example of Physical Law." (pp. 11-34)[11]

Schedule:

Tuesday (9/29): *The forces that be: Newton's Laboratory.*
Thursday (10/1): *Rocketry (Weather permitting — meet in stadium)*
Tuesday (9/22): *Environmental physics (Weather permitting — meet in LL221 and proceed outdoors. Wear appropriate clothing!)*
Thursday (9/24): Discuss *Laws and Theories of Science and what they mean*. (Response paper due. Problem and notebooks due next Tuesday.)

! **Suggested reading response questions** (although you are free to address another issue(s)):

The readings for the week discuss things called "laws" and "theories." What is the difference (or relationship) between a law and a theory? (Possibly consider that Newton is heralded for a *law* and Einstein for a *theory*, both of which describe gravity.) Which is more important to science? Which is more useful?

Hawking talks about being a "realist" and a "positivist." What do you think this means? Could one be a scientist and be something other than a realist or a positivist? Would Feynman fit into the same category? How do you know?

! **Lab problem(s):**

1. Based on your acceleration of gravity measurement from the freefall motion lab, and your acceleration measurement for a thrusting model rocket, determine the force (measured in some multiple of your own weight – e.g.: twice your "real" weight, etc.) you would experience if you had been a tiny passenger on the bright orange rocket.

2. Based on our outdoor experience and an analysis of torque, estimate the amount of force required to keep a branch attached to a tree. Use a decent sized branch (no twigs) for your calculation. (Show your measurements, calculations and assumptions.) When in doubt, Fermi it out! (

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[9] Hatton, J., & Plouffe, P. B. (Eds.). (1997). *Science and Its Ways of Knowing*. Upper Saddle River, NJ: Prentice-Hall, Inc.

[10] March, R. H. (1996). *Physics For Poets*. (4th ed.). New York: McGraw-Hill.

[11] From: Feynman, R. (1965). *The Character of Physical Law*. The M.I.T. Press: Cambridge, Massachusetts. This book is composed of the transcripts from seven invited lectures that Feynman gave at Cornell University in 1964.