INTEGRATING POPULAR SCIENCE BOOKS INTO COLLEGE SCIENCE TEACHING

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The use of popular science (PS) books is a long neglected tool in teaching. The characteristics of PS books are pointed out. A painless way to incorporate PS books in our regular physics teaching has been tried in the last five years. The method is to offer extra credit to the students for writing a book report based on PS books. The experience is reported here, which is also applicable to other science courses as taught in colleges or high schools. The idea is to help the students to broaden their scientific knowledge base as demanded by the real world out there, to foster a lifelong habit of buying and reading PS books, and become a science-informed citizen.

1 INTRODUCTION

On the average, every year there are about 5.5 graduating physics majors per physics department in the United States.[1] In reality, in the introductory calculus physics courses I have taught, there were usually zero (and occasionally one or two) physics majors in a class of 40 to 50 students. In the upper-division "Thermodynamics and Statistical Physics," a required course for physics majors I taught recently, there were only *two* students out of 14, who aspired to go on to a graduate program in physics. Obviously, the composition of students in our physics courses has changed. New thinking is required!

Current educational reform in physics courses concentrates on how to improve the teaching and learning of the physics topics, or on changing the curriculum itself.[2] Yet, there are just that much one can do if the incoming students are ill prepared (or wrongly taught for 12 years in science and mathematics) before they come to college and show up in our classes. Consequently, partly out of frustration but mostly driven by the basic training of a good physicist—which is to be innovative and make the best out of whatever a bad situation—in the last few years, I started to look at these courses from a fresh angle. While it remains true and noble that we should try our best to help our students to learn a subject, these physics courses actually offer the teacher a unique chance to help the students in another important aspect, that is, *to broaden their scientific knowledge base* (see Sec. 2). And the method I adopted was to integrate popular science books into our teaching.[3,4] In the following, the method of doing this and the experience gained will be discussed.

2 POPULAR SCIENCE BOOKS: A NEGLECTED EDUCATIONAL TOOL

In the last decade, within many countries—the USA in particular—there was much discussion and a consensus that the education of students has to be broadened. This is prompted by the rapid development of science and technology, and the emergence of the new economy. To satisfy the needs of the business world and the big corporations, the knowledge base of the workers should be as broad as possible. However, in all universities, the source of most new employees, there is hardly any program or mechanism that would train students to meet this demand. In a university, the disciplines are still being divided into smaller and smaller domains, under the jurisdiction of a large number of departments. For example, there is hardly

any course that would cover three different subjects. This situation in the universities cannot be changed overnight, and may in fact remain for a long time to come.

At the same time, a new science called complex systems emerged.[5-8] Complex systems cover every branch of science, from the natural sciences to humanities to the social sciences, and is considered essential to be mastered by any world power.[9] Due to its broad coverage, a course on complex systems requires the students to possess a broad knowledge base in a short time. When I first taught such a course in my university, more than ten years ago,[5] I realized that there was none and may never exist a suitable textbook for such a multidisciplinary course.

Yet, to address these two problems, there is in fact a neglected educational tool out there, which could be used to help the students to broaden their knowledge base—painlessly. This educational tool is the use of popular science books. We note that

1. Popular science (PS) books are available in every bookstore in every town, unlike the technical science books which are available in special bookstores in a university town.
2. Many of the PS books are written by the inventors/pioneers themselves (including Nobel laureates) or very gifted science writers, who may be journalists or simply other scientists.
3. These books are affordable to almost everybody (about 15 US dollars for a paperback).
4. These books are the places to learn how research and discovery were actually done in very recent times.
5. Quite often some PS books offer a unifying theme or outlook linking a large number of disciplines or topics, which may not be transparent to someone who works only in one of these topics.
6. These books, at least in the USA and for the majority of them, contain no equations and are easy and very entertaining to read.

3 HOW TO INTEGRATE POPULAR SCIENCE BOOKS INTO REGULAR TEACHING

In the last five years, I integrated PS books into my teaching.[3,4] Two different versions were tried:

First version

In both the lower- and upper-division courses, extra credit is offered for a simple book report based on a PS book. From the beginning, a large majority of students took these options. After a refined explanation of the advantages from the instructor, almost all the students took it, with very positive results. Here are the details.

It is announced at the beginning of the (14-week long) semester that, to do the book report, the student

1. Should make the decision of doing the book report about two weeks into the semester and inform the instructor in writing. (I let the student fill in a form and sign it.)
2. Then, go to a nearby bookstore herself/himself (e.g., Borders, Barnes & Nobles, etc.), several times if necessary.
3. Browse the "Science" section (*not* the "Science Fiction" section).
4. Select and buy a PS book. (The topic needs *not* be related to the content of the course).
5. Show the book and receipt to the instructor in about four weeks into the semester. (The book has to be approved by the instructor; the instructor will sign the receipt; each student should buy her/his own book; a paperback book costs about $15).
6. Submit a hard copy of the book report (4-10 pages long, font size 12) about two weeks before the end of the semester.
7. Has the option of *not* doing the book report at the last moment.

Here are the rationales behind these steps. Step 1 is to force the student to make the decision early and allow the student about two months to read the book. Step 2 is to pass the message to the students that there is always a bookstore nearby that has a large number of PS books. Step 3 is to force the student to flip through many books so they know what a large variety of books are out there. By forcing the students to actually buy a book with their hard-earned money in Step 4, hopefully, they will want to sample a large number of books before they settle down on the ones that really interest them. It is important not to confine the topics to the class material you are teaching, because the aim of this scheme is to enlarge the knowledge base of the students.

In Step 5, the instructor can choose to refuse a book bought in by the student, and give the student a weekend to go back to the bookstore to replace the book or buy a new one. The instructor should give the reasons to the student and advise on a new book which, usually but not always, is related to the theme of the rejected book. In most of the cases, I rejected a book simply because the book is too thin and too brief (there are book series for these books) for the student to learn anything. Then I would tell the student if a thick book is picked, the student does not have to read through the whole book, but only the major chapters. (Students are smart; they rarely pick a thick book anyway.) On some occasions, very often when a student picked a book on science and religion, and if I personally did not agree with the approach expounded in the book, I would inform the student that there are other books out there that take the opposite view and reach the opposite conclusion. I would advise the student to buy and read at least one of the latter in the future, after the student read the one she/he bought. I did not force the student to replace the one she/he bought because books of different views are always out there in the bookstores, and it is not practical to keep students away from those books we personally find unfavorable. Of course, in the extreme case that the instructor finds a book to be deplorable or repulsive—either it is pseudoscience or antiscience or something else—the instructor can always reject the book. I never encountered a case like this, though.

Signing the receipt in Step 5 is crucial, to ensure that the student will not simply borrow a book from their friends or the library, and thus defeat the purpose of showing them the new books in the bookstores. For the same reason, I discourage students from buying books

online. In fact, browsing through a real book will let the student pick up some knowledge from that topic even though that book may not be bought eventually

About three weeks before the deadline of the book report in Step 6, a page of instruction on how to write the report is given to the students. I require a title, a short abstract, headings of sections, personal opinions about the issues, and references. The book reports are *not* returned to the students; and so they can be graded very fast (see Sec. 5). And it is fun and important to read the personal opinions—to spot them easily, you should require the students to highlight them.

Step 7 should be put there. Such an option encourages the students to take up the book report offer, knowing that they can change their mind later, and especially after you point out to them that the opposite is not true. That is, they cannot decide to do the book report after the third week into the semester; this is to make sure that they have two months to read the book.

A few students chose not to do the book report. Some said they were not good at writing, or there were already too many papers to write from other courses they took. After explaining to them that the required report is short, they changed their mind.

Second version

In the upper-division course "Thermodynamics and Statistical Physics" I taught, I gave extra credit for a report based on a PS book. In this case, I made up a list of PS books that were related to the course topic, and asked each student to pick a different book. Steps 1 and 4-7 above were followed.

In all these versions, the instructor does not "teach" the PS books. First, it is impossible to do this because the instructor cannot know all the topics out there. Second, the PS books are written for self-reading in the first place. Some students may come in to discuss the materials, and the instructor can chat with them and refer them to other books or published materials. It is a lot of fun, for both the students and the instructor. And the instructor, by reading all the final reports, actually has his knowledge widened in no time.

At the end of the semester, I gave a survey. The students reported very positive experience in going through this. A large majority admitted that the reading of a PS book increased their interest in science in general. A student wrote, "I think it is a good idea to write a term paper. To force us to read a science book makes me gained more knowledge on science and also increases my interest, because I will never buy a science book if I don't have to." As the instructor is concerned, the idea is to help the students to foster a lifelong habit of buying and reading popular science books. Success is not guaranteed. But since the reward is high and it involves minimal effort on our part, that is the least we can do as educators.

4 SAMPLE OF POPULAR SCIENCE BOOKS SELECTED

For illustration, the list of PS books selected by a particular freshman class is presented in Table 1. Those selected by the instructor for the upper-division class of "Thermodynamics and Statistical Physics" in a particular semester is given in Table 2. (Note that a useful checklist of popular books about physics and related sciences, intended to help physics teachers to provide advice and guidance to students and the public, is recently published.[10])

Table 1. Popular science books chosen by a freshmen physics class in Spring 2000.

Title	Author	Year
The Art of Happiness	Dalai Lama/Cutler	1998
The Big Bang Never Happened	Lerner	1992
Beyond Einstein	Kaku/Thompson	1995
Black Holes, Worm Holes, & Time Machines	Al-Khalili	1999
A Brief History of Time	Hawking	1998
Calendar	Duncan	1998
Clones & Clones	Nussbaum/Sunstein	1998
Comets	Levy	1998
Computer	Campbell-Kelly/Aspray	1996
The Diamond Makers	Hazen	1999
Darwin On Trial	Johnson	1993
Faster Than Light	Herbert	1988
Fuzzy Logic	McNeill/Freiberger	1994
Fuzzy Thinking	Kosko	1993
Genesis & the Big Bang	Schroeder	1990
The Hidden Heart of the Cosmos	Swimme	1996
Immortality	Bova	1998
The Little Book of the Big Bang	Hogan	1998
The Meaning of It All	Feynman	1998
The Mind of God	Davies	1992
Night Comes to the Cretaceous	Powell	1998
101 Things You Don't Know About Science and No One Else Does Either	Trefil	1996
The Physics of Star Trek	Krauss	1995
The Real Science Behind the X-files	Simon	1999
Relativity Simply Explained	Gardner	1997
Science, Technology & Society	Bridgstock et al	1998
Seven Ideas that Shook the Universe	Spielberg/Anderson	1987
Sex & the Origins of Death	Clark	1996
Skeptics & True Believers	Raymon	1998
Skies of Fury	Barnes-Svarney	1999
Steven Hawking's Universe	Filkin/Hawking	1997
To Engineer is Human	Petroski	1992
The Universe and the Teacup	Cole	1998
There Are No Electrons	Amdahl	1991
Why Sex is Fun?	Diamond	1997
Why the Earth Quakes	Levy/Salvadon	1995

Table 2. Popular science books selected by the instructor for the upper-division class of "Thermodynamics and Statistical Physics" in Spring 2000.

	Author	Title	Publisher	Year	Remark
1	H.C. von Baeyer	Warmth Disperses and Time Passes: The History of Heat	Modern Library, NY	1998	Story of heat and the scientists involved, Maxwell's Demon, time's arrow
2	T. Schachtman	Absolute Zero and the Conquest of Cold	Houghton Mifflin, NY	1999	Story of how scientists lower the temperature; not that exciting, author not a scientist.
3	M. Riordan & L. Hoddeson	Crystal Fire: The Invention of the Transistor and the Birth of the Information Age	Norton	1997	Very exciting story; shows how good science was done at Bell Labs; a must read especially if you live in the Silicon Valley.
4	G. Johnson	Fire in the Mind: Science, Faith, and the Search for Order	Vintage	1995	Science and religion near Santa Fe, including study in information and complexity.
5	A. Guth	The Inflationary Universe: The Quest for a New Theory of Cosmic Origins	Addison-Wesley	1997	Written by the inventor of inflationary universe; unique; exciting physics and story.
6	T.A. Bass	The Eudaemonic Pie	Penguin	1985	The story of UC Santa Cruz students, applying what they learn about Newtonian mechanics and chaos to beat the roulette in Las Vegas.
7	W. Poundstone	The Recursive Universe: Cosmic Complexity and the Limits of Scientific Knowledge	Contemporary	1985	All about cellular automata, with computer program for Game of Life.
8	J.D. Barrow	The Artful Universe: The Cosmic Source of Human Creativity	Little, Brown and Co.	1995	Power laws, fractals, music.
9	M. Schroeder	Fractals, Chaos, Power Laws: Minutes from an Infinite Paradise	Freeman	1991	Fits our course; highly recommended

5 SUMMARY AND DISCUSSION

We note that

1. Many students in our introductory physics classes are not physics majors.
2. Many of the undergraduate physics majors will not go on to get a PhD in physics.
3. It is highly desirable to train our students to be knowledgeable in many disciplines, in order to be a marketable and productive worker in this rapidly changing world.
4. We want our college graduates—the voters—to be informed in science matters and friendly to the science enterprise, especially if they become millionaires or billionaires, or influential politicians who control our science budgets.
5. There is no textbook out there that teaches really, truly multiple disciplines for freshmen.

All these considerations lead us to incorporate the use of PS books into our regular teaching, by offering extra credit to the students for writing a book report based on PS books. The exact extra credit offered is up to the instructor; it could range from a few points to 10 points, percentage-wise. The extra credit may eliminate the need of "curving" the grades or change the "curving function" in assigning the overall grades at the end of the semester. It is to be decided by the instructor.

Let us emphasize again that the PS book option is not a substitute for improving our physics teaching; the latter requires different efforts.[2,11] Our aim is more moderate and thus doable. We simply want (1) to help the students to broaden their scientific knowledge base as demanded by the real world out there, (2) to foster a lifelong habit of buying and reading PS books, and (3) become science-informed citizens.

The success of this approach hinges on the fact that it would *not* add too much extra burden to both the students *and* the instructor, who are usually well overloaded in their duties. Easy grading is essential to get the instructor to participate. The book report is just to ensure that the student has honestly read the book; it is not and should not be a test of how much the student understands the book. After all, it is a PS book. How much a honest and qualified reader—a college student in this case—can understand the book actually depends largely on how skillful a writer the author is. Never blame a qualified PS book reader for not understanding the book; blame the author. And this is the secret and the beauty of PS books, as the reader is concerned.

Naturally, this PS book option can be used by not just physics instructors, but by instructors in any science course. It can also be adopted in high schools as well as in colleges, and in any other country.[12]There may be isolated efforts in the past, especially in liberal arts colleges, to link PS books to the classrooms, perhaps in some physics survey courses. *What we advocate here is to link the PS books to mainstream teaching, to every science course, in a large scale.* Adopting this option in the whole country or worldwide will fundamentally improve the science education for our students, the future average citizens. An immediate side effect is that in a few short months, all the PS books on the bookshelves of every bookstore will be wiped out. The PS book market will be drastically improved, attracting more skillful writers into the PS books profession, benefiting everybody. For example, in China today—a country of 1.3 billion in population, one-fifth of the humanity in the world—there is not a single full-time author who can make a living by writing PS books alone.[13] Our proposal, when implemented successfully, will change all that.

Social science is the study of a particular material system made up of biological bodies, called *Homo sapiens*. And natural science is about the study of Nature which includes, of course, *all* material systems. Consequently, natural science (physics in particular) forms the basis of all social sciences[14-17] (including history) and hence should be learned by every member of the human society. Furthermore, science and literature are equally important in shaping our modern lives. The time has thus come to make *both* natural science and literature writings an essential reading for college students. This can be easily done by incorporating a few PS books—such as James Watson's *The Double Helix*—into the list of required readings in the general education of every student in every university.

While PS books have been around for a long time,[18] their full potential as an educational tool in mainstream teaching remains largely unexplored. Our proposal is a small step to tap this huge potential—to free the genie from the bottle, so to speak.

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