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Science Education and Liberal Education

Matthew B. Crawford

> *I doubt whether we are sufficiently attentive to the importance of elementary text books…. I do not think the authors of this book intended any harm…. At the same time, I shall have nothing good to say of them.*
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> –C. S. Lewis, *The Abolition of Man*

Teaching is a curious thing. It seems to be effective only when the student is made to feel pleasure in learning. That pleasure is inherently private, yet the learning of science is generally promoted on the ground that it serves some public good. In the era of Sputnik, that public good was clear to all: national defense. Now we hear that scientific literacy is important if America is to maintain its technological edge—not because we are in a race with the Soviets, but because technological innovation drives economic growth. But such fretting in a public-policy mode fails to get at the private experience of individual students. "Why should *I* study physics?" Imagine the question as posed by a truculent sixteen-year-old, staring you down from his desk in the back row. The question is legitimate and compelling, and cannot be evaded with blather about economic growth.

The answer spoken by educators is necessarily a public thing, and education surely serves a public good, but that good must be founded on the private pleasures of the student, not on some abstract desideratum like technological progress. Appealing to self-interest, a teacher might be tempted to say, "Look at how much money techno-geeks have made for themselves in the last decade," but this is sleight of hand, since the new billionaires have been primarily in software, and manipulating the conventions of computer code has little to do with natural science. There are countless ways to make a fortune that are more reliable and less demanding than the study of nature.

The effort required to learn any subject well can be sustained only if the satisfactions are intrinsic, rooted in the activity of learning itself. As a sometimes tutor of physics, I have seen an expression of pleasure spread

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across a student's face as some realization sets in. "Nature loves to hide herself," as Heraclitus said. When a student has spent hours in pursuit, and experienced every kind of frustration, such moments of disrobing are all the more sweet. They answer quite well to the longings of adolescents.

As a component of liberal education, science is both similar to and different from the humanities in spirit and effect. The humanities might be understood simply as a record of the best that has been thought about the human situation. Acquaintance with this record has the effect of freeing us from the present, with its necessarily partial view, and opening us up to the full range of human possibilities. Further, to enter truly into the great works of the past, or of other cultures, requires an *effort* to free oneself from the present and its certainties. A cultivated willingness to make that effort is perhaps the cardinal intellectual virtue. Science makes similar demands, with similarly liberal effects. In studying nature closely, we are confronted with the fallibility of common sense. In fact, heavier things do not fall faster than lighter ones. More radically, the very idea of nature stands as a rebuke to convention altogether.

Yet science surely differs from the humanities as well. Pascal famously spoke of *l'esprit de finesse et l'esprit de géométrie*, representing different habits of mind. What is really on offer, then, in a physics class? The math instills a taste for rigor, and through experiment one learns intellectual responsibility: facts often astonish theory and compel one to rethink one's position, starting anew from first principles. In its subject matter as well as its method, physics ennobles the mind by directing it to the permanent order of the world. One learns, first, that the world *has* such an order, and that it is intelligible; that there is a mere handful of truly fundamental things, and that these can be expressed with haiku-like economy. To arrive by argument at a relation such as $F=ma$ is to experience a genuine revelation. One can't help but feel that there is some deep harmony between the natural world and our efforts to understand it, or understanding wouldn't be so pleasurable. Through such pleasures one acquires the tastes of a serious person.

But science is hard. It is therefore inherently "elitist," merely in this obvious sense: as with skateboarding, some will be demonstrably better at it than others. One can fall on one's behind while skateboarding, and when it happens there is no interpreting away the pavement. Similarly, in a physics course there are answers in the back of the book, standing as a silent rebuke to error and confusion. This sits ill with the current educational imperative of self-esteem. It has been clear for some time that the

elephant of anti-elitism has run amok in education; my purpose is to report what happens when this elephant runs into the cold, hard surface of Newton's laws. The material covered in a physics course can't be dumbed down *ad absurdum*, as can that in a history or social studies course. What is to be done, then, to make physics more "inclusive"? The author of a physics textbook has certain artificial devices available to make his subject suitably democratic-looking. He can recite the technological blessings for consumers that flow from scientific research. He can emphasize good work habits or vocational skills that may incidentally be developed by a student in the course of his studies. These efforts to popularize in a superficial way carry the implicit message that science, and intellectual life more generally, must answer to the tribunal of economic life; physics has no standing as something worthwhile for its own sake. Far from giving physics a wider appeal, I suspect this merely disheartens students. Because it treats them as though they are insensitive to intellectual pleasures, this kind of anti-elitism seems strangely … elitist. As though students are merely being prepared to assume their place as workers and consumers.

The Problem with Textbooks

One can learn a great deal by surveying the physics textbooks now in widespread use, as I recently did as part of a project directed by the Environmental Literacy Council. Begin with some superficial impressions: On nearly every page one finds boxes, insets, three-dimensional marginalia in four colors, and all manner of gratuitous graphics. It is difficult to discern any rank order to the different kinds of information presented. Since physics depends on coherent argument, this manner of presentation is clearly ill-suited to the books' purpose.

Naïvely, I initially thought the formatting of the books might be intended to suit the cognitive peculiarities of today's students. I recently taught a course (not physics, but Latin) in a suburban public high school. I was shocked to discover that relatively few students at this "Blue Ribbon National School of Excellence" (so says the Department of Education) seemed capable of real concentration. My impression was confirmed by veteran teachers who speak of a dramatic change in students over the last fifteen years. The culprits they name are familiar enough: the near-complete demise of reading, coincident with the rise of video games and the Web. The ability to follow a monological narrative or argument from beginning to end seems to have been diminished, along with the habit and taste for reading. So surely the textbooks are adapting to this sad fact in a principled way, out of necessity,

guided by the latest findings of cognitive science? Not so, it turns out—as becomes all too apparent when one learns how textbooks get produced.

Not surprisingly, the textbooks offered by publishers are products of market demand. Like any market, the market for textbooks does not exist in a political vacuum. In the U.S. there is no omnipotent ministry of education that sets standards for curriculum; the states set their own standards. There are a number of well-meaning, semi-official organizations that try to bring good sense to bear on the chaos. For example, in 1993 the American Association for the Advancement of Science issued its "Benchmarks for Science Literacy," and in 1996 the National Research Council issued its "National Science Education Standards." But these efforts have had little real effect. The movement toward states setting their own standards received a sort of federal blessing with the Improving America's Schools Act of 1994, which linked federal funding for schools to states' efforts to set content standards and assess academic performance.

The problem is not so much federalism itself as the way most states actually operate. Each jurisdiction sets out standards in excruciating detail, including long lists of topics to be covered. These lists are given to the publishers as "bid specs." Publishers can maximize the likelihood that a book will be widely adopted by including everything in the bid specs of the ten or fifteen biggest markets. It is no surprise, then, that textbooks often run as much as 900 pages long. The reason this simplistic business strategy is successful, and the reason publishers' salesmen push for allocating an ever greater share of a book's development costs to graphics, has to do with the way textbooks are adopted.

The members of a state's textbook adoption committee are often appointed so as to obtain geographical and political representation (they come from different congressional districts), not because of any expertise in the subject matter. In most states it is a one-time appointment, and a form of political patronage. Members generally have other jobs. In a typical scenario, they come away from their first meeting with a couple of documents from the state's Curriculum Task Force to help them: a list of *several hundred* "behavioral objectives" to be accomplished by the state's schooling in general, and another list of perhaps a hundred topic items specific to the subject. The coverage of these topics is to be checked off on a form, ranked on a scale of one to five for each textbook and the mass of materials that go with the book: teachers' editions, consumable workbooks, wall charts, ready-made transparencies and exams, demonstration materials, lab manuals, and all manner of classroom pizzazz. Committee

members had better have a spare bedroom available. As one close observer put it, "Back in their homes, committee members leaf through the mass of materials aimlessly, not sure of what to look for. Some members alight on pages they don't understand. Some of them conclude that things must have changed quite a bit since they were young, and others conclude that they are too tired to tackle the task and go to bed."

Even for a diligent committee member, the best that can be accomplished under such a system is merely to ascertain the *presence* of requisite topics, not the clarity or depth with which they are presented. The reality is that *nobody involved in the selection process is actually reading the books*, so from a publisher's perspective, the important thing is that every conceivable topic be *mentioned* and, just as important, listed in the index for quick reference. The Third International Mathematics and Science Study found that the average U.S. science middle school textbook covers 50 to 65 topics, while texts in Japan include only five to 15 topics and German textbooks cover an average of seven topics. The superficial treatment of dozens of topics comes at the expense of students' conceptual understanding.

In the end, the question whether students can get any pleasure or meaning out of the text is never really brought to bear on this process. And the superficial nature of the selection process dictates a coffee-table approach by the publishers, leading them to produce a lavish physical product that is heavy on impressive-looking graphical clutter. "Thus the *de facto* national curriculum is a thin stream of staccato prose winding through an excessive number of pictures, boxes and charts," as Harriet Tyson-Bernstein puts it in *A Conspiracy of Good Intentions*. Teachers, of course, needn't follow such texts slavishly, and in fact those teachers who have real mastery of their subject typically depart from the text and conduct their own classroom investigations. But textbooks are relied upon quite heavily by less-experienced and less-knowledgeable teachers. More generally, research conducted as part of the Third International Mathematics and Science Study (TIMSS) indicates that textbooks have a major impact on teachers' decisions about how to present their subject material. In a survey of 16,000 science teachers conducted by Education Market Research in 2001, over 80 percent of science teachers reported using a traditional science textbook.

In many middle school texts, questions at the end of each chapter require students to do no more than repeat some definition verbatim from the text. Students generally have deeply held prior beliefs about natural phenomena, often wrong, and they can easily answer such textbook ques-

tions without recognizing the inconsistency between their understanding and the text they are memorizing. The result is that students work their way through the material without being changed by it, and often without really seeing the point of the questions asked or the answers given.

Intellectual Life and the Spirit of Commerce

The culprit here is obviously more diffused than the two individual authors pilloried by C. S. Lewis in his critique of an elementary English primer—"modest practicing schoolmasters who were doing the best they knew." Yet for all the diffusion of responsibility and fog of perverse incentives in our current textbook system, the problem is not merely procedural; there remains a discernible set of sensibilities that guides the process. Accordingly, in what follows, I will refer to "the author" of *Glencoe Physics*, one of the industry leaders, as though there were such an entity. The man whose name appears on the cover may be a hapless bystander rather than a villain, but I intend to hold him responsible nonetheless. Moreover, the wrong-headedness of this single text reveals some of the deeper sources of the confusion that prevails in contemporary education.

The first chapter is entitled "What is Physics?" This is a fundamental question. One might expect an answer that goes to the root of things; an attempt to articulate the basic idea of nature, perhaps, or the idea of science. It begins thus:

> What do you think of when you see the word *physics*? Do you recall friends saying how hard it is? Do you think of chalkboards filled with equations such as $E=mc^2$? Does the word conjure up images of an atomic bomb's mushroom cloud? Perhaps you think of scientists in white lab coats.

Though one might object to its superficiality, this paragraph follows the sound pedagogical principle of beginning from where the students are. The author has probably received such answers on the first day of class when he asked his students: What is physics? But the point of eliciting the students' untutored responses is to prepare the way for an ascent. Physics is merely the study of nature, so its subject matter is something familiar. Yet the first day of a physics class is a moment ripe with new possibilities. Students will learn to use their own powers; to see things clearly in their simple aspect. It is a striking idea that is implicitly on offer: that happiness can be had through careful reasoning. Here is the radical moment that defines liberal education, and it is especially pregnant with liberation

when we consider the manipulations of mass culture that children are regularly subjected to.

This opportunity is squandered when the third paragraph begins with a grudging concession and then, by way of apology, a list of consumer goods:

> Yes, many physicists worked together to develop the atomic bomb. Physicists also played a role in developing the computer chips used in PCs and video game systems; the graphite-epoxy materials used in guitars and golf clubs; the CDs and DVDs on which your favorite music, computer games, and movies are recorded; and the lasers you use to play them. Physics plays a primary role in the development of new technologies for leisure….

Is it really necessary to list *both* "video game systems" and "computer games" in this attempt to justify physics to adolescents? Bending over backward to please bored children, assimilating science to their untutored priorities, resembles the strategy of a salesman more than that of an educator. It does not go to the root cause of the boredom, which, I would hazard, is a passive mind not engaged with real things. In *Glencoe Physics*, physics is presented as a mere means: it provides "technologies for leisure." By contrast, according to an older understanding, physics is itself the quintessential leisure activity. Consider the ancient scientist Archimedes, who practiced geometry for amusement and, by his engineering prowess, single-handedly defended the city of Syracuse from Roman assault. Once the emergency had passed, Plutarch reports that Archimedes took up again his pure research; "regarding the work of an engineer and every art that ministers to the needs of life as ignoble and vulgar, he devoted his earnest efforts only to those studies the subtlety and charm of which are not affected by the claims of necessity."

Returning to our textbook, the first chapter concludes with a page of photographs. We see a man shaving, with the following caption: "Razor blades are coated with thin film materials using plasma physics techniques." Never mind that plasma physics is beyond the ken of any textbook, so its mentioning here can only be meant to dazzle us, exactly as in a razor advertisement. One is reminded of a headline in the satirical newspaper *The Onion*: "Comb Technology: Why Is It So Far Behind the Razor And Toothbrush Fields?" If the point of the pictures is to suggest that physics is all around us, any number of visually elegant, familiar phenomena could have been chosen to show nature's mathematical patterns. Why something as artificial as a state-of-the-art razor, the very icon of

our absurd obsession with technology? In another picture we see a newfangled car. "Billions of dollars are saved by consumers as automobiles are built with lighter composite materials…." In this book, material goods and economic considerations provide the only justification for the activity of the mind; there is no distinction between science and technology. Accordingly, one gets little sense of science as an intellectual activity, or of what its attractions might be.

Part of the problem is the way each subject is framed. On the first page of each chapter, there are two headings in the margin: *What You'll Learn* and *Why It's Important.* The *Why It's Important* section for the first chapter, then, is charged with nothing less than motivating or justifying the study of physics altogether. Here it is: "An understanding of physics will help you make informed decisions as a citizen in an increasingly complex world." One could comment on the utilitarian character of this justification. I wish to focus rather on its abstraction. It is a meta-level public-policy justification, remote from the student's concerns. It might be the reason for some public entity to fund science education. But it can't *really* be the reason for me to want to understand, say, the conservation of momentum, because such understanding doesn't actually hold much utility for practical life; most people get by just fine without it. The real reason is intellectual gratification. This latter, however, seems not to be a *universal* motivation (many are indifferent to such pleasures, or not susceptible to them). It therefore will not do as a good *democratic* justification for science. Above all, this book strives to keep a democratic appearance. Maybe the author is afraid to appear elitist by speaking the truth about scientific understanding, namely that it is available only to those who are willing and able to think hard. With his public-spirited-sounding blather about "citizens in an increasingly complex world," the author draws a veil over his own activity as a scientist. If his rhetoric didn't cater so single-mindedly to the least curious of his readers, he might reveal enough of the true character of scientific inquiry to entice a few gifted students onto his mountaintop. Sadly, that seems not to be his priority.

Precisely because our author gives no indication of the deeply human character of scientific inquiry, he is compelled to use trite sociological digressions to try to "humanize" the scientist. That is, to make him recognizable as one of us, a regular guy. "The Mars exploration team is made up of many women and men…. They love their work, but they also have many outside interests such as music, drama, sports, and mountain climbing. When they were younger they took science and mathematics

courses, but they were also involved in many activities in and out of school." The assumption seems to be that the scientist *as* scientist is engaged in something incomprehensible. His motivations are not apparent. Rather than convey those motivations and express the joy of science, the author is satisfied to present the scientist as benefactor of the masses, a bringer of material progress.

With its concepts of entropy and irreversibility, thermodynamics offers nothing less than an account of why time must exist, and why it must flow in only one direction. It is heady stuff. On the other hand, our author gives us the reasons *Why It's Important*: "Thermal energy provides the energy [*sic*] to keep you warm, to prepare and preserve food and to manufacture many of the objects you use on a daily basis." All true enough. But how drab. How utterly uninspiring. Orienting by the lowest common denominator, trying to justify the life of the mind according to reasons that are *universally* acceptable because rooted in the body (we *all* get cold and hungry), the highest human activity appears as mere drudgery. This is not the way to awaken a longing for knowledge in the most capable students. The author perhaps intends it rather as a political defense for science in a mass democracy. But it is a short-sighted strategy. Where will the scientists of the future come from? Who would want to become a scientist, if the vocation of science is a sort of dreary community service?

Let the obvious be stated: thermodynamics is not important because it keeps us warm (it doesn't—fire does). In fact it is not important at all, by the utilitarian lights of the book. In the locution of ancient thought, now somewhat foreign to us, thermodynamics is noble rather than necessary. By so doggedly effacing the distinction between science and technology, measuring everything against the needs of the body, this book implicitly yet aggressively denies the very existence of the noble. This is its fundamental error. It will be objected that this criticism amounts to nothing less sweeping than a criticism of modern science altogether, since modern science is famously a project for the relief of man's physical needs. I plead guilty, on the conviction that the imperatives of education require some modest resuscitation of the ideal of ancient science, or learning for its own sake.

Education is something more than the acquisition of a set of technical skills. A student who is already interested in physics could probably acquire such skills well enough from this book. But for most students to develop a taste for such demanding material, they must be shown things that are high and low *in their true colors*, and encouraged to make these

evaluative judgments by the example of teachers (and textbooks) who are unembarrassed about the rank order of human pursuits. The goal is not merely to train a technician, but to form the affections of the student, connecting his head to his heart with true judgments about what is worthy of love and what is not. If we want students to love things that are hard and demanding (like physics), such things must be recognized and publicly affirmed as being more worthy than other things that are paltry and absurd (like "fashion marketing," a subject offered in the high school I taught at). The anti-elitist rhetoric of *Glencoe Physics* undermines this central, affective task of education.

Under a heading that revisits the question "Is physics important?" we learn more about the Mars exploration team: "Above all, they have learned how to work as a team: dividing the work but making sure that everyone understands, exploring all possibilities but agreeing on one method, and checking to make sure that the problem really was solved. Finally, they have learned how to make presentations, orally or in writing, that communicate what they have learned to their coworkers, their friends, and the general public." Team-building, consensus, public relations: physics as preparation for life in a corporate cubicle. Perhaps one member of the textbook adoption committee was there to represent the Chamber of Commerce. And indeed, scattered throughout the chapters are mock "Help Wanted" advertisements that seem to promise a livelihood for those who do their physics homework. Thus we have job descriptions for Vending Machine Repairer, Chiropractor, Power Plant Operations Trainee, and so forth. The book casts its net widely, aiming at different demographics. We get both Optometrist and Optician. In a sly bit of rhetoric, we find buried among these a job description for Particle Physicist. The effect is comical. "The successful candidate will analyze elementary particles (quarks, leptons, and bosons)…." Hey, we're all just working stiffs. But in reality, of course, the vending-machine repairer needn't know any physics, and the particle physicist isn't a worker in the usual sense. The author's dogmatic anti-elitism distorts the reality of both laborer and scientist, for the sake of making them resemble one another. Does the author (a Harvard Ph.D.) really believe this?

The pose of anti-elitism seems to be a cover for something far more disturbing, something that is perhaps typical of elite anti-elitists. The author writes, "Sometimes the results of the work of physicists are of interest only to other physicists. Other times, their work leads to devices…. that change everyone's life." Are these the only two possibili-

ties? Physicists on their mountaintop, speaking only to one another, and the rest of us in the plains, waiting for them to descend bearing magical *devices*? Nothing in-between? Aren't there intelligent, curious people who are not professional physicists, but who have the patience and desire to learn? I believe it is this dichotomization of humanity into two ideal types, professional scientists and ignorant consumers, that is responsible for this book's cynicism. The author doesn't seem to think his readers are really capable of being educated. This is the worst sort of elitism. Paradoxically, we have here the worst of both worlds: an anti-elitist *rhetoric* that discredits the higher human possibilities, the very possibilities by which the author orients his own life as a scientist, together with a more *substantive* elitism that views students from so far above that it can't be bothered to cultivate in them those same human possibilities.

Democracy and Elitism

The author's cynicism is ultimately rooted in a common confusion, a false conflict between democracy and elitism, one that forgets the ways in which these two human ideals actually depend on one another. Thomas Jefferson envisioned a "natural aristocracy," made possible by the liberation of talents that comes with equality of opportunity. He suggests that democracy not only makes such a natural aristocracy possible, it is also peculiarly in *need* of cultivated human beings who can exert a leavening effect on society, giving our common freedom the character of liberty rather than license. That distinction seems to turn on the objects toward which freedom is directed. It is a distinction that allows us to speak of liberal pursuits, such as music, science, literature, mathematics, and so forth. If liberal democracy requires a critical mass of liberally educated citizens, it would seem to require a regime of education guided not only by the love of equality but also by the love of thinking. Happily, such a love is requited by those beautiful things that unveil themselves before a powerful and disciplined mind working at full song. Here is a logic that reconciles the private good of the student with public felicity. It is the logic of liberal education, classically understood.

A great teacher once said that precisely because we are friends of liberal democracy, we are not permitted to be its flatterers. With its confused anti-elitism, this book flatters the lowest elements of the democratic spirit. This is unfortunate because it is precisely the democratic spirit that, at its best, provides the most fertile home for the spirit of scientific inquiry. *Glencoe Physics* takes a very dim view of the educability of

students, never venturing to lead them beyond the narrow concerns of comfort and entertainment. This is not so much meeting the students on their own terms as capitulating to the terms offered to students by mass commercial culture. Cowed by the times, our author lacks political courage on behalf of thinking, something that is incumbent on all teachers.

A physics textbook needn't address in any explicit way the pleasures of studying physics. Just give us the physics. Give it to us straight. Don't clutter it up with vulgar trappings that obscure the nature of the thing. The truth is, students appreciate something fine, and rarely get it.