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WHAT MAKES ENGINEERING AND SCIENCE HARD?

by Sheila Tobias

I want to start by justifying the role of the "outsider" in a field like engineering and science. Like many of you I am not trained in the mainstream of these fields, but I will argue tonight outsiders like ourselves have much to contribute. Indeed, as a historian of science once explained to me, much good science has been the product of "newness to the field."

The conventional wisdom in the field of history of science, is that breakthroughs in science have to be made by very young (usually) males at the very outset of their careers. The reason this matters so much to us feminists is that, given the different roles women play in their lives, it is not always possible for women to make contributions when they are young. As you know from your efforts to counter discrimination, women are not simply discriminated against because they are "women," per se, but because of some other category they inhabit: because they are married, or mothers, or pre-menopausal, or post-menopausal. In this instance, there appeared to be a reluctance to support 28 and 30 year old graduate women in science because they were "too old."

But in fact, like so many shibboleths about science, the "they-must-be-young-to-make-a-contribution" theory is false. This historian, who had done a number of statistical analyses of the work of 19th century scientists, said that older scientists continued to be very productive, and that the data was skewed statistically simply because they died young.

I start with this analysis because I want to shape an argument that it is the "outsider status" that makes us good critics. And from that perspective, I would like to present tonight an agenda for us to serve women in science and engineering.

The first point to be acknowledged is that we are in a quasi backlash situation. (We don't need Susan Faludi to tell us that.) That means we have to work a little harder and be a little angrier than we have been over the past few years. But also the times are rich in opportunity, as American institutions are beginning to look critically at themselves. They see this as a time for reassessment: of American industrial productivity, of industrial policy, of science and engineering education. Whether or not you buy into the anticipated "shortfall" of scientists and engineers, everyone agrees that something is amiss. The demonstration of this is that people like ourselves who have been working on women's issues for ten and twenty years mostly talking to eachother are now being asked to help the "establishment" figure out what to do....

So, I have four themes: I think the time has come to stop trying to adapt women to existing structures and to negotiate, instead, for changes in established courses, institutions, and the work place, to fit women.[1] Second, we must be looking not just for palliatives but for more radical action. Third, it saddens me that on a lot of campuses undergraduate and graduate women in engineering don't discover their feminist roots or their feminist histories until they're in trouble. It's when they go to the "sexual harrassment" office and are told it is not in their interests to "make waves" that they pick up the campus directory and start looking for the women's studies office on campus. We need to encourage young women in science and engineering to appreciate what we've done for them and to acknowledge that they must be <u>tithed</u> to support the next generation by being assertive, activist, and feminist.

And fourth, we should not expect to have to accomplish all this alone. This is a propitious time for coalition building. With so much going on in science and engineering education, science and engineering more generally, the search for an industrial policy, we ought to be able to find willing and powerful allies in new places.

I did not begin as an advocate for mathematics and science. I started out as an associate provost at a formerly men's college that, in 1970, went coed. Four years later, when the college was fully integrated, I decided to look at the females' transcripts and found, what I later named, a "slippery slide off the quantitative." Transcripts of juniors and seniors, compared to declared interest as freshmen, showed that prospective physics and chemistry majors were finding their way into biology. Prospective biology majors, discovering that introductory biology required a concurrent course in chemistry, were finding their way into English. Prospective psychologists, discovering that psychology had a rigorous statistics requirement, were moving into the softer sciences. I began to interview faculty in the quantitative fields, as well as the students they were losing, and from these interviews came a question that has driven my research for twenty years, namely: Why do otherwise bright, able students, who have no difficulty coping with the ambiguous and challenging college level work of the social sciences and the humanities, have task-specific disabilities in mathematics and science?

The simple answer to that question is that such people are "dumb in math," or "dumb in science," or "don't have what it takes..." And so I found myself engaged in what became a two-decade enterprise, to find another set of answers to this question.

My first discovery was that there is a variable, other than intelligence, that gets in the way of success in math and science. That other variable I named "anxiety" and I attributed it to sex-role socialization, a sense many young women have that they are "out of role" when they do well in mathematics (engineering or science) because these disciplines (uniquely) require a certain kind of "mental masculinity." By meeting their emotional needs, in three short years, we managed to bring 600 "anxious" students -- many but not all of them women -- to

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[1] See Marcia Matyas and Shirley Malcom, <u>Investing in Human Potential: Science and Engineering at the Crossroad</u>, AAAS, 1991.

the door of calculus and through the first course.[2]

When I turned nine years later to specific problems some students have with introductory college science, I found another variable at work: the unvoiced conventions and habits of teaching these subjects that put off many of the ablest students in college, a group I called the "second tier."[3] My strategy was to locate smart people who mathematicians and scientists would not be able to dismiss as "ignorant" or "lazy" or "dumb" and to put those people into a setting where they would publicly struggle with science as newcomers to the field. My hunch was that if smart people had trouble with introductory college material, the professors might be persuaded that there was a problem in the manner in which these materials are scoped, sequenced, and packaged.

I began at the University of Chicago where thirty faculty members and deans were deployed as "surrogate learners" in a unit of introductory physics over a two-day period. The topic was "waves in elastic media" and the learners were from law, theology, literature, psychology, and social science. The purpose was to expose these newcomers to physics, and have them grapple with new material presented ably but in a conventional manner. Then, by means of a double entry set of notes to have them provide a running commentary on how it <u>felt</u> to be in that class. The results of this phase of my research has been published elsewhere.[4]

To summarize, they found the "packaging" of the material not as useful to their way of thinking as other presentation modes would have been. To take one example, demonstrations. Our instructor could not imagine teaching "waves in elastic media" without a counter full of demonstrations and, because he had gone to so much trouble (as had the technician) to ready this class, he was unwilling to let the students interrupt until they had seen every last one of them. For his adult auditors, "stopping Isaac was like stopping a moving freight train." He was convinced the demonstrations would be more useful than answering their questions. They wrote in their journals that it was not.

The intelligent outsiders found much difficulty with the language of physics. They expected the physicist to use certain language in different ways. But they had no way of knowing which of the many terms and phrases descending on them were part of physics, and which were not. So, a term like "static measurement," as one wrote, was confusing. She couldn't tell whether it meant "measuring something that is still and not moving," or whether it had a specific meaning in relativity. In other similar experiments other "assumptions" were

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[2] See the author's <u>Overcoming Math Anxiety</u>, W.W. Norton, 1978 and <u>Succeed with Math</u>, The College Board, 1987.

[3] See Sheila Tobias, <u>They're Not Dumb, They're Different: Stalking the Second Tier</u>, Research Corporation, 1990.

[4] See appropriate issues of <u>Change</u>, <u>American Journal of Physics</u>, <u>The Physics Teacher</u>, <u>The Chronicle of Higher Education</u>, 1986-1991.

exposed that faculty make which "work" with one subset of students -- the ones I call "younger versions of themselves" -- but may drive other, able students out of science -- the ones for whom, for example, verbal cues are at least as important as demonstrations and verbal ambiguities more problematic.

Conversely, when I did the experiment in reverse, bringing fourteen science and engineering faculty from Cornell University into an artificially constructed week-long seminar in the poetry of Wordsworth and Chaucer, we got just as interesting comments about the approach to literary analysis. For one, the scientists and engineers found it impossible to follow a lecture that was, as they put it, "words, and more words." Worse yet, there was "nothing on the blackboard, no outline, no key terms, no nothing." In a third incarnation of this experiment at the University of Florida in Gainesville, we combined a morning of philosophy and an afternoon of physics, each presented to nonspecialist faculty. There we had another blackboard experience that was full of lessons for the teachers on both sides of the campus. The philosophy professor used the blackboard as a kind of scratch pad, first constructing columns of contrasts. (His topic was the "mind body problem in philosophy.") Then, ignoring his own columns, just scribbling other words. This totally confused his science-auditors, though he did not notice what he had done until they told him.

When I got through with these experiments, I was encouraged by others to do a longer, most substantial semester-long experiment with introductory college courses, employing graduate students in literature, American studies, classics, and anthropology. And this is summarized in the book distributed this evening.[5] My surrogate students had to meet two conditions: first, that they had liked science in high school, and second, that they were not mathemaphobic. So they were very able students, though not science/engineering "types." They had two tasks in this experiment, first to do as well as they could (and they did), and the other to take careful notice of everything they found strange or different from studying literature or history. They noticed among other things differences in examinations. One, Eric, who was first in his physics class and who exhibited a profound understanding of the physics he was having to learn, said of the examinations, "We were never asked to comment on or explain anything, only to complete a calculation." What we're dealing with here are teacher expectations that do not fit the students' strengths and an ever more narrowing intellectual experience that doesn't meet many good students' intellectual needs. Part of the reason for this is that there are so few "outsiders" in these courses...

When I report these findings to professors of physics and chemistry, they tell me fifteen reasons why nothing can be changed, either in the presentation, the homework assignments or the exams. I retort that the reason they are not motivated to change is that the students they are interested in -- the younger versions of themselves -- do manage their courses. Why should they teach otherwise?

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[5] They're not dumb... op. cit.

Yet, the very challenge Eric was looking for, to "comment on and explain" would be very useful in the training of engineers where, as professionals, they are going to have to explain a great deal of technical material to nontechnical people in order to persuade them to engage in and to pay for some enterprise...

What are the chances for change? On the good news front, research is now shifting from what's wrong with minorities and women that causes them not to "fit in" to gender independent studies that reveal how widespread the problems are that women and minorities complain about, problems like absence of community, too much competition owing to grading on a curve, an absence of overview, not enough applications (context), "all scales, and not enough music." I found it curious that although there were five females and two males among my graduate students in the science courses, the many reviewers of my book never commented on this. I think this is because the responses could not be gender differentiated. This means that, what you are dealing with in your work -- apart from sex discrimination and sexual harassment which are of course particular problems for women -- may have more to do with intellectual style and expectations than with simple prejudice against women. Students who are "not dumb but different" can make the professor uncomfortable, just as they can make such young people feel "there's no place for me in engineering."

Two researchers at Boulder, Nancy Hewitt and Elaine Seymour, did something different but similar to mine in their study of why certain students drop out of mathematics, science, and engineering majors.[6] They interviewed 140 students from a variety of Colorado institutions who stayed in these majors after their junior year -- the last opportunity to change majors -- and compared them to 140 students who left. Again, the gender differences are noted, but not marked. What drove students out? Not grade point average, or "success" on other scales, but rather an experience so negative that everyone would have left had there not been some intervening variable that kept them in: a parent who would not tolerate their dropping out, too much time and money already invested in the major, or a group of like-minded students who studied together. Theirs were remarkably consistent findings with mine. As one of my graduate students wrote of physics, "My IQ was sufficient for this course; my OQ (my obedience quotient) was too low." Now Hewitt and Seymour's study will be extended to 1400 students nationwide.

My strategy in writing <u>They're not dumb they're different</u>... was to have a professor reading the book to think, upon reading Eric's comments, "Boy, would it be fun to have someone like Eric in my class," and then, several chapters later, to begin to wonder whether perhaps there is an "Eric" in his class, but that the way the class is structured, there is no way for him to find out; nor to assure that "Eric" would be there next semester. I wanted to rattle their

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[6] Nancy Hewitt and Elaine Seymour, "Factors contributing to high attrition rates among science, mathematics, and engineering undergraduate majors," Report to the Alfred P. Sloan Foundation, 1991.

cages, to make science and engineering professors worry, not about "doing good" -- you don't get much action out of people when you push their "good" button. I wanted them to worry about "doing well" for the field, to wonder: Who are we losing in engineering? Are they creative people? People, who, as my physicist husband describes creative physicists, "pick up the stick from the other end" are not likely to show much obedience in class and will want to do more than computation. Someone who stands outside of science may be the only one who can argue this point. Indeed, this is just what I did in 1975 when I took a question for which everybody else thought they had an answer, and said "supposing it's not true, supposing these students are not 'dumb in math,' what else could explain their avoidance?

I wish you a stimulating conference and apologize for not being able to stay.

The end