Science, Mathematics, and Student Values

Loring Coes III

COLLEGE GRADUATIONS THESE DAYS SEEM TO feature plenty of social science majors and business majors, but precious few degrees in science, engineering, and mathematics. The impression is an accurate one. The educational pipeline leading to technical fields is drying up [1]. It is clear that young people are turning their backs on science careers, and it is important for us to understand why, and to change the trend if we can.

One obvious reason for the problem is that science majors need to work hard, perhaps harder than others. This might not be absolutely correct, but it is a common perception among high school students looking ahead to college and among college students themselves. Science majors have to be dedicated, it seems, and there is not much room, or time, for fun. This view does not simply reflect student laziness. It is a view fueled by the impression, popular among many high school students and college freshmen, that entry level courses in mathematics and science are especially hard, and that one of the purposes of those courses is to weed out all but the very best students. College freshman, once used to the relative intimacy of the high school classroom, return from college to tell their younger friends war stories about cavernous lecture halls and a racing curriculum designed to scare away as many candidates as possible. Linked to this perception is the feeling, held by most of this nation, that science is the domain of exceptionally bright people, and that ordinary ability will not be enough for success [2] [3]. Some people have the talent, and some people simply do not, we tend to think.

We have nurtured the idea, somehow, that there is a science elite, small in number, highly intelligent, hard working and not all that much fun to be around.

Our system of advanced placement, of taking accelerated courses in high school for possible college credit, promotes the idea that science is only for the talented and accelerated. The advanced placement program clearly does not intend to create this impression, but it still does. Students who do not have some advanced standing upon entering college feel they are at a serious disadvantage compared to those who do. Many students are reluctant to jump into programs where they feel they are already a year behind the "smart" people in the department. This system naturally selects against late bloomers and against students from less sophisticated high schools. Resolving this problem will not be easy. Certainly we need to provide opportunities for eager and able high school students to do college work, but we should not, in doing so, put others at a serious disadvantage. Perhaps colleges can create programs specifically designed for late bloomers, for people who develop an interest in science after others, and for those whose high schools do not have advanced placement programs. With our advanced placement program we have inadvertently backed ourselves into an elitist system that discourages many students of great potential. It is not a system that invites the curious but uncertain student to take a chance on science. In a time when we need to generate interest in our subject, we do not need another barrier.

The stereotype of the science nerd feeds on these perceptions. We have nurtured the idea, somehow, that there is a science elite, small in number, highly intelligent, hard working and not all that much fun to be around. How and why we developed this popular and persistent myth is an interesting question. Changing this image would go a long way toward solving our problem. One way to examine the myth is to look at the medium in which it grows so well--the curricula of our schools, where our students get their first taste of math and science.

Our traditional elementary mathematics curriculum is boring, repetitive, and unchallenging. Our youngest math students practice paper and pencil arithmetic for years on end, rarely get to explore new ideas experimentally, and simply memorize facts and algorithms. As students progress from kindergarten through eighth grade, more and more of what they study has already been introduced [4]. Students grow accustomed to a slow pace, and come to realize that if they do not understand an idea today, they will study it all again next week anyway. Students view mathematics as a set of rules and drab facts, with few interesting connections to their lives. There are precious few glimpses of the power and beauty of mathematics in our traditional elementary curriculum.

Elementary school science is much the same. Young students get their first look at science through textbooks where science is basically a matter of vocabulary building. There is little experimentation, and not much chance to see science as it really is, a world of activity and thinking [5]. The standard science curriculum as we have come to know it is deadly dull.

0163-6804/90/0012-0052 $01.00 © 1990 IEEE

At the beginning of high school all this changes. The pace picks up dramatically in mathematics and science, covering a great deal of new material as quickly as it can be assigned [4] [5]. It is as if high school teachers needed to make up for lost time. However, certain characteristics remain. There is still a heavy emphasis, in both math and science, on the memorization of facts and the cranking of algorithms. There is not much room in high school for experimentation, conjecturing, and just plain thinking. It is in high school when students start to drop out of mathematics and science courses at an alarming rate. Essentially, in elementary school science and math we bore students to death, and then in high school we scare them to death.

It is also in high school that the stereotype of the science nerd starts to flourish. There must indeed be something special about people who can retain their love of science and math despite the mind-numbing elementary years and the breakneck pace of the high school curriculum. Those students who make it and go on to major in science and math must truly be exceptional. However, what is most alarming is that students in the next echelon down, bright, energetic people, future voters all of them, have learned to distrust math and science, and have never really had a chance to see these subjects in their true glory. That is the great tragedy.

What are the values that drive this system? How do we measure success in high school, and what does an ambitious high school student want? Most students will put good test scores, Scholastic Aptitude Tests (SATs), ACTs, and achievements at the top of the list. That is a good decision, because it reflects our country's educational values as well. There is much political pressure to improve test scores. Tests in large part drive our curriculum, and math and science are thoroughly tested. However, the format of the testing may also give us a clue to the alienation that students feel from math and science, and to the way the tests misrepresent these subjects. These one-hour tests

We know that students must actually do science in order to understand it. Students must be active in learning. Listening to a lecture and reading a textbook are not enough.

are made up of multiple-choice questions, and students must average about one question per minute to complete them. Quick recall of fact is king. High school students learn the value of skipping problems when no solution appears immediately, and also that it is a big mistake to become interested in a particular problem. The clock is ticking. Curiosity and perseverance, the real wellsprings of math and science, are deadly vices in the quick-answer world of the SAT. Students learn this lesson well, because this lesson counts. The deeper tragedy is that no scientist or engineer, or any professional for that matter, answers multiple choice questions for a living, and no professional is encouraged to give up on real problems after 60 seconds. This situation has become worse in recent years because several volumes of old tests are now available for study and practice, giving schools ample resources, inexpensive ones at that, to build curricula around test preparation. (It is far better to have the cram courses outside school and to steer the school curriculum away from multiple-choice thinking.) A generation ago we did not have this problem--a student took one or two shots at the SAT and that was that. Now test preparation is a focus of attention, a clear message about what we value and about what students should study. And it is clearly at odds with the real spirit of mathematics and science. We are sending the wrong messages about what our subject really is.

How can we change the testing? Clearly, it is easier and cheaper to ask lots of little questions with short answers than to ask big, interesting questions where there might not be a single correct answer. However, the big questions are what we really value, and our testing absolutely must reflect our values. If we can turn the testing around, we will go a long way toward solving our problem, toward showing students what math and science are really like, and toward attracting more young people into our fold.

Happily, many states are now developing what are called performance tests, where students write extended answers in essay form to complex, interesting questions. One important criterion for test questions is that they show a real use of mathematics and science. These pioneering states, among them Connecticut, California, New York, and Vermont [6], will soon provide a model for other states to follow. On another level, The National Council of Teachers of Mathematics, with its Standards [7] and The American Association for the Advancement of Science, through Project 2061 [8], have both promoted a vision of school math and science where students are active participants in investigating their world from the very beginning of kindergarten. We need curricula not overstuffed with facts and figures to memorize, but where students learn appropriate facts in the process of reasoning about our world. We know that students must actually do science in order to understand it. Students must be active in learning. Listening to a lecture and reading a textbook are not enough. An engaging experience for all students is the driving goal of this reform effort. If we can support these efforts and make them work, we will show all students what the true values of mathematics and science really are. We will show them that working hard can be worthwhile, and that careers in mathematics, science, and engineering can indeed be a lot of fun.

References

[1] National Science Foundation, "The Science and Engineering Pipeline," Division of Policy Research and Analysis, National Science Foundation, Washington, DC, 1987.

[2] Mathematical Sciences Education Board and National Research Council, *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*, Washington, DC: National Academy Press, pp. 9–11, 1989.

[3] K. C. Cole, "Science Under Scrutiny," "Education Life" supplement, *New York Times*, pp. 18–19, Jan. 7, 1990.

[4] J. Flanders, "How Much of the Content in Mathematics Textbooks is New?" *Arithmetic Teacher*, National Council of Teachers of Mathematics, vol. 35, no. 1, pp. 18–23, Sept. 1987.

[5] L. W. Foderaro, "High Hopes," "Education Life" supplement, *New York Times*, p. 21, Jan. 7, 1990.

[6] R. Rothman, "Student Assessment Rates Performance," *Education Week*, Editorial Projects in Education, vol. 9, no. 1, p. 22, Sept. 1989.

[7] National Council of Teachers of Mathematics, Commission on Standards for School Mathematics, *Curriculum and Evaluation Standards for School Mathematics*, Reston, Virginia: The Council, 1989.

[8] American Association for the Advancement of Science, Project 2061, *Science for All Americans*, Washington, DC: The Association, 1989.

Biography

Loring Coes III is the Chairman of the Mathematics Department at Rocky Hill School in East Greenwich, Rhode Island. He has taught all grade levels from fourth through twelfth grade although he currently teaches only high school courses. He has a B.A. from Williams College and a Master of Mathematics from Worcester Polytechnic Institute. He is President of the Rhode Island Mathematics Teachers Association, a 1987 Woodrow Wilson Fellow, a 1988 Presidential Awardee in Mathematics Teaching, and is a member of the Mathematical Sciences Education Board of the National Research Council.