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Why Science Majors Change Their Minds (It's Just So Darn Hard)

By **CHRISTOPHER DREW**

LAST FALL, President Obama threw what was billed as the first White House Science Fair, a photo op in the gilt-mirrored State Dining Room. He tested a steering wheel designed by middle schoolers to detect distracted driving and peeked inside a robot that plays soccer. It was meant as an inspirational moment: children, science is fun; work harder.

Politicians and educators have been wringing their hands for years over test scores showing American students falling behind their counterparts in Slovenia and Singapore. How will the United States stack up against global rivals in innovation? The president and industry groups have called on colleges to graduate 10,000 more engineers a year and 100,000 new teachers with majors in STEM — science, technology, engineering and math. All the Sputnik-like urgency has put classrooms from kindergarten through 12th grade — the pipeline, as they call it — under a microscope. And there are encouraging signs, with surveys showing the number of college freshmen interested in majoring in a STEM field on the rise.

But, it turns out, middle and high school students are having most of the fun, building their erector sets and dropping eggs into water to test the first law of motion. The excitement quickly fades as students brush up against the reality of what David E. Goldberg, an emeritus engineering professor, calls “the math-science death march.” Freshmen in college wade through a blizzard of calculus, physics and chemistry in lecture halls with hundreds of other students. And then many wash out.

Studies have found that roughly 40 percent of students planning engineering and science majors end up switching to other subjects or failing to get any degree. That increases to as much as 60 percent when pre-medical students, who typically have the strongest SAT scores and high school science preparation, are included, according to new data from the University of California at Los Angeles. That is twice the combined attrition rate of all other majors.

For educators, the big question is how to keep the momentum being built in the lower grades from dissipating once the students get to college.

“We’re losing an alarming proportion of our nation’s science talent once the students get to college,” says Mitchell J. Chang, an education professor at U.C.L.A. who has studied the matter. “It’s not just a K-12 preparation issue.”

Professor Chang says that rather than losing mainly students from disadvantaged backgrounds or with lackluster records, the attrition rate can be higher at the most selective schools, where he believes the competition overwhelms even well-qualified students.

“You’d like to think that since these institutions are getting the best students, the students who go there would have the best chances to succeed,” he says. “But if you take two students who have the same high school grade-point average and SAT scores, and you put one in a highly selective school like Berkeley and the other in a school with lower average scores like Cal State, that Berkeley student is at least 13 percent less likely than the one at Cal State to finish a STEM degree.”

The bulk of attrition comes in engineering and among pre-med majors, who typically leave STEM fields if their hopes for medical school fade. There is no doubt that the main majors are difficult and growing more complex. Some students still lack math preparation or aren’t willing to work hard enough.

Other deterrents are the tough freshman classes, typically followed by two years of fairly abstract courses leading to a senior research or design project. “It’s dry and hard to get through, so if you can create an oasis in there, it would be a good thing,” says Dr. Goldberg, who retired last year as an engineering professor at the University of Illinois at Urbana-Champaign and is now an education consultant. He thinks the president’s chances of getting his 10,000 engineers is “essentially nil.”

In September, the Association of American Universities, which represents 61 of the largest research institutions, announced a five-year initiative to encourage faculty members in the STEM fields to use more interactive teaching techniques.

“There is a long way to go,” says Hunter R. Rawlings, the association’s president, “and there is an urgent need to accelerate the process of reform.”

The latest research also suggests that there could be more subtle problems at work, like the proliferation of grade inflation in the humanities and social sciences, which provides another incentive for students to leave STEM majors. It is no surprise that grades are lower in math and science, where the answers are clear-cut and there are no bonus points for flair.

Professors also say they are strict because science and engineering courses build on one

another, and a student who fails to absorb the key lessons in one class will flounder in the next.

After studying nearly a decade of transcripts at one college, Kevin Rask, a professor at Wake Forest University, concluded last year that the grades in the introductory math and science classes were among the lowest on campus. The chemistry department gave the lowest grades over all, averaging 2.78 out of 4, followed by mathematics at 2.90. Education, language and English courses had the highest averages, ranging from 3.33 to 3.36.

Ben Ost, a doctoral student at Cornell, [found in a similar study](#) that STEM students are both “pulled away” by high grades in their courses in other fields and “pushed out” by lower grades in their majors.

MATTHEW MONIZ bailed out of engineering at Notre Dame in the fall of his sophomore year. He had been the kind of recruit most engineering departments dream about. He had scored an 800 in math on the SAT and in the 700s in both reading and writing. He also had taken Calculus BC and five other Advanced Placement courses at a prep school in Washington, D.C., and had long planned to major in engineering.

But as Mr. Moniz sat in his mechanics class in 2009, he realized he had already had enough. “I was trying to memorize equations, and engineering’s all about the application, which they really didn’t teach too well,” he says. “It was just like, ‘Do these practice problems, then you’re on your own.’” And as he looked ahead at the curriculum, he did not see much relief on the horizon.

So Mr. Moniz, a 21-year-old who likes poetry and had enjoyed introductory psychology, switched to a double major in psychology and English, where the classes are “a lot more discussion based.” He will graduate in May and plans to be a clinical psychologist. Of his four freshman buddies at Notre Dame, one switched to business, another to music. One of the two who is still in engineering plans to work in finance after graduation.

Mr. Moniz’s experience illustrates how some of the best-prepared students find engineering education too narrow and lacking the passion of other fields. They also see easier ways to make money.

Notre Dame’s engineering dean, Peter Kilpatrick, will be the first to concede that sophomore and junior years, which focus mainly on theory, remain a “weak link” in technical education. He says his engineering school has gradually improved its retention rate over the past decade by creating design projects for freshmen and breaking “a deadly lecture” for 400 students into groups of 80. Only 50 to 55 percent of the school’s students stayed through

graduation 10 years ago. But that figure now tops 75 percent, he says, and efforts to create more labs in the middle years could help raise it further.

“We’re two years into that experiment and, quite honestly, it’s probably going to take 5 to 10 years before we’re really able to inflesh the whole curriculum with this project-based learning,” Dean Kilpatrick says.

No one doubts that students need a strong theoretical foundation. But what frustrates education experts is how long it has taken for most schools to make changes.

The National Science Board, a public advisory body, warned in the mid-1980s that students were losing sight of why they wanted to be scientists and engineers in the first place. Research confirmed in the 1990s that students learn more by grappling with open-ended problems, like creating a computer game or designing an alternative energy system, than listening to lectures. While the National Science Foundation went on to finance pilot courses that employed interactive projects, when the money dried up, so did most of the courses. Lecture classes are far cheaper to produce, and top professors are focused on bringing in research grants, not teaching undergraduates.

In 2005, the National Academy of Engineering concluded that “scattered interventions” had not resulted in widespread change. “Treating the freshman year as a ‘sink or swim’ experience and accepting attrition as inevitable,” it said, “is both unfair to students and wasteful of resources and faculty time.”

Since becoming Notre Dame’s dean in 2008, Dr. Kilpatrick has revamped and expanded a freshman design course that had gotten “a little bit stale.” The students now do four projects. They build Lego robots and design bridges capable of carrying heavy loads at minimal cost. They also create electronic circuit boards and dream up a project of their own.

“They learn how to work with their hands, how to program the robot and how to work with design constraints,” he says. But he also says it’s inevitable that students will be lost. Some new students do not have a good feel for how deeply technical engineering is. Other bright students may have breezed through high school without developing disciplined habits. By contrast, students in China and India focus relentlessly on math and science from an early age.

“We’re in a worldwide competition, and we’ve got to retain as many of our students as we can,” Dean Kilpatrick says. “But we’re not doing kids a favor if we’re not teaching them good life and study skills.”

WORCESTER POLYTECHNIC INSTITUTE, in Massachusetts, one of the nation's oldest technological schools, has taken the idea of projects to heart. While it still expects students to push their way through standard engineering and science classes, it ripped up its traditional curriculum in the 1970s to make room for extensive research, design and social-service projects by juniors and seniors, including many conducted on trips with professors overseas. In 2007, it added optional first-year projects — which a quarter of its freshmen do — focused on world problems like hunger or disease.

“That kind of early engagement, and letting them see they can work on something that is interesting and important, is a big deal,” says Arthur C. Heinricher, the dean of undergraduate studies. “That hooks students.”

And so late this past summer, about 90 freshmen received e-mails asking if they typically received flu vaccines. The e-mails were not from the health services office, but from students measuring how widely flu spreads at different rates of vaccination. Two of the students had spent part of their freshmen year researching diseases and devising a survey. Now, as juniors, they were recruiting the newcomers to take part in simulations, using neon wristbands and stickers, to track how many of them became “infected” as they mingled during orientation.

Brenna Pugliese, one of the juniors and a biology major, says the two-day exercise raised awareness on campus of the need for more students to get the vaccine. “I can honestly say that I learned more about various biology topics than I ever learned in any other class,” she says.

Teachers say they have been surprised by the sophistication of some of the freshmen projects, like a device to harvest kinetic energy that is now being patented. But the main goals are to enable students to work closely with faculty members, build confidence and promote teamwork. Studies have shown that women, in particular, want to see their schoolwork is connected to helping people, and the projects help them feel more comfortable in STEM fields, where men far outnumber women everywhere except in biology.

Seventy-four percent of W.P.I. undergraduates earn bachelor's degrees within four years and 80 percent by six years.

Most of the top state research universities have added at least a splash of design work in the freshman year. The University of Illinois began this fall to require freshmen engineering students to take a course on aspirations for the profession and encourages them to do a design project or take a leadership seminar. Most technical schools push students to seek summer internships and take semesters off to gain practical work experiences. The hope is

that the lure of high-paying jobs during an economic downturn will convince more students to stick with it.

Some private schools have also adjusted their grading policies to ease some of the pressure on STEM students. The Massachusetts Institute of Technology has long given freshmen only “pass” or “no record” grades in the first half of the year while they get used to the workload. W.P.I. lets undergraduates take up to three classes for which no grade is recorded if they would have received less than a C. Any required courses would have to be repeated.

Ilea Graedel, a 20-year-old junior in aerospace engineering, says that policy provides “a nice buffer if you want to try something new, like a class outside your comfort zone.”

But what really helps Ms. Graedel get through the rigors of STEM, she says, is hanging onto her aspirations. She grew up in a farming area in Washington State, the only student from her high school class of 26 pursuing a technology degree. She has wanted to be an astronaut since she was 3, when her mother took her to Boeing’s Museum of Flight in Seattle and bought her a book called “I Want to Be an Astronaut.”

The space program has been sharply cut back. Still, she says, “I’m going to hold onto that dream very dearly.”

Christopher Drew covers military technology for The Times.

This article has been revised to reflect the following correction:

Correction: November 5, 2011

An earlier version of this article, in one instance, misstated Peter Kilpatrick’s surname as Kirkpatrick.