Physics for the Future U.S. Work Force

Principles of Technology is a controversial program that brings physics to students who wouldn't otherwise study it

San Bruno, California

IN A LABORATORY at Capuchino High School in San Bruno half a dozen groups of students huddle over lab benches on which sit pairs of copper pipes. They have filled the pipes with heated water and are learning about thermal resistance by comparing the rate of heat loss in insulated versus non-insulated pipes.

After the lab, the students watch a short video. It begins like an adventure movie: a Navy ship is sinking. Alarms sound, and the crew prepares to abandon ship, donning insulated survival suits to help maintain body heat in the frigid water while awaiting rescue. The video uses this dramatic scenario as a launching point for discussion of heat flow from warm bodies to cold water and the role of insulation in slowing that flow.

This may sound like a high school physics class, but it's not—in the usual sense, anyway. Nor is the teacher, Bill Faustine, a physics teacher, even though he has a good grounding in physics. When he's not teaching this class, you can find Faustine teaching auto mechanics and wood shop. As odd as that juxtaposition may sound, the students in this class actually have more in common with Faustine's auto mechanics students than with the average high school physics student: They aren't university-bound and wouldn't have believed physics could have any relevance to their lives. Through this course, called Principles of Technology, Faustine and teachers like him hope to change their minds.

Principles of Technology, PT for short, is an innovative attempt to solve a big problem: the lack of technical training in the U.S. work force. By teaching principles of physics rather than simply teaching techniques for auto repair or metalworking, the course's developers hope to provide students with the skills needed to adapt to a rapidly changing and increasingly technical workplace.

Is it a success? It may be a bit soon to say. PT has only been in operation for 3 years nationwide and the statistics aren't all in. But some tests do show that PT students have absorbed a great deal. And visits to classes where PT is taught show an enhanced enthusiasm for science and technology. Yet there are detractors of the course who feel that in its attempt to make physics palatable to a broader range of students, PT wreaks havoc with some of the discipline's most fundamental concepts.

PT is directed at the middle 50% of high school students, the so-called "neglected majority" who are not bound for a 4-year college and who, for the most part, will head from high school straight to the workplace. The 14-unit, 2-year course was developed in the mid-1980s by the Center for Occupational Research and Development (CORD) and the Agency for Instructional Technology (AIT), both nonprofit organizations that develop curricula for occupational training. PT is now being taught to 40,000 students in 1,500 U.S. high schools.

"Our target was to bring more kids into physics, but not into the higher track," says Leno Pedrotti, one of the course's originators at Texas-based CORD. "It's physics for technology and technicians. We use the laws of physics to show how everyday industrial devices work."

The course covers the concepts of force, work, rate, resistance, energy, and power and their applications in fluid, mechanical, electrical, and thermal systems. It emphasizes hands-on laboratory exercises, and supplements them with videos that, as Pedrotti puts it, "use real people saying 'its important for you to learn about energy or power or resistance, because I use it all the time in my job; let me show you how'."

Since PT is only in its third year of being taught nationwide, not enough time has passed for follow-up to see if the course has changed students' lives. But Faustine says he sees positive effects already. More than half of the 90 students in his classes this year have expressed an interest in pursuing careers in technology. The course encourages kids to give science a try, Faustine says. "And then they learn science can be fun."

Indeed, on a recent visit Faustine's students did seem to be having a good time. "We learned about why cars are shaped the way they are to reduce wind resistance," said one burly boy in a football jacket, who added that he was afraid to try to learn science before he took PT. "He taught us how a toilet works," laughed Sindi Massis, who said she failed biology because she found it boring, but is getting a B in PT.

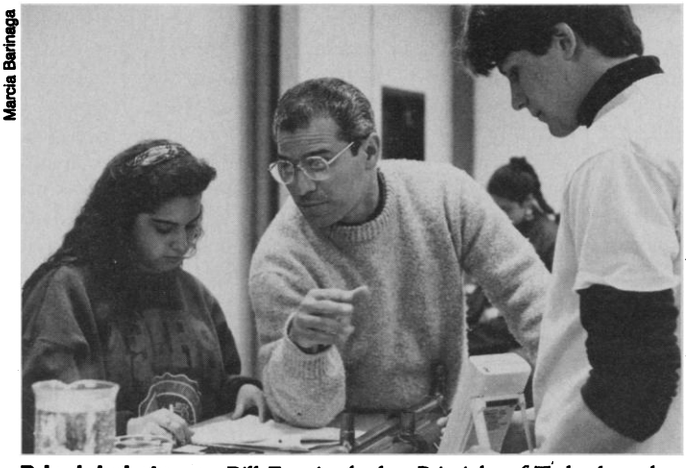
Faustine says 70% of his students earn an A or a B, despite the fact that the course is demanding—especially in its second year. "I can take a kid with a D in algebra, and he will do fine in here," he says. Faustine insists that that's not because he is an easy grader. "Applied math is so much easier to teach than theoretical," he says. "We do trig problems and the kids have no trouble."

"It makes it easier to understand math and science," agrees senior Stephen Nelms, a student in Faustine's second-year class who has decided to go to junior college and study technology or engineering, a career he says he wouldn't have considered before.

"You're looking at a real general crop of kids," Faustine says. "There are no Einsteins here. We're not cranking out an engineer who can go out and design a new device for the world, but these kids can walk into research and development–type places and run the equipment." They have the foundation necessary to be trained to maintain nuclear power plants, he says, or operate equipment for a NASA design team.

Indeed, many school districts that teach PT have developed coordinated programs with local community colleges, in which PT students get credit toward associate degrees in aeronautics, electronics, and other types of industrial technology.

But critics of PT complain that, in its effort to demystify physics, it is bungling physical concepts and turning out gradu-



Marcia Barinaga

Principled stance. *Bill Faustine leads a Principles of Technology class through a workshop on thermal resistance and heat loss.*

ates ill-equipped to communicate with the rest of the physics and engineering world. "There is a great deal of nontraditional vocabulary in the program," says James E. Dixon, assistant professor of physics at Iowa State University. "If you go through this program, you wind up speaking a different language of science."

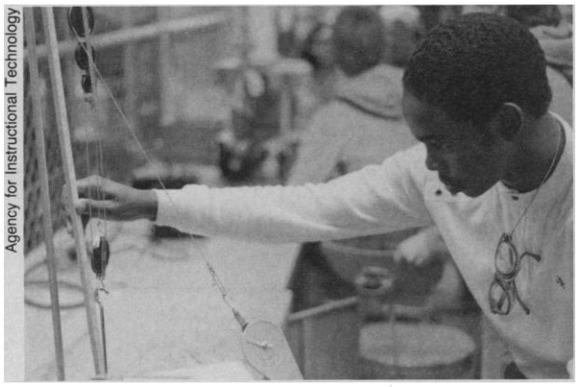
This new "language" comes out of the course's attempt to group similar concepts when presenting them to the student. For example, students first learn that force moves objects. Then they learn about other "force-like quantities," such as pressure, voltage, and temperature gradients, which cause movement in fluid, electrical, and thermal systems. This conceptual approach, central to the PT philosophy, can lead to terms that are anathema to physicists. Dixon, for example, bristles at what PT makes of the term "actual mechanical advantage." In physics, actual mechanical advantage (AMA) is the ratio of output to input force in a simple machine, but in PT its definition is broadened to include the voltage ratio of an electrical transformer. "AMA doesn't relate to a transformer," Dixon groans. "Any physicist isn't going to know what you're talking about."

There are other criticisms as well. Steven Iona, a Colorado physics teacher who has taught PT for 2 years, faults the course for providing little sense of the importance of experiments in science. The PT lab devoted to heat flow could allow students to compare the properties of various materials, Iona says, but instead they are locked into testing only aluminum. "The equipment is designed so you could not take out the aluminum to put in other materials," he says.

Iona also complains that the PT course material spoon-feeds mathematics to the students. The prepared exercises provide the students with all the equations they need to solve the problems, he says. "I don't know how 'real life' that is for a technician."

But defenders of PT say the course has different goals than a college-prep physics course because its students have different needs. PT's mission, they say, is to instill the concepts essential in the technological workplace—not to stimulate the abstract thinking needed in academic science. "The biggest complaint people have is that it's not a standard physics course," says John Roper, principal of North Shore Regional Vocational High School in Beverly, Massachusetts. "But we're not talking about a standard physics student. These kids would normally not be taking physics, so whatever they get is an advantage."

Even with good material, inspiring and engaging that group of students is a challenge. And all involved in PT agree that it is difficult to find the right kind of teacher for the course. The ideal is someone like Bill Faustine, who has industrial experience as well as a strong background in physics. But there aren't many Faustines around. "The majority [of vocational teachers] are not equipped to teach PT," says William Callahan, a consultant in industrial and technology education for the California Department of Education.



The pull of knowledge. *Studying a pulley system in a PT course in Fort Wayne, Indiana.*

But Callahan isn't dispirited by this. "You can't send them back to college," he says, "but you can teach them how to teach applied physics." Which is why California plans to follow the lead of other states and provide summer workshops for teachers, taught by successful PT instructors like Faustine.

John McDonagh of the Massachusetts Department of Education says such workshops have been successful in his state, where PT was pilot-tested from 1984 to 1986 and is now taught in 40 high schools. Although the state has not done follow-up studies on the students, McDonagh says there are signs that PT is being well taught: enrollment is growing and not one school has dropped the course.

There's another reason schools may be reluctant to drop PT. That's the money they have invested in it. It costs $20,000 to $40,000 to outfit a PT laboratory—big money for a high school. But industry, which has developed an interest in PT, is beginning to come to the rescue. In Washington State, Boeing has launched a $300,000 grant program to help high schools set up PT programs. Says Kathy Nepean, administrator of corporate education relations at Boeing: "Most of the business community is starting to recognize that demographics are showing that the technical skills are going to be lacking unless something is done earlier to interest students." Boeing feels that PT can help channel more students into community college programs from which it hires its technicians.

The $64,000 question in all of this is: Can PT actually reach the mid-range students and improve their interest and performance in science? Pedrotti points to studies that suggest the answer is yes. Edward Terceiro, associate dean of Bristol Community College in Fall River, Massachusetts, helped create a "tech-prep" program at local high schools, which included PT. He tracked the attendance and performance of the students in the program. Compared to the students' own records from the previous year, or to the records of their peers who weren't in the program, the group improved its attendance by 10% and its tardiness by 20 to 22%. In the first graduating class, some improved their overall grade average by a point or more and even went on to 4-year schools. "Many of these were youngsters who would not have completed high school, let alone graduated from college," Terceiro says. "We've been very pleased with the results of the program."

John Dugger, chairman of industrial education and technology at Iowa State University, compared 257 PT students from 15 Iowa high schools to 275 students who had taken standard high school physics. The students were given the same physics skills test before and after the course. The physics students went from a pretest mean of 55 out of 120 to a posttest mean of 66; PT students raised their average from 48 to 80.

But Iowa State's Dixon is highly critical of that test. One third of the question, he says, deal with technology topics such as gauges and machines that are not part of a standard physics curriculum. Others use PT terminology—such as the "actual mechanical advantage of a transformer"—that would leave students of traditional physics without a clue. The test, Dixon says, "is not a valid measure of what a student learns in a high school physics course."

Dugger defends his test, saying that, although it was designed to measure the objectives of PT, he had physics teachers examine the questions for relevance to their courses. Furthermore, he says, the results are striking even if you ignore the comparison with physics students and just look at the progress made by PT students.

Between classes, Bill Faustine gestures toward some students who have come into his classroom to tinker with equipment. "Upon graduation, so many of these kids will walk away saying 'I don't know what I just did for the last 4 years.' I'd like to think we're making a little dent in that kind of thinking." ■ MARCIA BARINAGA