A Push to Reorder Sciences Puts Physics First

By TAMAR LEWIN

For generations of high school students, the sequence of science has been a given: 9th-grade biology, 10th-grade chemistry and, for the minority who make it that far, 11th-grade physics.

But that sequence, established a century ago when science was a simpler matter, is now being questioned, with a growing number of scientists and educators arguing that physics ought to come first.

While only a few schools have actually retrained their teachers and made the difficult transition to ninth-grade physics, there is increasing consensus that flipping the sequence gives the curriculum a coherence it now lacks, and allows students to build on concepts they have learned.

"We're proposing a kind of conceptual physics that is not so mathematical, using just the algebra ninth graders know," said Leon Lederman, a Nobel Prize-winning physicist who is the leading advocate of physics first. "You can teach Newtonian motion, the conservation of energy, and give a feeling for what an atom is, so they can walk into chemistry the next year with grace and confidence. Having those concepts first seems to be especially helpful for girls and minorities. I'm sure it's a winning battle, but like truth and justice, it's going to take some time."

In good part, the push to reorder science education is a response to a century's worth of advances in scientific knowledge.

"The old curriculum came from the 1800's when biology was very descriptive," said Michael Bernstein, who teaches ninth-grade physics at Friends Seminary, a Manhattan private school. "Kids would go out in the field, collect samples, draw pictures and dissect things.

"They didn't learn the chemistry of what goes on inside cells, because it wasn't known. And in chemistry, they would do some

Continued on Page 17

Laura Pedrick for The New York Times

A Slinky is used in an energy test by Bibi Deitz, left, and Kelly Edwards in an Annandale, N.J., class.

Continued From Page 1

pretty things in test tubes and learn some basic reactions. But now biology is by far the most complicated of the sciences, with much, much more biochemistry."

Mr. Bernstein said that giving freshmen a thick biology text full of new vocabulary and new concepts, as he did at the public school where he used to work, runs the risk of putting them off science altogether.

"These poor little ninth graders come in with no chemistry or physics," he said. "You can talk to them about energy, but they don't really know what energy is, so they end up with this huge textbook, having to memorize things they don't have the background to understand. With hands-on physics as their first high school science, they can really get excited about learning fundamental principles."

One measure of the success of putting physics first is the enormous growth in the number of students taking advanced courses at schools that have flipped the sequence.

At North Hunterdon High School in Annandale, N.J., for example, there were only 38 students enrolled in any Advanced Placement science class in 1990-91, the last year of the old sequence. The new curriculum has brought steady increases in those numbers, and this year, a record 226 students are in Advanced Placement science: 98 in biology, 49 in physics, 41 in environmental science and 38 in chemistry. Students who complete

In a new course sequence, students can build on the scientific concepts they have learned.

spring, some hefty margins of error — but by the end of the hour, all but one of the groups had proved, more or less, that energy was conserved.

"This makes more sense, to start with physics, to go from gravity to machines to motion, and study how the whole world works before you start breaking it up," said Amy McKinsey, a ninth-grade student planning to move into advanced chemistry next year.

The switch to physics first is slow, though. While no one knows exact figures, fewer than 100 schools teach ninth-grade physics. Not coincidentally, several are in the Chicago area, Dr. Lederman's home territory. Naperville North High School, 30 miles west of Chicago, began offering ninth graders a choice of earth science or physics in 1996. That first year, most chose earth science, but now the balance has tipped, with slightly more choosing physics.

"The kids really do like it," said Bill Engler, the science coordinator. "And now the teachers want to teach it, both because it's a fun course, and because they've seen that the kids who've had it can do more advanced work when they go on to the other subjects. We're guessing that next year, for the first time, we'll have to offer an advanced physics course."

Nationwide, putting physics first seems to have been adopted at as many private schools as public ones. In New York, it is mostly private schools, including Friends, Packer, Calhoun and Trevor Day. But in Philadelphia, the school board is hoping to nudge all 42 public high schools toward ninth-grade physics over the next few years.

"It has this whole wonderful domino effect," said Natalie Hiller, the Philadelphia system's science education coordinator. "Once students know the big ideas, it opens the whole world of science for them. This is something that's been bubbling under the surface of science education for years, but now it's really beginning to happen. It's a big change, though, and it's not always met with open arms."

For one thing, there are far more

the Advanced Placement courses and pass Advanced Placement exams with good marks can get college credit for their work.

"I really think this sequence helps students stay with science, by presenting it logically," said Tom Palma, chairman of the North Hunterdon science department. "In any ninth-grade biology class, you keep hearing the teacher say, 'You'll understand this better next year when you study chemistry.' And in chemistry they say, 'You'll understand this better next year, when you get physics.' So why not teach it that way?"

In most ninth-grade physics classes, many activities are planned around practical questions, like why sunsets are red, how a lightning rod protects a house, which part of a hot pizza burns your mouth, or why a bird can sit on a power line without being electrocuted. Students may estimate how many kernels of corn they would have to pop to fill a coffee can, analyze the mechanics of a roller coaster, launch water rockets or design a container that would keep an egg dropped from a roof from breaking.

At a recent North Hunterdon lab, 23 ninth graders were studying conservation of energy with cut-up Slinkys taped to a yardstick. Working in noisy groups of three, they attached different weights to the Slinkys, measured how far they stretched, graphed the data and calculated whether the gravitational potential the weighted spring lost from its scrunched-up position equaled the springing-back potential it gained when it dropped.

There were weights that fell off, mathematical errors, conceptual confusions — and, because of the difficulty of measuring moving

open arms."

For one thing, there are far more biology teachers than physics teachers, in part because under the traditional sequence, only a quarter of all high school students ever got to physics. In the course of the transition there comes a year when there is no introductory biology class, forcing all the biology teachers to teach physics, a subject many feel ill-prepared to tackle.

"The biggest problem of turning this thing upside down is that you have a big group of teachers who are heavy on the life sciences end of things, the descriptive part, not even the biochemistry," said Jim Nelson, a teacher trainer in Florida. "It's a major problem to find teachers who are comfortable teaching physics. Teacher training is still an important component of what's going on."

At North Hunterdon, Mr. Palma offered twice-weekly after-school training for the physics-teachers-to-be and promised them that, if necessary, he would come into the classroom and teach the first lesson of the day, while they took notes so they could teach it for the rest of the day.

"It only came down to that a few times," he said. "But the logistics of the switchover years are four years of hell."

There are other obstacles, too. There are no biology or chemistry texts written specifically for students who have had introductory physics. And even physics teachers accustomed to teaching a math-heavy curriculum to the most advanced students, often object to the prospect of taking on ninth graders.

"You get a lot of physics teachers who say they don't do freshmen," Dr. Lederman said. "But uniformly, the people who are doing it are enthusiastic."

In Science magazine last summer Dr. Lederman and a co-author, Mar

jorie Bardeen, published "Coherence in Science Education," arguing that the time is right for physics first, given schools' increasing trend of requiring at least three years of high school science, as called for in the 1996 National Science Education Standards, published by the National Research Council.

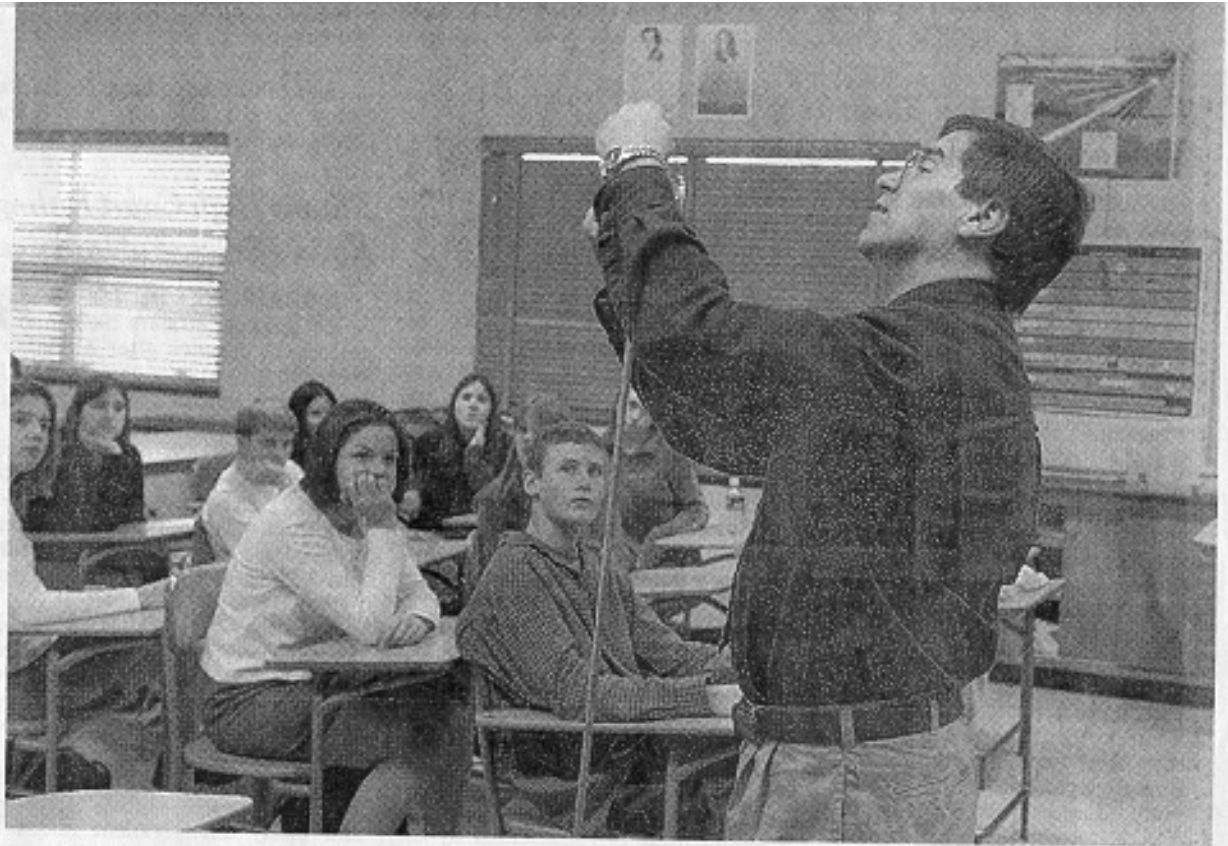
While there is widespread criticism of American science education, and interest in reform, physics first is not the only approach being considered.

Some favor the European model, in which students typically take two science courses at the same time, progressing through, say, biology and chemistry simultaneously, with both the text and the teaching coordinated so that the fundamentals in chemistry are covered before the biochemistry comes up in biology.

Others, especially in seventh to ninth grades, are integrating the sciences by studying each topic as a physicist, biologist or chemist might, looking, for example, at the chemistry of water, its specific heat and its effect on weather.

"People are talking about all kinds of different approaches," said Harold Pratt, director of science projects at the National Academy of Science's Center for Science, Mathematics and Engineering. "Physics first is maybe a little bit of a physicist's perspective. Other scientists might say ninth graders can learn a lot about their bodies or the environment without knowing chemistry. But physics first is the model you see schools changing to."

Two widely used ninth-grade physics curriculums are "Conceptual Physics," the textbook used at North Hunterdon, and "Active Physics," a series of projects on different themes, each lasting several weeks.



Laura Pedrick for The New York Times

Tom Palma teaches a ninth-grade physics class at North Hunterdon High School in Annandale, N.J. "I really think this sequence helps students stay with science, by presenting it logically," he said in an interview.

Arthur Eisenkraft, the science coordinator at Fox Lane High School in Bedford, N.Y., favors "Active Physics," in part because of the flexibility it gives students who miss a unit, or have trouble with one topic.

"We might start out with developing a sport that could be played on the moon," Mr. Eisenkraft said. "To do that, students have to learn about weight on the moon, air resistance on the moon, friction on the moon. All sports involve friction. After a couple weeks, students have enough knowledge to start creating their sport.

"They find that a lot of sports wouldn't work on the moon, like in baseball, a hit could take 30 seconds. Then the next project might be how to have a rock concert where people's hearing won't be damaged, so we start talking about decibels. For kids who had trouble with the moon sport, you can say, just try this one."