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Shaking Up Science

Putting Physics First Changes More Than Sequence

For more than 100 years, biology has been the first stepping-stone in high school science. However, some educators are now flipping the traditional biology-chemistry-physics sequence to better mesh with the latest discoveries of science and the evolution of science teaching. By teaching physics to students as early as 8th grade, and chemistry and then biology in subsequent years, teachers aim to help students understand more deeply the concepts and connections across these sciences.

Such a change brings challenges. Physics, which is typically taught to the top 25 percent of high school students with a strong grasp of abstract math, has to be retooled for younger students who lack such math skills. For students who've had little or no algebra, physics teachers favor hands-on and inquiry approaches that ground concepts such as energy, force, and motion in the real world rather than rely on mathematical scenarios found in traditional textbooks.

Putting physics first is also driving changes in subsequent high school chemistry and biology curricula. Students who have studied physics, for example, enter chemistry class with a stronger understanding of atoms and how these combine to form molecules, which, in turn, helps them with the complexities of modern biology.

Science educator Earl Legleiter, who helped El Dorado Unified School District 490 in Kansas move to a physics-first sequence, recently presented a paper at the Biology and the Physics First Curriculum symposium held in Colorado Springs, Colo. In his presentation, Legleiter maintained that the inquiry approach recommended by the National Science Education Standards favors a physics-chemistry-biology sequence. "Experiments in physics are the easiest to do as students manipulate physical phenomena that they can touch. Inquiry is more

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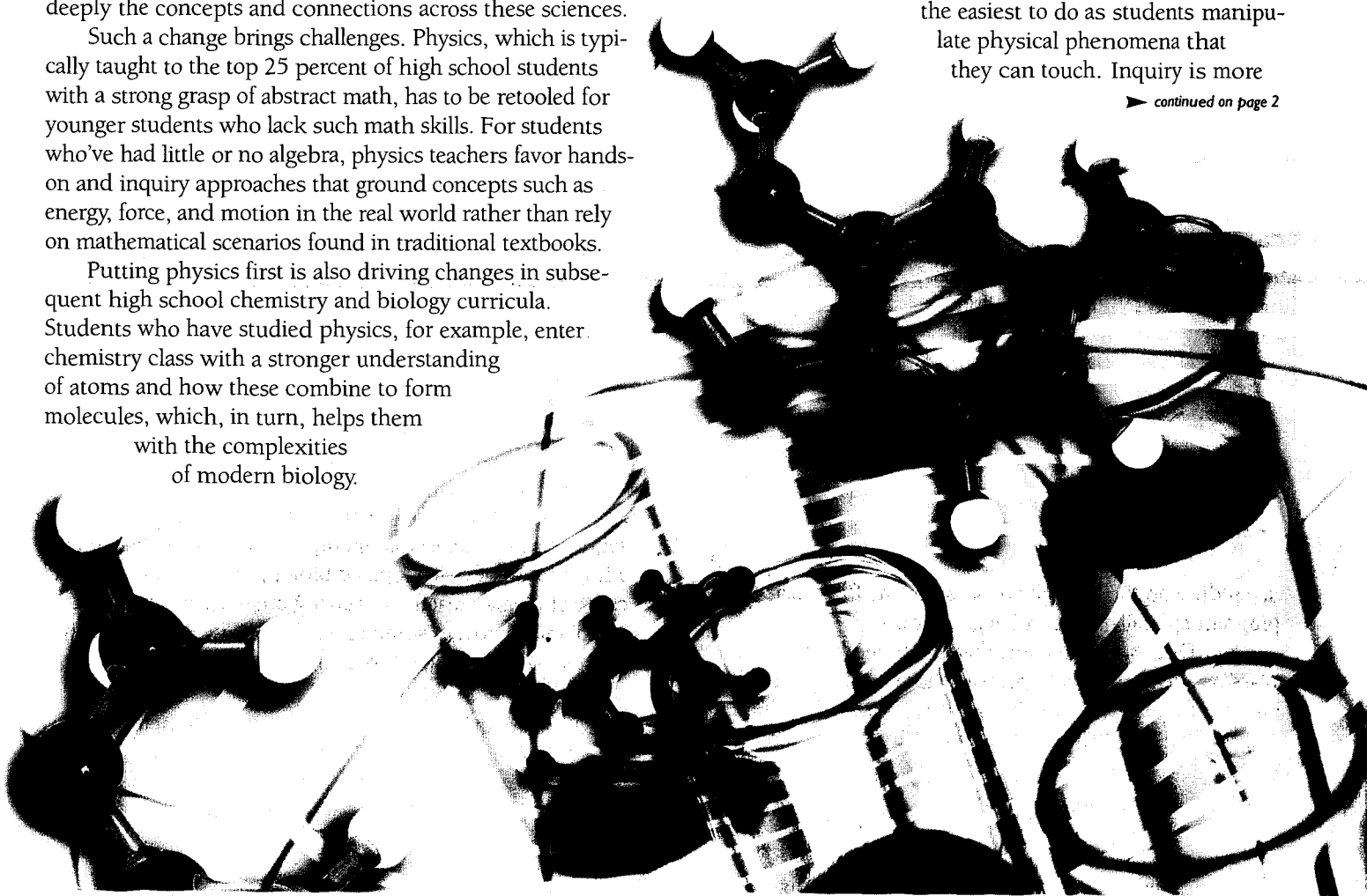

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abstract in chemistry, where students are required to relate the macroscopic world in the test tube to an atomic model they can only infer," he said. According to Legleiter, biology experiments are the most difficult for high schoolers because these experiments have so many variables to control and the results require special analysis.

An Outdated Order?

Biology became the science most high schoolers study based on the 1893 recommendation of an education task force known as the Committee of Ten. At the time, biology consisted of botany and zoology under the umbrella of natural history and involved training students to observe, describe, and even draw plants and animals as accurately as possible for the sake of categorization. Because biology didn't require the lab equipment and time that chemistry and physics needed, these educators believed it was the most realistic course for high schools to offer, says Kenneth Roy, director of science and safety at Glastonbury Public Schools in Connecticut.

Today, biology is no longer merely the study of the physical characteristics of organisms; it probes more deeply into how the chemistry of DNA, for example, determines the functions of a cell, the basic unit of every living system. Because biology now deals with more complex learning, some educators believe reordering the biology, chemistry, and physics sequence will benefit students.

Glastonbury shifted its teaching of physics to 8th graders in 1995. The district, which had already set itself up as a curricular leader by pioneering Russian language study during the Sputnik era, began teaching topics such as force, motion, heat, and nuclear science "without the heavy math," says Roy. He points out that before the physics requirement, most students would never have studied these matters.

By Roy's reckoning, Glastonbury's curricula shift has met with success because of the depth of its high school science offerings. After all students take 8th grade physics, they can choose either academic (a conceptual approach) or honors (college prep) achievement levels for the chemistry and biology that follow. Choosing levels is flexible: because the science sequence starts in 8th grade with physics, students who initially study conceptual science courses can still choose to add college prep or advanced placement (AP) chemistry, physics, or biology before they graduate. In grades 11 and 12, students can pick from a variety of science electives including anatomy, biotechnology, geology, genetics, or meteorology.

Roy credits the 8th grade physics courses with inspiring additional students to continue more difficult levels of science study and bringing about an equal number of boys and girls in upper level physics classes. AP physics enrollment "has gone through the roof," he says. Glastonbury High School, which had only one such class 10 years ago, now offers four and will add a fifth this fall, Roy explains. In 2000, the district was recognized as a regional leader for increasing the number of students in AP science courses and increasing AP test scores. "This is another indicator that physics-first is working," Roy notes.

A Sea Change in San Diego

San Diego City Schools, the eighth largest district in the United States, adopted a physics-first curriculum in 2001, but the curriculum transformation that has all 10,000 students in the 9th grade taking physics this year has been formidable. For starters, the district had to hire 10 new physics teachers and retrain 25 biology and chemistry teachers.

San Diego's switch to physics-first came as part of an effort to make district graduates more qualified for entry into the California state university system. University officials' suggestion that high school students take three years of science as preparation for college became a district mandate. Also, biology teachers had been lobbying to teach their course

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Curriculum Update

Curriculum Update reports trends, research findings, exemplary programs, and available resources in a specific curriculum area. The views expressed herein are not necessarily official ASCD positions.

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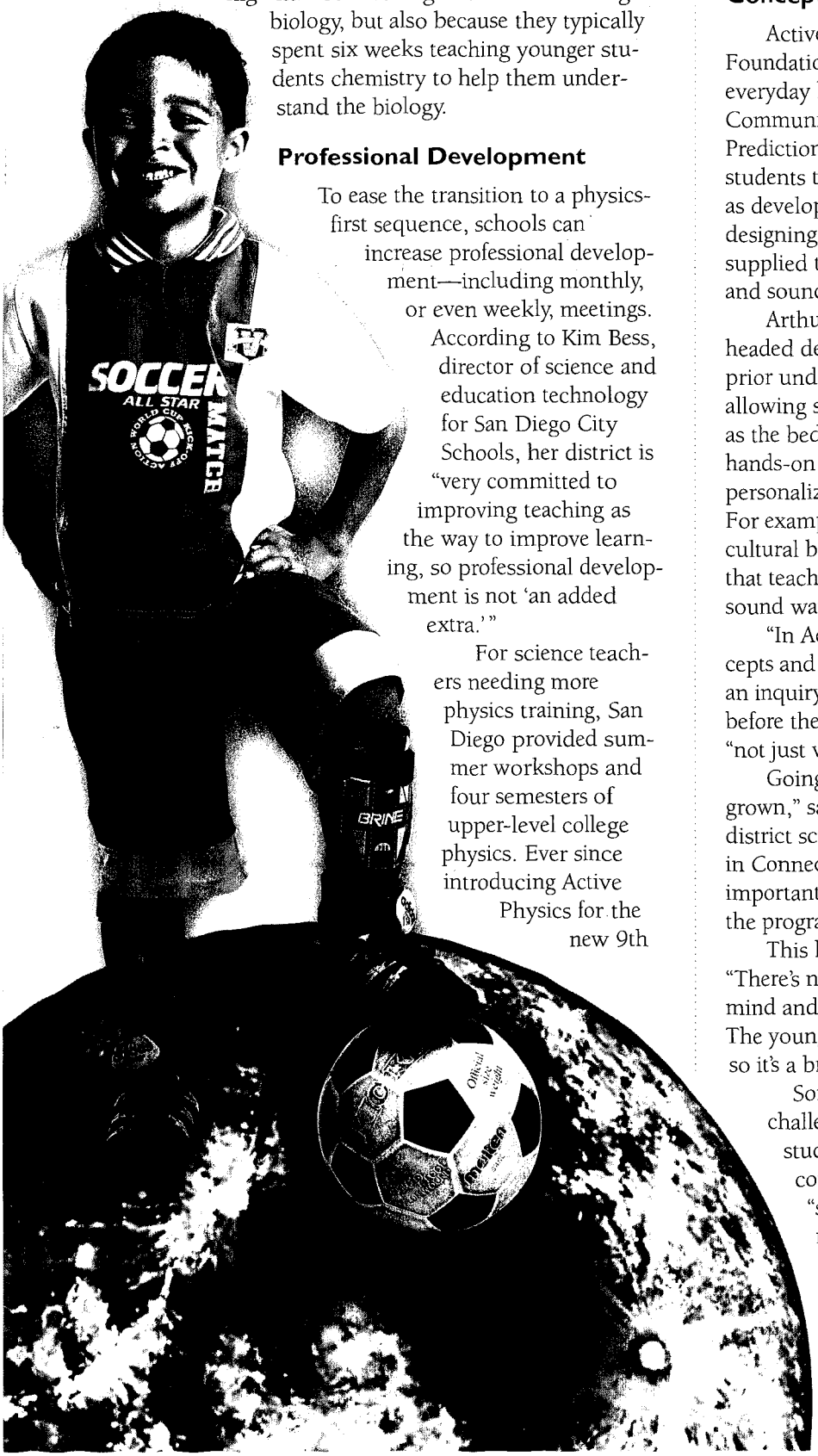
later in the science sequence, not only because they had a high number of 9th grade students failing biology, but also because they typically spent six weeks teaching younger students chemistry to help them understand the biology.



Professional Development

To ease the transition to a physics-first sequence, schools can increase professional development—including monthly, or even weekly, meetings. According to Kim Bess, director of science and education technology for San Diego City Schools, her district is "very committed to improving teaching as the way to improve learning, so professional development is not 'an added extra.'"

For science teachers needing more physics training, San Diego provided summer workshops and four semesters of upper-level college physics. Ever since introducing Active Physics for the new 9th grade curriculum, district physics teachers have met monthly to preview the next month's work with curriculum leaders and discuss potential classroom challenges through a hypothetical "student lens," Bess says.

Concepts, Not Calculus

Active Physics, which grew out of a National Science Foundation project, ties major physics concepts to everyday life. Curriculum units include such themes as Communication, Home, Light Up My Life, Medicine, Predictions, Sports, and Transportation. Activities challenge students to use physics concepts to solve such problems as developing a sport that could be played on the moon, designing an appliance for a land where electricity is supplied through wind generators, or even creating a light and sound show.

Arthur Eisenkraft, a veteran physics teacher who spearheaded development of Active Physics, says using students' prior understanding, engaging students intellectually, and allowing some freedom of choice to shape an activity serve as the bedrock principles for the curriculum. Through hands-on activities, students become "experts" who can personalize their knowledge to share with other students. For example, students often use elements from their own cultural backgrounds in a light and sound show project that teaches them to apply the physics principles of optics, sound waves, and electronic circuits, among others.

"In Active Physics, we introduce activities before concepts and concepts before vocabulary," says Eisenkraft. Such an inquiry approach allows students to do an experiment before they are told what the results would be, so they're "not just verifying what the textbook tells them," he adds.

Going further, conceptual physics can be "homegrown," says Fred Myers, science department chair and district science coordinator at Farmington High School in Connecticut. "We don't view the textbook as real important—it's a tool. It's really the teachers who bring the program to life," Myers asserts.

This liveliness is a key to reaching younger students. "There's no question that we're dealing with a different mind and body between 9th graders and 12th graders. The younger students are enthusiastic and try harder, so it's a breath of fresh air in the classroom," Myers says.

Some physics concepts, however, can still be challenging for younger minds. When 9th grade students had difficulty understanding the key concept of acceleration, Farmington teachers "spent a lot of time attacking the issue from many different angles," Myers says, but it was still not getting through to the students.

Finally, teachers used an array of six tasks,

including one titled Slippery Delivery. In that activity, an imaginary scenario required that a sled loaded with jewels be moved from one location to another in a certain amount of time. To model the story, small groups of students worked to decide what amount of weight on a string was needed to pull the block of wood—the "sled"—in the designated time. Such fantastic scenarios with silly titles are "actually a big hit" with students, Myers says, and often students will continue the fun as they weave the activity's storyline into their lab reports.

Myers says it is more than mere coincidence that Farmington students have the highest scores in the state on the science experimentation portion of the Connecticut Academic Performance Test for 10th graders. "The emphasis on experimentation enables students to experience laboratory investigations and practice scientific methods early in their high school careers," says Myers. Physics, more than earth science, for example, lends itself to classroom experiments, he contends.

Riding Out Test Anxieties

Unlike Connecticut, California has not retooled its state science tests for an inquiry approach. In addition, students must take the subject-area test in the year they take the course. Initially, San Diego's 9th graders did not fare so well on the state physics test, which is still aimed at 12th graders. But Bess says 9th graders' scores did improve dramatically the second year. She attributes this to the district's professional development and a greater comfort level for those teaching physics to younger students—both factors that can help students grasp the content. "If students have a deep enough conceptual understanding of a content area, we think they'll be able to succeed on the test," Bess says.

The proof will be in 2005–06, Bess contends, when the first group completing the new science sequence will take the California Standards Test in biology. "We'll blow the lid off that test," she predicts.

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Effects on Chemistry and Biology

In San Diego, the change to physics-first and the emphasis on inquiry and hands-on approaches have affected the chemistry and biology curricula, as well as the physics curriculum. This year, the district adopted Living by Chemistry, a curriculum developed at the Lawrence Hall of Science at the University of California, Berkeley. Using units titled Alchemy, Foods, Showtime, Smells, Toxins, and Weather, the curriculum's authors weave in student investigations that encourage a conceptual understanding of chemistry in a context students can relate to.

For the upcoming school year, San Diego adopted a new, inquiry-based, learner-centered curriculum developed by the Biological Sciences Curriculum Study (BSCS) called BSCS Biology: A Human Approach. A traditional biology text might merely explain DNA, which regulates the development of all living things, as a complex of molecules arranged in a characteristic helix. In the new approach to biology, students might be required to assemble models of DNA with colored beads and predict how the model would change

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depending on the data given, says Danine Ezell, science program specialist for San Diego schools.

San Diego's requirement that all students take three years of science will help prepare them not only for college but also for jobs in a growing industry—after San Francisco and Boston, San Diego ranks as the third-largest biotechnology center in the country, Bess points out. Even though most students may not decide to become physicists, chemists, or biologists, "these new curricula help students to see the big ideas and apply them to a real-world context," Bess says. "If you do that, you can hook kids."

Further changes to biology curricula are in the works, say researchers who use the working title "capstone biology" to denote its new place in the high school science sequence. The content of a capstone biology course varies depending on the amount of integration of physics, chemistry, and earth science that takes place in prior years, according to the report from a recent BSCS symposium, Biology and the Physics First Curriculum.

The new focus is not just on molecular biology, says BSCS Executive Director Rodger Bybee. A capstone course "would have greater depth and breadth of biological concepts and provide more opportunities for students to study a greater range of topics related to health, the environment, the human genome, or population resources."

Although many educators whose schools have switched to physics-first are satisfied with the results, not everyone is convinced that the approach is the only way to reform science. Wayne Carley, executive director of the National Association of Biology Teachers, agrees that the physics-first sequence has "intellectual merit," but also notes that "there's a huge cadre of well-prepared biology teachers and a small cadre of physics teachers." Having other science teachers retool for physics in summer workshops won't be enough, "despite what people tell you," Carley warns.

Carley's counterpart at the American Association of Physics Teachers, Bernard Khoury, agrees that many practical questions for science teachers need to be hammered out, but calls himself "an advocate of physics for all."

"We need to do away with the presumption that physics is only for the best and brightest," Khoury says. Although he agrees that physics-first is not the only way to go and suggests that curricula that integrate life science, physical science, earth science, and technology could also work, Khoury, nonetheless, is pleased that significantly more students are taking physics now than were taking it 30 years ago. He attributes that interest to the rise of conceptual physics curricula.

Let's stop presuming that physics is only for "the best and brightest."

The goal of getting all students to take physics first—which can motivate them to take further science courses—isn't to create more scientists for the future, says Nobel prize-winning physicist Leon Lederman, the leading advocate of the physics-first movement. The goal is to have educated citizens who can make decisions about science's role in society. "I'm mostly interested in improving public science literacy. By the end of high school, a student should be ready for all possible futures, whether at work, in the military, in engineering school, college, or family life. A good science and math education prepares students for life."

—Rick Allen

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