'Depth' Matters in High School Science Studies

By Sean Cavanagh/*Education Week* March 11, 2009

The scientific world is vast. One key to students' developing a strong understanding of it could be having them focus on relatively few topics, in great depth.

That is the main conclusion of a recent study that examines one of the most enduring debates in science instruction—whether "depth" or “breadth” of knowledge is most important. Its authors come down on the side of depth.

High school students who focus more intensely on core topics within their biology, chemistry, and physics classes fared better in beginning college science than those who delved a little bit into a larger list of topics, the study found. Observers say those findings could offer direction to developers of science curricula, tests, and textbooks.

A central finding is that "breadth-based learning, as commonly applied in high school classrooms, does not appear to offer students any advantage when they enroll in introductory college science courses," the authors conclude, "although it may contribute to scores on standardized tests."

Delving Into the Subject

Students, on average, reported taking high school science courses in which in-depth coverage of topics was common.

Arguments over depth vs. breadth are common across subjects. In science, however, that debate is especially vexing.

Numerous scientific organizations and researchers have called for teaching and tests that are more focused on mastery of big topics. In their view, that position is backed up by the opinions of scientific experts and research on cognition and how humans build knowledge.

Yet paring down scientific topics, and determining which ones merit the most attention, is not easy. Many textbooks are written to meet the academic standards of multiple states, and as a result, are crammed with information, or "encyclopedic," as the study notes. Teachers also face pressure to prepare students for the questions they will encounter on state-mandated science tests, which are in turn based on the content found in state academic standards.

The study, published online in December by the journal Science Education, suggests that approach is misguided. It was written by Marc S. Schwartz, a professor of mind, brain, and education of the University of Texas at Arlington; Philip M. Sadler, the director of the science education department at the Harvard-Smithsonian Center for Astrophysics, in Cambridge, Mass.; Gerhard Sonnert, a research associate, also at the Harvard center; and Robert H. Tai, an associate professor of science education at the University of Virginia, in Charlottesville.

Mechanics and Mastery

The authors build their research on a national survey of 8,310 undergraduates enrolled in their first college science course. Students were asked how much time they spent in high school biology, chemistry, and physics classes on various subtopics.

In each subject, the researchers said students had been exposed to a topic in depth if they reported spending at least one month on it—for instance, mechanics or electromagnetism in physics or evolution in biology. They controlled for other factors, such as students' socioeconomic background and math proficiency.

The results show that students who had spent at least one month on one particular topic earned higher grades in college science courses than students who had not. By contrast, those who had been exposed to a relatively long list of topics, but not in depth, did not have any advantage in college chemistry or physics and were at a disadvantage in biology.

One possible explanation for the benefits of in-depth study is that asking students to achieve "some level of mastery" provides them with confidence and a "yardstick for comprehension" in science, Mr. Sadler speculated in an e-mail. They become aware of the time and effort it takes to learn something new in science and in college studies specifically, he said.

Mastery also can help students overcome common false impressions in science, he added in an interview.

"If you study something in depth, you have the time to deal with some of the misconceptions that impede you when you get to college," Mr. Sadler said.

In-depth teaching can have a major impact, the authors maintain. Students who experience deeper coverage of physics in high school perform in college as if they had received two-thirds of a year more preparation than those who had the opposite mix of depth and breadth. In chemistry, students appeared to gain the equivalent of one-quarter of a year's worth of study from in-depth lessons, the authors found.

In biology, students taught under an approach emphasizing breadth performed as if they had received a half-year less preparation in high school in that subject.

The researchers acknowledge that the study does not address important questions, such as how much depth is the right amount. It also does not evaluate which subtopics within biology, chemistry, and physics have the greatest benefit; they are conducting a follow-up study on that issue, Mr. Sadler said.

The study also points to high-stakes science tests as a factor promoting overly scattered science teaching.

If those exams "require recall of unrelated bits of scientific knowledge," they influence teachers to do the same, the authors say. They cite a 2005 study that found science frameworks in the United States, on which tests typically are based, are loaded with more topics than those of other countries that outperform the United States.

AP Approach

In recent years, some testing entities have sought to place greater emphasis on probing students' depth of science knowledge. The College Board, which has been criticized for promoting what some say is a diffuse approach on its Advanced Placement science exams, is redesigning them to emphasize depth and scientific reasoning, said Trevor Packer, a vice president of the New York City-based nonprofit organization. The first of those revisions, to the AP Biology test, will be unveiled in September.

The study's findings reinforce the importance of the College Board's revisions, Mr. Packer said. Even so, he said he expected that some scientists and educators would be disappointed with the changes to the AP science tests, in the belief that one topic or

another was being improperly de-emphasized. Among scientists and subject-matter experts, such disagreements are common.

"We've had to take a stand," Mr. Packer said. "All of these topics are important, but they don't all have to be learned at the same time."

One of the benefits of encouraging students to focus more deeply on science topics is that they develop a stronger grasp of science, overall, and are likely to be more motivated to pursue factual knowledge in future studies, said Senta Raizen, the director of the National Center for Improving Science Education. Her center, based in Washington, is part of the testing and research nonprofit WestEd.

A motivated science student "is willing to play a lot of catch-up," Ms. Raizen said.

Francis Eberle, the executive director of the National Science Teachers Association, in Arlington, Va., said the study does not address an important issue: the disconnect between high school and college science courses. Too many postsecondary courses emphasize "straight, rote learning" through lectures, and suggest to undergraduates that their goal is to "prepare the best" among them, a departure from the more nurturing approach many students encounter in high school, Mr. Eberle argued.

Even so, the study will likely challenge a common assumption in the scientific community that schools need to focus on breadth to produce professional-level scientists, who know all aspects of the subject, he said. Changing teaching and testing methods is difficult, Mr. Eberle added.

"Our traditions are so strong. Our system is designed for breadth," he said. There are other factors, too. "Any time you change the system" for teaching science, Mr. Eberle said, "parents will say, 'That's not the way I had it.'"