Preparing Your Students for Careers in Science and Engineering: How Is Your State Doing?

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With one glance at the starting salaries of new bachelor's degree recipients in Fig. 1, a teacher or parent can see the career fields to which their high school students interested in the best economic opportunities might aspire: several engineering fields (chemical, electrical, mechanical), computer science, physics, and mathematics.

And which high school courses do these students need to take to prepare best for these fields? Common sense likely suggests higher-level math and science courses. Research agrees: taking physics and calculus in high school is the best preparation for students who want to pursue degrees in science, technology, engineering, and math (STEM).

A group from the Departments of Sociology and Anthropology and the Center for Career and Community Research at the University of South Florida examined the critical role that course-taking in physics and calculus plays in preparing students for bachelors' degree programs in STEM fields.[1] Their results are illustrated in Figs. 2 and 3, which depict bachelor's degree attainment rates by the highest math and science courses students have taken in high school. In each figure, the top panel illustrates the attainment rate for a bachelor's degree in any field. The STEM degree attainment rates are shown in the bottom panel.

The top panel in Fig. 2 demonstrates that taking Algebra 2 makes a great contribution to making a student college ready; students who continue through trigonometry, pre-calculus, or calculus are even better prepared for college. However, the bottom panel makes it clear that Algebra 2 falls far short of preparing a student for success in a STEM bachelor's degree program—continuing through calculus is clearly a much better strategy for a student with STEM aspirations. In fact, students who complete calculus in high school are almost seven times more likely to earn a bachelor's degree in a STEM field than those whose top math course is Algebra 2.

Figure 3 makes a similar case in science. While chemistry is associated with being college ready (top panel), it takes physics to make a student STEM ready (bottom panel). A student who completes physics is twice as likely to complete a bachelor's degree in a STEM field than one who takes only chemistry; taking a second course in either subject increases the likelihood of earning a STEM degree even more. This likely seems self-evident to most high school physics teachers, but it is generally not appreciated among teachers in other fields—even other science fields—and principals. In fact, staff at the American Physical Society hired a marketing firm to address the issue[2] and *The Physics Teacher* has published an article about how to recruit students into physics classes.[3]

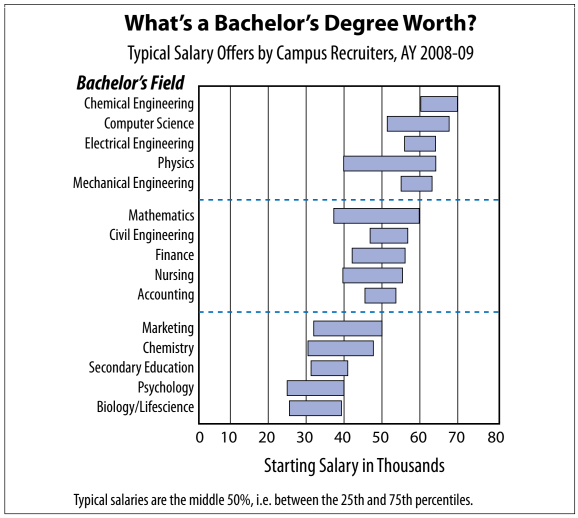

Fig. 1. Typical salary offer to new bachelor's degree graduates by field for Academic Year 2008-2009. **Source: AIP Statistical Research Center, reprinted from the Fall 2009 Salary Survey, with permission of the National Association of Colleges and Employers, copyright holder.**

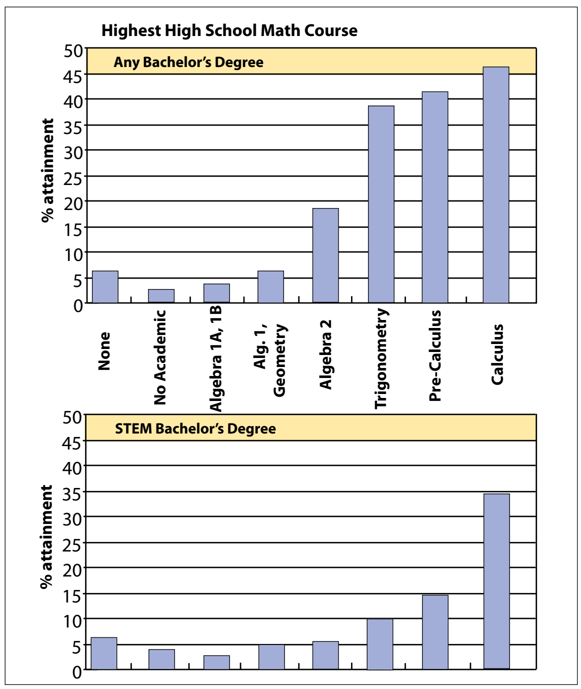

Fig. 2. Bachelor's degree attainment rates for all fields (top panel) and STEM fields (bottom) panel, sorted by the highest level math course taken, from Tyson et al. [1]

The degree to which students are well prepared for bach-

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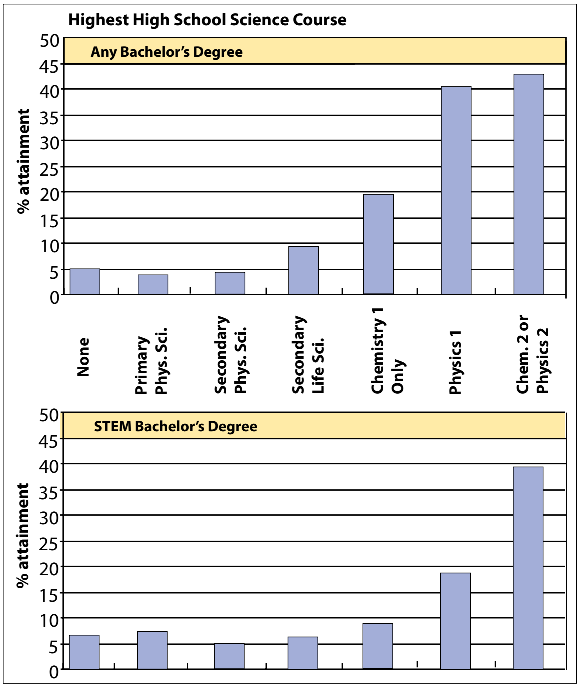

Fig. 3. Bachelor's degree attainment rates for all fields (top panel) and STEM fields (bottom) panel, sorted by the highest level science course taken, from Tyson et al. [1]

elors' degree programs in science and engineering varies dramatically from state to state. We recently devised a metric, the Science and Engineering Readiness Index (SERI), that demonstrates these striking variations.[4] The index incorporates results from the National Assessment of Educational Progress[5,6] (NAEP, conducted periodically by the U.S. Department of Education), Advanced Placement examination results in calculus and physics,[7] the physics course-taking results from the American Institute of Physics National Survey of High School Physics Teachers,[8] and information on teacher certification requirements in science compiled by the National Council on Teacher Quality (NCTQ).[9] (More details about each of these data are provided in a technical note at the end of this article.) The information from these sources is gathered into three scores on mathematics performance, science performance, and teacher qualifications. The scores are then used to assign each state a single composite score. The formulation of this index provides an opportunity for examining the strengths and weaknesses of each state's K-12 mathematics and science programs.

The final product of the SERI analysis is a sorting of the states into seven categories—"Best in the U.S." (awarded to Massachusetts), "Well above average," "Above average," "Average," "Below average," "Far below average," and "Worst in the U.S." The states are color coded by categories in Fig. 4.

Given the disappointing (but not surprising) performance of the United States on the PISA assessment of 15-year-olds in science and math,[10] it is worth pondering this question: How good does a state have to be to compete successfully at an international level in science education? A hint at an answer is given by a paper published in the journal *Science* by researchers in Ohio, Maryland, and China.[11] They pre-tested freshmen students in their universities before they took physics at college using two well-validated assessment instruments —the Force Concept Inventory [12] and the Brief Electricity and Magnetism Assessment.[13] The differences between the score distributions of the American and Chinese students are striking and reflect the high priority given to pre-college physics instruction in Chinese schools. Ohio (rated "average" by the SERI) and Maryland (rated "above average") are clearly not able to compete with the Chinese in physics preparation. Furthermore, it is unlikely that any American state can at present, including Massachusetts. It is likely that Chinese students outperform students from all states.

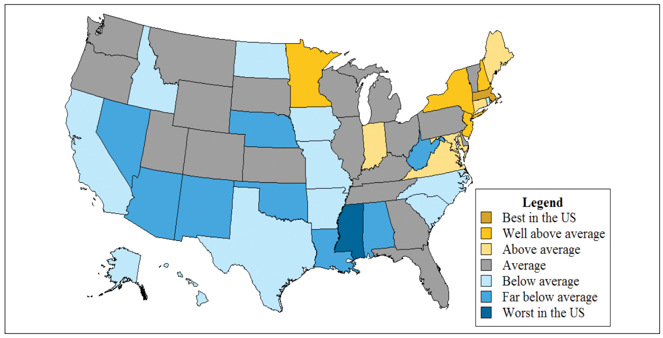

Fig. 4. State ratings using the Science and Engineering Readiness Index.[4]

At present Massachusetts defines the level of excellence for American states. Other states should examine the Massachusetts model to see how to improve the preparation of K-12 students for success in college and beyond.

Technical note

The data for the Advanced Placement exams come from the College Board and represent every student who took the respective AP® exam.

For the physics-taking data, AIP surveyed a nationally representative sample of 1/6 of all the schools, both public and private, in the U.S. and extrapolated up to population estimates controlling for state, type of school (public/private), and size of school (number of seniors). So the physics-taking numbers, while they come from a sample of students, are calculated and intended to represent all students.

Likewise, the NAEP data are also derived from statewide representative samples. The "About State NAEP" web page (nces.ed.gov/nationsreportcard/about/state.asp) states: "NAEP provides results about subject-matter achievement, instructional experiences, and school environment, and reports these results for populations of students (e.g., fourth-graders) and subgroups of those populations (e.g., male students or Hispanic students)."

In both cases where a sample was used, statistical sampling procedures were used to insure that the sample data are representative of the entire population.

Finally, the National Council for Teacher Quality data are based on NCTQ's analysis of state policies regarding state high school science licensure requirements.

The authors used the data as reported.

References

1. W. Tyson, R. Lee, K. M. Borman, and M. A. Hanson, "Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment," *JESPAR* **12**, 243-270 (Oct. 2007).
2. G. Popkin, "Recruiting Physics Students in High School," *Newsletter of the Forum on Education of the American Physical Society* (Summer 2010), pp. 30–31.
3. E. Barrett, "Increasing physics enrollment in your school," *Phys. Teach.* **47**, 399–400 (Sept. 2009).
4. S. White and P. Cottle, *Newsletter of the Forum on Education of the American Physical Society* (Summer 2011), pp. 7–11.
5. 2009 National Assessment of Educational Progress in Mathematics, National Center for Education Statistics, U.S. Department of Education; nces.ed.gov/nationsreportcard/mathematics/.
6. 2009 National Assessment of Educational Progress in Science, National Center for Education Statistics, U.S. Department of Education; nces.ed.gov/nationsreportcard/science/.
7. "7th Annual AP Report to the Nation," College Board, 2011; apreport.collegeboard.org/report-downloads.
8. S. White and C. L. Tesfaye, "High School Physics Courses & Enrollments: Results from the 2008-09 Nationwide Survey of High School Physics Teachers," American Institute of Physics, 2010; www.aip.org/statistics/trends/reports/highschool3.pdf. (For state-specific data, contact Susan White at swhite@aip.org)
9. "The All-Purpose Science Teacher: An Analysis of Loopholes in State Requirements for High School Science Teachers," National Council on Teacher Quality, 2010; www.nctq.org/p/publications/docs/NCTQ_All_Purpose_Science_Teacher.pdf.
10. H. L. Fleischman, P. J. Hopstock, M. P. Pelczar, and B. E. Shelley, "Highlights from PISA 2009: Performance of U.S. 15-year-old Students in Reading, Mathematics and Science Literacy in an International Context" (NCES 2011-004), U.S. Department of Education, National Center for Education Statistics.
11. L. Bao, T. Cai, K. Koenig, K. Fang, J. Han, J. Wang, Q. Liu, L. Ding, L. Cui, Y. Luo, Y. Wang, L. Li, N. Wu, "Learning and scientific reasoning," *Sci.* **323**, 586–587 (Jan. 2009).
12. D. Hestenes, M. Wells, and G. Swackhamer, "Force Concept Inventory," *Phys. Teach.* **30**, 141–158 (March 1992).
13. L. Ding, R. Chabay, B. Sherwood, and R. Beichner, "Evaluating an electricity and magnetism assessment tool: Brief electricity and magnetism assessment," *Phys. Rev. ST Phys. Educ. Res.* **2**, 010105 (2006).

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