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Feature

From the National Academies: The Challenges and Opportunities for Improving Undergraduate Science Education through Introductory Courses

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Unlike previous articles that have informed readers of *Cell Biology Education* about education initiatives at the National Academies, this article is written primarily to stimulate and elicit your comments and feedback about introductory undergraduate science courses and ways to better serve a changing and more diverse student body. I hope to stimulate an exchange of ideas through an electronic discussion forum (details are provided below). Contributions from readers will be posted by *CBE* and made available to the members of the National Research Council's Board on Science Education, which is seeking input from the postsecondary science education community about the most critical issues related to introductory undergraduate science courses. Input from *CBE* readers, participants at a small workshop held in June 2004, and participants in other activities will guide the Board in deciding on possible studies or other programs that will explore high-priority issues in greater detail.

OVERVIEW OF ISSUES

Introductory science courses often give undergraduates their first and, for many students, their last formal exposure to a deeper understanding of science. Thus, introductory courses might be the only opportunity to provide a basic level of scientific literacy for the educated lay public. The importance of introductory courses cannot be overstated!

These courses also greatly influence whether many students, especially those from populations that are underrepresented in science, technology, engineering, and mathematics (STEM), will continue to study more science in college. On the basis of experiences in introductory courses, impressions about science are especially important for students who will become K–12 teachers because they will influence the attitudes and the science content preparation of the next generation of students (National Research Council, 1999).

Students, Teaching, and Learning Issues

However, there is no general agreement about how best to serve diverse student audiences and, in some disciplines, no formal consensus about desired learning outcomes. As a result, introductory science courses have evolved into a plethora of approaches and emphases. In some departments, only a single introductory course is available to everyone, regardless of the major or career path that students migh choose. In others, there might be separate courses for prospective majors in the discipline, those who will major in a different science discipline (e.g., physics for engineering majors), those going on to careers in teaching, or others who are pursuing majors outside the sciences. Some courses require laboratory components, whereas others do not. Some departments permit students with high scores on Advanced Placement (AP) or International Baccalaureate (IB) examinations to earn credit and either move to a higher level course immediately or fulfill the science requirement completely without taking any science at the college level. Conversely, other departments refuse to accept advanced placement or other examinations as substitutes for enrollment in introductory courses (e.g., see National Research Council, 2002).

In addition to these questions concerning content and organization, debate about effective pedagogies in introductory courses is ongoing. Emerging research on human cognition and learning (e.g., Etkina *et al.*, in press; Hake, 1999; McNeal and D'Avanzo, 1997; National Research Council, 2000, 2003a) is beginning to yield insights and direction on ways to improve science education at all levels. Unfortunately, few faculty are familiar with this literature; therefore, it is rarely applied in classroom and laboratory settings.

Introductory Courses as Gatekeepers: The Issue of Alignment

Students often decide whether they will major in science on the basis of their experiences in introductory courses (e.g., Seymour and Hewitt, 1997). In too many cases, students who enter college planning to major in one of the sciences change their plans after completing an introductory course. Course content, methods of teaching, and testing in introductory undergraduate science courses can be completely different from what students experienced during high school. At the same time, content can be largely a repetition of the courses taken before entering college (especially for those who were enrolled in AP courses or IB Programs; see National Research Council, 2002).

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Introductory courses often become de facto gatekeepers, filtering out students who do not have an adequate background from their high school experience or those whose learning styles are not readily adapted to the environment of larger, less personal classrooms and teaching laboratories. This filtering process has significant consequences for the talent pool most essential to the continued vitality of the scientific community: future scientists, K–12 (and postsecondary) faculty in science, and those working in the technical sectors of the economy. Importantly, among those who decide not to pursue scientific majors and careers are large numbers of underrepresented minorities and, in some disciplines, women. One of the most discouraging aspects of this loss is that students who enter college with intentions to major in science and then change their minds following completion of introductory courses have academic credentials equal to those who continue to major in the natural sciences (Seymour and Hewitt, 1997). Thus, poorly taught introductory courses could be contributing to the loss of a significant and more diverse talent pool from the STEM disciplines.

In contrast, positive experiences in introductory science courses can encourage students who intended to pursue other career paths to focus on science instead. Thus, another challenge for individual faculty and science departments collectively is to find ways to build on these positive experiences and enable students to study more upper-level science even though they might not want to formally declare a major in one of the science disciplines.

Institutional and Professional Issues

Beyond issues of teaching and learning, introductory courses are inextricably bound to, and influenced by, the culture and infrastructure of both modern science and higher education. For example, these courses can be quite expensive, particularly when many instructors or labs require expensive instrumentation and consumables. Cutbacks in funding for higher education are compelling educators to find ways to reduce such expenses at many institutions. Laboratories, field experiences, or smaller course sections that require greater numbers of faculty and teaching assistants might be compromised as a result. Faculty members have many competing interests and responsibilities and many different incentives. If introductory courses lack institutional support, teaching in these courses can rank near the bottom of the priority list for many faculty.

These problems could be compounded if academic departments do not spend the time required discussing and adjusting the role and place of their introductory courses with respect to upper level courses within the discipline and service to other disciplines, as well as in response to the needs of the increasingly diverse student body that is enrolling. A lack of attention can lead to discontinuities in content, differing emphases among sections of the same course, or large and unpredictable changes over time as different faculty are rotated through these courses. It also can result in lack of articulation with upper-level courses in the discipline and with the high school experiences that students bring with them to college (National Research Council, 2003a). Many such problems can be resolved by having members of departments assume "collective responsibility" in articulating the learning goals, content, and skills that students should acquire during the introductory course sequence (National Research Council, 2003b).

Accountability

Legislators, policymakers, and educators at the state and national levels are increasingly examining the higher education system in the United States. Calls for improved methods of assessment and greater accountability for the ways that undergraduates are educated are becoming more frequent.[1] Introductory courses will likely be increasingly scrutinized. Given the many changes in approaches to teaching, learning, and assessment that are now permeating undergraduate education in STEM, a critical examination of the different approaches in introductory science courses and how these courses might be improved is needed and timely.

NEXT STEPS—YOUR INPUT AND PERSPECTIVE ARE NEEDED!

The National Research Council's (NRC's) Board on Science Education[2], currently under the chairmanship of Nobel Laureate Dr. Carl E. Wieman, has been facilitating a number of planning activities focused on the current status of introductory science courses. These steps are crucial to help the NRC decide whether formal studies or other convening activities would be of service to the higher education science community. One of these planning activities was a small workshop in June 2004 made possible by funding from the National Science Foundation, in which invited participants addressed the following framing questions.

- *What is the vision for the roles that introductory science courses might play?* Given the current organization of science, basic learning goals, disciplinary knowledge, and need for alignment with high schools, how can introductory courses be improved?
- *What is the scope of the issues?* What do the data show about course-taking patterns, pass rates, and placement statistics in and out of first-year courses, both for prospective science majors and for prospective science teachers? What are the workforce needs and issues in science and technology sectors?
- *What is present and what needs to be?* What is the state of introductory courses at present with respect to issues, including alignment with high school courses; placement of incoming students; interdisciplinarity; appropriateness for nonmajors, majors, and teacher education students; and assessment?
- *What are the policy drivers at the institutional, state, and national levels that influence the current structure of introductory courses?* How might those drivers need to change in order to achieve the vision?

[1] Additional information and numerous links to information are available from the National Association of Colleges and Universities (http://www.naicu.edu/Accountability/national/). See also Brakke and Brown (2002), Venezia (2002), and the National Research Council (2003b).

[2] For more information about the mission and activities of the Board on Science Education, see http://www7.nationalacademies.org/bose/.

Within this larger set of four framing questions, more specific questions posed to workshop participants included the following.

- What are the factors shaping introductory science course experiences?
- What mechanisms are available to determine student placement in introductory courses and are those mechanisms well aligned with high school graduation requirements in science?
- What does research tell us about course-taking patterns after the introductory course for science majors, non-majors, and teacher education students?
- How are learning outcomes for introductory courses determined?
- What pedagogical assumptions shape introductory courses and lab experiences?

A workshop with a small number of invited participants might not reflect the views and perspectives of the larger science education community. Therefore, we are seeking input from a broader cross section of faculty (both K–12 and postsecondary) and others who are directly involved with the preparation, teaching, and administration of introductory undergraduate science courses. The editors of *Cell Biology Education* have agreed to assist this effort by establishing a series of discussion threads on their Web site that can be accessed directly at http://www.cellbioed.org/discussion/public/main.cfm or through a link from the online version of this article.

The discussion threads will be organized on the basis of the four framing questions noted above. A separate "Other" thread also will be available for comments that do not fit within any of the four themes or that address the five more specific questions. You are encouraged to submit new comments about one or more of these questions or respond to comments posted by other readers. We will download comments and responses regularly and compile them for distribution to members of our Board on Science Education at their Spring 2005 meeting.

Your comments and perspectives are very much appreciated and valued by the Board on Science Education of the National Research Council.

REFERENCES

Brakke, D.F., and Brown, D.T. (2002). Assessment to improve student learning. In: Building Robust Learning Environments in Undergraduate Science, Technology, Engineering and Mathematics, ed. J.L. Narum and K. Conover. San Francisco: Jossey-Bass, 119–122. Available at http://www.pkal.org/template2.cfm?c_id=350.

Etkina, E., Mestre, J.P., and O'Donnell, A. (in press). The impact of the cognitive revolution on science learning and teaching. In: The Impact of the Cognitive Revolution on Educational Psychology, ed. J. Royer. Greenwich, CT: Information Age Publishing, Inc.

Hake, R.R. (1999). Research, Development, and Change in Undergraduate Biology Education: A Web Guide for Non-Biologists. http://www.physics.indiana.edu/~redcube/redcube.pdf (accessed 23 September 2004).

MacNeal, A.P., and D'Avanzo, C., ed. (1997). Student Active Science: Models of Innovation in College Science Teaching. Orlando, FL: Harcourt Brace.

National Research Council. (1999). Transforming Undergraduate Education in Science, Mathematics, Engineering, and Technology. Washington, DC: National Academies Press. http://nap.edu/catalog/6453.html (accessed 23 September 2004).

National Research Council. (2000). How People Learn: Brain, Mind, Experience, and School, Expanded Ed. Washington, DC: National Academies Press. http://nap.edu/catalog/9853.html (accessed 23 September 2004).

National Research Council. (2002). Learning and Understanding: Improving Advanced Study of Mathematics and Science in U.S. High Schools. Washington, DC: National Academies Press. http://nap.edu/catalog/10129.html (accessed 23 September 2004).

National Research Council. (2003a). Improving Undergraduate Instruction in Science, Technology, Engineering, and Mathematics: Report of a Workshop. Washington, DC: National Academies Press. http://nap.edu/catalog/10711.html.

National Research Council. (2003b). Evaluating and Improving Undergraduate Teaching in Science, Technology, Engineering, and Mathematics. Washington, DC: National Academies Press. http://nap.edu/catalog/10024.html (accessed 23 September 2004).

Seymour and Hewitt. (1997). Talking About Leaving: Why Undergraduates Leave the Sciences. Boulder, CO: Westview Press.

Venezia, A. (2002). A Student-Centered P-16 Accountability Model: Encouraging High Standards, Equitable Educational Opportunities and Outcomes, and Flexibility Within A Seamless System of Education. Issue Paper. Washington, DC: Education Commission of the States. http://www.ecs.org/clearinghouse/40/04/4004.htm (accessed 23 September 2004).