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Book Review: Advanced Biology Programs in U.S. High Schools

Learning and Understanding: Improving Advanced Study of Mathematics and Science in U.S. High Schools: Report of the Content Panel for Biology, by the Committee on Programs for Advanced Study of Mathematics and Science in American High Schools, National Research Council (William B. Wood, Ed.); 300 pp.; 2002; National Academy Press (Washington, DC); http://www.nap.edu/catalog/10129.html

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REPORT OF THE CONTENT PANEL FOR BIOLOGY: BACKGROUND

The National Research Council's (NRC's) Committee on Programs for Advanced Study of Mathematics and Science in American High Schools recently conducted a study and published its results in a book that describes the current status and recommendations for improvement of advanced science and mathematics education in U.S. high schools (NRC, 2002a). The parent committee formed four content panels to conduct the study over a 2-yr period: biology, chemistry, physics, and mathematics. The Content Panel for Biology, responsible for the report reviewed in this column, comprised a member of the parent committee, two high school biology teachers (although only one teacher's name was listed on the panel membership list near the front of the book), and four university professors.

The biology panel was charged with evaluating the Advanced Placement (AP) and International Baccalaureate (IB) programs in biology with regard to 1) the curricular and conceptual frameworks of the programs that structure teaching and student learning; 2) the role of assessment in supporting student learning; 3) the quality of teaching in the programs and teacher preparation; 4) the alignment between each of the programs and the recommendations in the *National Science Education Standards* (*NSES*; NRC, 1996); and 5) the degree to which the programs prepare high school students for success in college courses beyond the introductory level. Both the AP program and the IB program offer advanced high school courses in science and mathematics and examination-based, end-of-course scores for reporting student achievement. Each program has operated for 40 to 50 yr, and both are currently experiencing rapid increases in the numbers of participating schools and students. Readers are encouraged to refer to the NRC book for a good description of the similarities and the substantial differences between the two programs.

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The biology panel report describes AP and IB biology programs in the United States, assesses the relative strengths and weaknesses of each program, and offers recommendations for improvement. Only summaries of the panel reports are included in the book (NRC, 2002a). However, the full reports from all four content panels are available as pdf files at www.nap.edu/catalog/.

CURRENT CONDITIONS AND RECOMMENDATIONS FOR AP AND IB BIOLOGY

The biology panel's principal findings and recommendations fall under the following areas: curriculum, instruction and professional development, assessment, and the secondary–postsecondary interface. The findings and recommendations are distributed over several chapters with useful descriptions and commentary on the programs. Three recommendations are identified as "primary" to accentuate their importance:

1. The College Board should certify schools and teachers for AP biology and provide suitable professional development, assess AP programs and teachers using samples of student work, and add the use of student work to the current system of using only final exam scores in assessing student achievement.
2. Certification and assessments of both the AP program and the IB program should align with pedagogical and content knowledge recommendations in the *NSES* (NRC, 1996) and recent research on cognition and learning.
3. Colleges and universities should not use AP or IB test scores as the sole basis for placement out of introductory courses for biology majors and course distribution requirements for nonmajors.

The following four subsections briefly describe the findings and the secondary recommendations of the biology panel.

Curriculum

AP and IB curricula are out of date and overemphasize environmental, population, and organismic biology. Both

curricula lack areas of significant and rapid progress in cell and molecular biology, such as genomics, cell signaling, development, and molecular evolution. Too much content is often covered in too little time. The IB curriculum lacks two important content themes—energy transfer and heredity—whereas the AP curriculum lacks sufficient integration with other subjects, which results in a lack of interdisciplinary material. Finally, the AP curriculum in particular lacks sufficient inquiry-based laboratory activities. These findings prompted seven recommendations by the biology panel:

1. AP biology should not be offered as a first science course in high school; it should build on an introductory biology course.
2. AP and IB curricula should be updated to represent current interest and research in the field of biology.
3. AP and IB curricula must be better balanced (more molecular and cell biology in AP and more evolutionary biology in IB).
4. The College Board should consider offering a molecular/cell biology course and a separate environmental/population/organismic course, both with an emphasis on evolution and each with a corresponding AP exam.
5. Depth should be emphasized over breadth in the AP curriculum.
6. The AP laboratory work needs improvement: more inquiry-centered activities, a greater choice of laboratory investigations, mandatory laboratory pedagogy workshops for teachers, more laboratory questions on the AP exam, and a requirement for AP schools to offer high-quality laboratory experiences.
7. The AP program should include more interdisciplinary activities that link to local issues.

Instruction and Professional Development

Many teachers are unprepared to teach advanced-level high school biology content. Furthermore, the pedagogy used in the AP and IB courses is often not aligned with recommendations for inquiry-centered instruction in the *NSES* (NRC, 1996) or recent research on cognition and learning (NRC, 2000a). AP and IB programs do not provide sufficient professional development in either the content or the standards-based pedagogy, although the IB program is better in this regard. The biology panel deemed these findings so important that one of its primary recommendations, stated previously, is focused on appropriate pedagogy and professional development for teachers.

Assessment

AP and IB final exams focus largely on rote learning. However, the IB program includes a broader array of assessment instruments including student portfolios, laboratory notebooks, and other student work. Both programs assess what is easily measured rather than what ought to be most highly valued: well-structured conceptual knowledge and understanding of biological phenomena. The biology panel recommended inclusion of a wider variety of student work and more exam questions designed to assess student understanding of major concepts. Also, the biology panel recommended that the AP program make the students' exam answers available to teachers after student evaluations.

Secondary–Postsecondary Interface

Many university-sponsored outreach programs could serve as resources for the advanced biology programs, and the biology panel encouraged communication through this avenue. Many AP and IB courses should not substitute for introductory college biology. In particular, the AP course is not focused strongly enough on molecular and cellular biology. AP and IB courses should better align teaching and curriculum across the advanced high school biology–introductory college biology interface and approach the challenge in a systemic way involving schools, colleges, universities, and the College Board.

COMMENTARY ON THE REPORT

This report is a valuable contribution to discussions of advanced biology education in the United States. Many of the recommendations are not new, yet they seem even more important than similar recommendations did 12 yr ago when they appeared in the publication *Fulfilling the Promise*: *Biology Education in the Nation's Schools* (NRC, 1990). Enhanced biological literacy and the improvement of biology education, elementary through college level, seem imperative today. Rapid advances in the fields of cellular and molecular biology continue to make major contributions to our understanding of the living world. We are also in a better position today to improve biology education with the publication of the *NSES* (NRC, 1996) and the recent findings of research on cognition and learning, particularly with respect to science and mathematics (NRC, 2000a).

Strengths

The biology panel should be commended on several points. First, the report focuses on the systemic need for improving AP and IB biology programs. Two of the primary recommendations (certifying schools and teachers for AP biology courses and eliminating the sole use of AP or IB exam scores for placement out of introductory biology courses) are directed mainly at two important entities within the advanced biology system: the College Board and colleges or universities. The biology panel is commended for emphasizing that AP courses lack oversight, which can result in inadequately prepared teachers and insufficiently equipped schools. Schools appear to allow any teachers who are qualified to teach general biology to also teach AP biology. The biology panel may have taken an even stronger stance on this issue, as their chemistry colleagues did (NRC, 2002b), by recommending that AP and IB biology teachers hold master's degrees or higher in biology. The College Board ought to take the responsibility of AP biology teacher certification, school certification, and the necessary alignments with the *NSES* (NRC, 1996) and recent research results on cognition and learning. Furthermore, colleges and universities are critical drivers in the current teach-to-the-test state of affairs in AP biology classrooms. When students are allowed to place out of introductory biology courses, they focus their attention on achieving high AP and IB exam scores rather than on learning. The biology panel appropriately laid the blame on the entire AP and IB systems, and not on high schools and teachers, for these conditions. The systemic solution for

improving advanced biology education at the high school level is a critical point made by the biology panel in its report.

A second strength of the report was its emphasis on building advanced programs on the basis of recent research findings in the learning sciences (NRC, 2000a, 2001b). The emerging field of cognitive science has documented many elements of cognition that should be of great interest to educators. A sampling of these research findings include differences between novices and experts in knowledge acquisition, knowledge structuring, and information retrieval; qualities of metacognitive activity; experts' abilities to "chunk" knowledge into contextualized schema; and conditions that enhance efficient transfer of knowledge to novel problem-solving contexts. Research findings from the learning sciences are contributing to an emerging "pedagogy of understanding," which is endorsed by the biology panel's report.

A third strength of the report was the frequent reference to the *NSES* (NRC, 1996), which provides a roadmap for K–12 curriculum development and assessment of student readiness for advanced biology. Furthermore, the *NSES* promotes the importance of inquiry-centered pedagogy in all science courses including AP and IB courses. Supplements to the *NSES* also provide descriptions and examples of inquiry-centered instruction (NRC, 2000b, 2001a). The biology panel report is a critical endorsement of the standards-based movement in K–12 and a call to higher education faculty members to be mindful of the *NSES* in designing their own instruction (see National Science Teachers Association, 2001).

Omissions

In the 1990 conclusions and recommendations (NRC, 1990), the Committe on High School Biology Education recommended that "a consensus needs to be reached as to what the AP biology course should be" (p. 86). This was the first of several recommendations written for AP biology in the 1990 report. Yet, a critical analysis of this issue is absent in the 2002 report. For what outcomes should AP and IB biology prepare students? Should the focus be replication of college-level biology in high schools? Many college-level introductory biology courses are not the best models for representing either the discipline or the inquiry-centered pedagogy. Then why should replication of the college or university courses be the goal of AP and IB biology?

It would have been interesting to read the biology panel's discussions of questions such as these: Would a second-year experimental biology course, not necessarily offered as AP or IB, be a better precollege preparation for students interested in the life sciences? Should colleges and universities serve a more direct role in such courses in high schools? If universities accept AP and IB credit for student placement out of their courses, should university biologists be responsible for teaching these high school courses? If not, what should the college and university involvement entail? Should university biology departments develop and administer biology entrance exams similar to those used by mathematics departments to place undergraduates in their first mathematics course? Such exams could assess whether or not students understand the material composing the introductory course for which they seek to earn credit. The biology panel's discussion of these, or similar, questions may have brought some closure to the issue raised by the 1990 report. A critical examination of "what the AP biology course should be" was missing throughout the 2002 report.

A second issue missing from the 2002 report is a discussion of the relationship between advanced biology and the projected insufficient numbers of teachers in the near future, particularly in mathematics and science. The biology panel recommends that AP teachers, in particular, be better prepared in both content and standards-based pedagogy. The report calls for more professional development and greater oversight of the certification of teachers at the advanced level. However, the call comes at a time when many states and school districts are making becoming a teacher easier rather than more rigorous. For example, in Arizona, school districts regularly grant emergency teaching certificates so that vacant teaching positions can be filled, especially positions in mathematics and science. This situation suggests that hiring better prepared teachers or investing in rigorous professional development of currently practicing teachers is unlikely. Teacher preparation for the advanced courses is a systemic problem that will require systemic solutions.

REVIEWER'S CLOSING COMMENTS

Life science educators at all levels, but particularly at the college and university level, will find the NRC report both interesting and thought provoking. For example, I found myself wondering if the current AP and IB biology systems can realistically change in response to the issues raised in the report. Can advanced biology curricula ever keep pace with the rapidly expanding knowledge base in biology? As the biology panel pointed out, even university-level introductory courses, for which the AP and IB are designed to substitute, often do not reflect the contemporary field of biology. Only rarely are university courses aligned with the *NSES* (NRC, 1996) or recent research on cognition and learning. Does the report ask disproportionately more of the high school curricula and teachers than it asks of colleges and universities?

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