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Essays

Advanced High School Biology in an Era of Rapid Change: A Summary of the Biology Panel Report from the NRC Committee on Programs for Advanced Study of Mathematics and Science in American High Schools

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A recently released National Research Council (NRC) report, *Learning and Understanding: Improving Advanced Study of Mathematics and Science in U.S. High Schools*, evaluated and recommended changes in the Advanced Placement (AP), International Baccalaureate (IB), and other advanced secondary school science programs. As part of this study, discipline-specific panels were formed to evaluate advanced programs in biology, chemistry, physics, and mathematics. Among the conclusions of the Content Panel for Biology were that AP courses in particular suffer from inadequate quality control as well as excessive pressure to fulfill their advanced placement function, which encourages teachers to attempt coverage of all areas of biology and emphasize memorization of facts rather than in-depth understanding. In this essay, the Panel's principal findings are discussed, with an emphasis on its recommendation that colleges and universities should be strongly discouraged from using performance on either the AP examination or the IB examination as the sole basis for automatic placement out of required introductory courses for biology majors and distribution requirements for nonmajors.

Keywords: Advanced Placement, College Board, International Baccalaureate, pedagogy.

INTRODUCTION

In 1999, the National Research Council (NRC) formed a committee of educators, teachers, and university mathematicians and scientists to prepare a report on advanced study of mathematics and science in U.S. high schools. This study was commissioned partly in response to the results of the 1996 Third International Mathematics and Sciences Study (TIMSS), which appeared to show that U.S. students, even the select group exposed to advanced course work in high school, scored in the lower half among the 17 participating nations, in every area of math and science tested (National Center for Education Statistics, 1998). Subsequent reanalysis of the data demonstrated that our most advanced students in mathematics and physics performed as well as those from any other country (Gonzales *et al.*, 2001), but the NRC study nevertheless seemed a highly worthwhile project in view of the recent explosive growth in the Advanced Placement (AP) program and other high school advanced study programs such as the International Baccalaureate (IB) program. For example, the AP program expanded almost fivefold during the 1990s, from 277,000 examinations taken in 1990 to 1,277,000 in the year 2000, with significant effects on the entire high school math and science curriculum as well as admissions and introductory courses at colleges and universities.

The NRC committee included educators with primary interests ranging from learning theory and assessment to access and equity issues; university professors representing mathematics, physics, chemistry, and life sciences; and high school teachers in each of these disciplines. The committee's charge was to evaluate the content, pedagogy, assessment techniques, and outcomes of advanced high school math and science courses, in the context of recent advances in understanding how people learn (e.g., NRC, 1999a) and the recently

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formulated *National Science Education Standards* (*NSES*; NRC, 1996a, 2000b). For practical reasons, the committee limited its analysis primarily to the AP and IB programs, which involve the largest number of students and for which the most information is available. The committee's report was released online in the spring of 2002 and was subsequently published as a bound volume available through the National Academy Press, entitled *Learning and Understanding: Improving Advanced Study of Mathematics and Science in U.S. High Schools* (NRC, 2002b).

During its work, the committee constituted a separate panel for each discipline, chaired by one of the committee members and again including educators, university scientists, and teachers not from the parent committee, to address discipline-specific issues. Each of these disciplinary panels also produced a report, which will not be published as hard copy but is available online. The findings and recommendations of these panels are summarized in Appendix A of the printed report from the parent committee.

I had the privilege of serving on the parent committee and chairing the Content Panel for Biology.[1] I have summarized here some of the findings and principal recommendations of the *Report of the Content Panel for Biology* that may be of interest to American Society for Cell Biology members. For additional discussion and details (the Panel made 14 recommendations in all), readers are urged to view or download the entire report (NRC, 2002c). This issue of *Cell Biology Education* also includes a commentary on the report by Debra Tomanek.

PRINCIPAL FINDINGS AND RECOMMENDATIONS

There is no question that AP, IB, and other advanced biology courses in high schools have done much to upgrade the teaching of biology at the secondary level during the past three decades. However, there is also much room for improvement in the present state of these courses generally and the AP course in particular. The following three factors have contributed to some of the current shortcomings:

1. Rapid expansion of these programs has made quality control difficult.
2. Recent advances in understanding how people learn have not yet been adequately incorporated into teaching these courses.
3. The ongoing explosion of knowledge in biology has raised serious breadth versus depth issues for advanced biology curricula.

Quality Control

When a school wants to begin offering the IB program, it must undergo an assessment by the International Baccalaureate Organization (IBO) to ensure that the teachers are qualified and that resources are adequate, before being certified as an IB school. In contrast, the College Board exercises no quality control over AP programs. To offer an AP course, a school must only obtain a copy of the "Acorn Book" (the syllabus and teacher's manual; Educational Testing Service [ETS], 1999) and assign a teacher. Therefore, not surprisingly, many AP biology teachers lack the academic preparation required to teach this course effectively. (All of us on the parent committee heard anecdotes about the football coach's being assigned to teach AP biology or physics and being handed the Acorn Book 2 weeks before the beginning of classes. I made the mistake of mentioning this cliché in one of our Panel meetings, whereupon Pat Ehrman, a member of the Panel and one of the most impressive high school biology teachers I have encountered, let me know that he was also the football coach.)

Certification of AP schools and teachers would be a daunting undertaking because of the numbers involved: more than 9000 AP biology courses were offered in the year 2000. Some people might argue that student results on the AP exam provide an adequate measure of the overall quality of an AP course. Nevertheless, the Panel's first recommendation was that the College Board should develop a method for evaluating and endorsing AP teachers and programs. Whether or not some form of certification is realistic, the Board should mandate more and better preparation and professional development opportunities for AP teachers, both in subject matter and pedagogy.

Standards of Pedagogy and Content

Recent educational research has validated several important insights into optimal conditions for student learning, as summarized, for example, in the NRC report *How People Learn: Brain, Mind, Experience, and School* (NRC, 1999a). These insights in turn have become the basis for widespread efforts to reform the way that science in particular is taught, from elementary school through college (e.g., NRC, 1999b, 2000a, 2000b), and they provided some of the foundations for the *NSES* (NRC, 1996a), which is having a growing influence on science teaching at all levels (NRC, 2000b, 2002a). The Panel found that the AP courses, and to a lesser extent the IB courses, had not yet incorporated many of the new pedagogical standards. For example, laboratory projects tended to be "cookbook" rather than inquiry based; syllabi emphasized learning of facts over problem solving; formative[2] assessments in AP courses were largely lacking; and the summative[3] AP exam tested rote memorization more than in-depth understanding. Broad themes, intended to provide integration of different topics, were stated in both the AP Acorn Book and the IB teachers guide. However, two omissions from the IB list—energy transfer and heredity—seemed surprising, and the extent to which themes were emphasized in presenting subject matter appeared to depend on individual teachers' decisions. The IB program was rated excellent for its integration of biology with mathematics and other sciences, whereas the AP course had few interdisciplinary connections.

The Panel recommended that both the AP program and the IB program include more emphasis on the new pedagogy

[1]Members of the Content Panel for Biology were Robert A. Bloodgood, Professor of Cell Biology, University of Virginia; Mary P. Colvard, Biology Teacher, Cobleskill–Richmond High School; Patrick Ehrman, High School Outreach Coordinator, Department of Molecular Biotechnology, University of Washington–Seattle; John R. Jungck, Professor of Biology, Beloit College; James H. Wandersee, UEIT Professor of Biology Education, Louisiana State University; and myself as panel chair and report editor.

[2]Ongoing, cumulative, providing feedback during a course.

[3]One-time, high-stakes, at the end of a course.

in preparation and professional development programs for teachers. It also recommended that the College Board and the IBO use their evaluation and endorsement of programs to ensure that the new standards of curriculum design, teaching, assessment, and professional development are being implemented.

Content Standards: Breadth versus Depth

Are the AP and IB courses keeping pace with the continuing explosion of knowledge in biology? The Panel found both AP and IB course syllabi out of date in some areas, such as membrane structure and trafficking. Moreover, several areas of intense current interest in biology were not included—for example, genomics, proteomics, and the implications of having complete genome sequence and protein databases; mechanisms of animal and plant development and their genetic control; signal transduction and how cells communicate with each other in development and physiology; molecular evolution; and the remarkable molecular relatedness of all organisms. A high school course does not need to be up-to-the-minute to be successful and valuable. However, when these topics are omitted, teachers are missing the opportunity to relate classroom activities to the biology that students encounter daily in the media. The Panel thought that the AP syllabus in particular overemphasized the structure of plants and animals (32% of total class time) at the expense of molecular and cell biology.

However, the principal problem, especially for AP courses, is not that they teach too little but that they attempt to teach too much. The IB program alleviates this problem by teaching biology during a 2-yr period. In contrast, all the AP biology teachers whom we heard from complained about the pressures to "cover" virtually all areas of biology during a two-semester course, in preparation for the AP examination.

Even for the best teachers, this pressure has unfortunate results. In particular, it necessitates superficial treatment of most topics, with the emphasis on memorization of terms and facts rather than in-depth exploration and understanding.

From where do the pressures for comprehensive coverage come? One purpose of the AP and IB courses is to offer college-level biology to students in high school. Another goal, particularly for AP courses, is to provide students the opportunity for advanced placement out of introductory courses at the college or university that they subsequently attend. To meet the second goal, AP courses must attempt to teach students the biology that they would encounter in *any* introductory biology course at *any* college or university.

Our Panel was interested to learn how the syllabus for AP biology courses was developed. In 1997, when the last revision of the syllabus was produced, the College Board solicited about 500 colleges and universities for the syllabi of their introductory biology courses. Only 56 responded. Moreover, in the opinion of the Panel members, only about 6 of these were institutions generally recognized as first rank in teaching and research, and only 16–20 of the rest might be considered second rank. Therefore, until the present, the AP syllabus and exam in biology have been based on the introductory course content at a small number of colleges and universities that are not representative of our best institutions.

On the brighter side, we were pleased to learn that well in advance of our report, the College Board was taking steps to remedy this situation. In a recent report, the Board indicated that for the next revision it will rely on an appointed committee of leaders in biological sciences and pedagogy to help formulate the AP curriculum, to "ensure that current reforms and best practices are reflected in AP" and to "position AP as a lever for positive change in curriculum and instruction" (CEEB, 2001, p. 12).

Despite this welcome news, the breadth problem remains. The AP examination defines content that must be taught for the purposes of advanced placement. Therefore, teachers feel pressure to cover all of it. As a result, there is little time for in-depth study of any topic, and rote memorization tends to be emphasized at the expense of more substantial understanding. Although 12 laboratories are supposed to be a required part of the AP course, we were told by several sources that because the AP exam does not assess well whether students actually perform the laboratory experiments, many teachers omit (or substitute videos for) the laboratories to free more time for exam preparation.

A second problem with the advanced placement function of AP courses is that they are trying to hit a moving target: college and university introductory biology courses are changing. Many institutions no longer offer a single introductory course. Many offer two alternative full-year courses: one emphasizing ecology, populations, and organisms; the other emphasizing molecular, cell, and developmental biology. One solution for AP courses would be to follow suit and offer two alternative similarly oriented courses and corresponding exams. However, doing so would defeat the stated purpose of AP: that a high score on the exam should qualify a student for placement out of *any* introductory biology course at the college level. Therefore, AP courses continue to attempt comprehensive coverage of both areas, which the Panel believed to be impossible to do effectively in two semesters.

Is the Emphasis on Advanced Placement Detrimental to the AP Program?

The Panel's response to this situation was to recommend that colleges and universities should be strongly discouraged, by the College Board and the IBO as well as the NRC and other educational organizations, from using scores on AP and IB exams as the sole basis for granting automatic advanced placement out of specific courses for majors, or out of biology distribution requirements for nonmajors. Furthermore, these exams should be designed not for determining eligibility to bypass introductory courses, but rather for assessing ability to succeed at college-level work in biology.

When we are considering the implications of this idea, the word "automatic" should be emphasized. For example, the Panel's recommendation would mean that advanced placement in the form of elective credit toward a biology degree is appropriate, whereas automatic placement out of a required introductory course is not.

Current practices for granting advanced placement vary widely. Many top-rank colleges and universities already refuse to grant automatic placement out of required courses on the basis of only AP or IP exam scores. Instead, they treat incoming freshmen as they would upper-level transfer students, evaluating their preparation case by case. Others grant college credit but not automatic advanced placement out of specific courses. At the opposite extreme, in a few states automatic placement out of introductory courses with an AP exam score of 3 or better is mandated by law. This unfortunate policy, which can result in harm to less well prepared students and can cause disruption of the college curriculum, should be strongly discouraged.

The Panel's recommendation for advanced placement may seem radical, going against even the name of the AP program, but it has several arguments in its favor: First, and perhaps most important, it would cut the Gordian knot that currently ties together the content of AP and introductory college courses, which would free the AP curriculum from its current preoccupation with comprehensiveness and allow a more in-depth study of selected areas in biology. Second, it would also free the College Board to develop more effective instruments than the current AP exam for evaluating real understanding, including more formative assessments and free-response questions. At the same time, the current valuable assets of the AP and IB programs would be retained. For example, high performance on AP and IB exams would continue to be a predictor of success in college work, with the accompanying advantages for college admission. Also, potential college tuition savings could still be realized by granting elective credits.

CONCLUSIONS

What Are the Goals for Change?

Near the beginning of our report, we described our vision of how advanced high school biology should be taught (NRC, 2002c):

> An advanced high-school biology course should reflect the current excitement in biology today, where the field is now, where it is going, and the increasing extent to which it impinges on all of our daily lives. An advanced course should be up-to-date and broad enough to give students an overall picture of biology, but should not attempt to be comprehensive, since that is impossible in a one-year biology course at any level. It should be demanding, not in the sense of "covering" all or even any particular areas of biology, but rather in requiring students to read and comprehend a college-level text and science articles at the level of, for example, *Scientific American*, solve problems, carry out meaningful experiments, collect, analyze and interpret real data, write coherently about their conclusions, relate these conclusions to real-life situations and their other academic course work, and take some responsibility for their own learning. It should allow them *not just to acquire biological knowledge, but rather to experience the process of biological science*, including generation of hypotheses from observations, design of experiments, unexpected results, collaborative learning and laboratory work with other students and teachers, and presentation of their analyses and conclusions for critical review by their peers. (p. 278)

The implications of this vision for needed changes are clear. Moreover, most of them apply not just to advanced courses in high school, but also to all levels from kindergarten through graduate school, emphasizing the necessity for systemic change in the way biology is too often taught. In particular, the Panel agreed with the view (NRC, 1996b, 2000b) that many of the current shortcomings of secondary school courses result from the mode of instruction experienced by high school teachers as college students. Teachers tend to teach as they have been taught, and it can be argued that one effective way to change the way high school courses are taught may be to change the content and pedagogy of the college courses taken by prospective teachers (e.g., Lawson *et al.*, 2002). Many college courses could benefit from the reforms recommended in this report. Desirable systemic changes include better preparation and development opportunities for primary and secondary school teachers, and, at all levels, more attention to recent developments in pedagogy, less emphasis on memorization of terms and facts, and more inquiry-based learning in the classroom.

Is Real Change Possible?

Most of the Panel's general conclusions and recommendations are not new. Similar ideas can be found in several recent reports (NRC, 1990, 1996a, 2000b; U.S. Department of Education, 2000), as well as in much older reports. During its work, the Panel unearthed the following four recommendations from an earlier committee:

1. More emphasis on "reasoning out" rather than memorization
2. More attention to developing a "problem-solving" and a "problem-raising" attitude on the part of students
3. More applications of the subject to the everyday life of the pupil and the community
4. Less coverage of the territory (progress no faster than pupils can go with understanding)

Do these recommendations look familiar? They were made in a report from the Central Association of Science and Mathematics Teachers in 1910 (Hurd, 1961, pp. 25–26).

Must meaningful change in our educational system always remain only a dream? The Panel believed that such change may be more possible today than ever, for several reasons. First, we have new understanding of how learning takes place and the conditions that promote it (NRC, 1999a). Second, there has been increasing acceptance of the *NSES*, which includes standards for both pedagogy and content that are designed to create these conditions (NRC, 1996a, 2000a, 2002b). Third, we have the Internet, whose enormous power to make knowledge and educational materials available to everyone, at low cost, is just beginning to be tapped. Fourth, the public appears to be becoming increasingly aware that education, of scientists in particular, must be improved if the United States is to compete effectively in the global economy. Improving advanced high school biology courses is only one small part of the task, but the Panel believed that there is hope for systemic reform, particularly if persons involved in teacher professional development continue to promote the new standards and if those of us teaching undergraduates can manage to set an example by adopting these standards ourselves. Likewise, we must persuade more well-trained young people to consider primary or secondary school teaching as a rewarding and honorable career.

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