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Advanced Placement and International Baccalaureate Programs for Talented Students in American High Schools: A Focus on Science and Mathematics

Carolyn M. Callahan
University of Virginia
Charlottesville, Virginia

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RM03176

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Carolyn M. Callahan
University of Virginia
Charlottesville, Virginia

ABSTRACT

The Advanced Placement (AP) and International Baccalaureate (IB) Programs have become increasingly prominent service options for gifted and talented secondary students, and are often the primary option in many school systems. This review presents the general historical background, overriding philosophies, procedures, perceived advantages and disadvantages, and a discussion of the growth of the programs, as well as the research on the AP and IB Programs. There is an emphasis on the fit of AP and IB Programs for gifted students seeking advanced study in science and math. As a result of this review, recommendations for parents and educators are provided.

Advanced Placement and International Baccalaureate Programs for Talented Students in American High Schools: A Focus on Science and Mathematics

Carolyn M. Callahan
University of Virginia
Charlottesville, Virginia

EXECUTIVE SUMMARY

The evolution of Advanced Placement (AP) and International Baccalaureate (IB) Programs as the fundamental core of offerings for gifted and talented students in America's high schools has been a relatively recent phenomenon. Over the past two decades the vacuum created by "de-tracking" high schools has been filled with increased enrollment in AP and IB Programs. A historical perspective on the development of these courses and programs, the philosophy underlying the offerings, a review of the rapid growth of these options, and the research currently available on AP and IB options are the focus of this review.

General Background Information and the Philosophies of the Advanced Placement and International Baccalaureate Programs

Origins of the Advanced Placement Program

The major impetus for the creation of Advanced Placement Programs and examinations came from a group of educators responding to concerns that a program that provided scholarships to high school sophomores to attend prestigious colleges was taking the most promising students away from their secondary schools. Recommending that able students take freshman college courses during their senior year in their home schools (General Education in School and College, 1952, as cited in Rothchild, 1995), they contracted with the Educational Testing Service (ETS) to develop individual courses to provide an opportunity for motivated students, not necessarily gifted students, to earn credit in American colleges while still in high school. ETS has continued to expand the offerings across the traditional core disciplines.

AP Exams and Scope of Options

Students may elect to take standardized examinations for courses developed by the College Entrance Examination Board and scored by independent examiners. The AP Programs and examinations initially developed for 5% of high school seniors soon became available to wider groups of seniors, to juniors as course options increased, and eventually to even younger students (Casserly, 1986; Rothchild, 1995). The College Board does not assign college credits; rather credits are assigned according to the policy of the college or university to which the student applies. A score of 3 or greater is described by the College Board as acceptable to most colleges for granting credit or advanced placement, but this does vary depending on the selectivity of the university (Lichten, 2000; Morgan & Ramist, 1998).

International Baccalaureate

While the College Board does not specifically tailor its courses to gifted students, early descriptions of the International Baccalaureate Program asserted that the program was "a rigorous pre-university course of study, leading to examinations, that meets the needs of highly motivated and academically gifted secondary school students" (International Baccalaureate North America, 1986, p. 1). However, the most recent literature of the diploma program describes its target as "highly motivated secondary students" removing gifted as a descriptor of their target population (International Baccalaureate Organisation, 2000).

Organization and Philosophy

A distinguishing feature of the IB Program is that it is designed to be a *program* of studies that includes specific requirements in both the humanities and the sciences, including independent study projects, comprehensive essays, and multiyear classes. Further, the goals of the IB Program go beyond the achievement of particular content related goals to include the goal "to provide students with values and opportunities that will enable them to develop sound judgment, make wise choices, and respect others in the global community" (IBO, 2000, p. 1).

Grading of IB Programs and Exams

Grading of the external examinations for IB Programs is done by independent IB examiners; however, teacher examinations and project grading account for 20% of the final grade in a specific course for school records and student transcripts. As with AP credit, individual colleges and universities determine whether they will accept IB credit and what level of performance will be required for advanced standing or credit.

Growth of the Advanced Placement Program and International Baccalaureate Programs

Participation in the Advanced Placement and International Baccalaureate Programs has grown steadily over the last 45 years. Potential explanations for increased enrollment in AP Programs include the readily available curriculum and training, lack of other rigorous and challenging options, government financial support for advanced placement, potential benefits in college such as earlier graduation and beliefs about the college entrance procedures (Center for Undergraduate Education in Science, Mathematics, and Engineering Education, 1999; College Entrance Examination Board and Educational Testing Service, 1999; Commission on Life Sciences, 1990; Hellerman, 1994; Matthews, 1999; Oregon University System, Oregon Department of Education, and Office of Community College Services, 1999; Sindelar, 1988; U.S. Department of Education, 1998), and the influence of using AP and IB Programs as indicators of school quality (Articulation and Coordinating Committee, 1994; Matthews, 1998, 1999). Further, in publications for secondary school principals, gifted educators, and educational researchers, the IB Program is cited as an example of ways to serve gifted students and transform schools into institutions reflecting world class standards (Cox & Daniel, 1985; Daniel & Cox, 1992; Feldhusen, 1995; Jacoby, 1992; Marnholtz, 1994; Pyryt, Masharov, & Feng, 1993).

However, the most frequently cited reason for the increased growth of AP and IB Programs has been the rigor and challenge associated with the course offerings. Not only does the challenge exist at the time of taking the courses; it also allows successful candidates to begin taking more advanced courses at the beginning of their college careers, to select more elective courses and feel better prepared for college (Hellerman, 1994). The *perceived* challenge has been documented in formal research studies. However, the degree to which the courses actually provide preparation for advanced college-level courses is not agreed upon (Commission on Life Sciences, 1990; Oregon University System, Oregon Department of Education, & Office of Community College Services, 1999).

Enrollment Requirements

Student enrollment in Advanced Placement and International Baccalaureate Programs is not regulated by the organizations, and is not dependent on prior identification as gifted. Acceptance into the IB Program is based on locally determined screening processes. Equity issues stem from concerns with access, preconceived notions of who will succeed in such programs, and the nature of the school. Gender inequities in achievement and enrollment in science and math AP Programs, and achievement in science and math courses in the IB Program have been documented (College Entrance Examination Board, 1999; Feldhusen & Poelzer 1996), suggesting that the ways in which these courses are taught and/or options available to females in the learning of advanced science and mathematics need to be examined. Systematic research on these issues is not available.

Research on Performance in the Advanced Placement Program and the International Baccalaureate Program

As early as 1968, Casserly reported student satisfaction with Advanced Placement Programs as generally high. However, no recent independent research has studied student satisfaction with the AP Program offerings. Research studies on outcomes of enrollment in AP Programs have focused primarily on documenting that AP students succeed in college courses (Breland & Oltman, 2001; Curry, MacDonald, & Morgan, 1999; Morgan & Ramist, 1998). However there are some methodological questions that make it difficult to determine whether the AP student has an advantage over non-AP students (National Academy of Sciences, 2002).

As with the AP Program, independent research on the impact of the International Baccalaureate Program has been limited. Further, like the AP research, lack of control for aptitude and motivational variables often inhibits clear interpretation of the results. In general, IB students tend to perform better or at least on par with students who do not participate in IB Programs (Feldhusen & Poelzer, 1996; Grexa, 1988).

Match of Gifted Student Learning Needs With Advanced Placement and International Baccalaureate Offerings

The examination of the appropriateness of Advanced Placement and International Baccalaureate offerings for talented learners in our schools rests on the consideration of several variables, including the quality of the curricular options and the match between these goals and the learning needs of gifted children. Due to the scant research on secondary learners in general, and gifted secondary learners in particular, there are questions as to the appropriateness of using a college class structure to teach math and science to all gifted or highly motivated students (Tall, 1992).

Definition of Giftedness and the Appropriateness of AP or IB Programs

One unresolved debate in the field of gifted education that impacts the discussion of all curricular or programming options available for gifted learners is the conception of giftedness that underlies decisions as to who is gifted and how those individuals should be identified and served. The options that might be appropriate for the several constituencies that make up the group known as gifted and talented students change based on the definition of gifted and talented students that one adopts, the gender of students, the socio-economic status of students, and the language and experiential backgrounds of students. Definitions and models that focus on current performance and base programming on having a faster pace of learning (e.g., Mönks & Mason, 1993) fit with the AP curriculum. However, definitions that regard other non-cognitive factors as having equal importance in defining giftedness and talent, such as that of Renzulli (1978) with his emphasis on task commitment and creativity, may fit better with the IB model.

Specific Research on Talented Teenagers

While there are no necessarily negative characteristics of AP or IB that would either contribute to or mitigate against a match between the development of talented adolescents, the structure of AP Programs and the IB option and the subsequent interpretation and implementation may reflect characteristics that are in contrast to conditions described as maximizing development (Csikszentmihalyi, Rathunde, & Whalen, 1993).

Issues With Math and Science Instruction

While the students in a study of talented teenagers (Czikszentmihalyi et al., 1993) recognized a high level of challenge and clear goals in their math and science classes, they complained about the rigidity of the structured curriculum and the reluctance of teachers to deviate from highly structured programs. They complained of little opportunity for choice, especially with regard to the pace of instruction. Independent work, engaged teachers, and extracurricular experiences has been found to be important to the talented mathematician (Bloom, 1985).

Given the documented over-extension of breadth of study incorporated into AP Programs (NAS, 2002), the likely scenario may be for teachers to focus on "covering," through lecture and teacher-guided discussion, the vast content of the course syllabi rather then to provide opportunities for students to interact with the content as co-learners.

Advantages and Disadvantages of AP and IB Noted in the Literature

In a student-written review of the International Baccalaureate (Choudbury, 1994), the list of advantages include practicing learning skills such as note taking and lab write-ups, feeling less stressed by college, having the ability to think critically, the flexibility, and emphasis on learning by discovery. Among the disadvantages listed by students taking Advanced Placement Programs is the emphasis on the exam and a false sense of preparedness for college courses (Hellerman, 1994).

The student sentiment that warns against a false sense of preparedness is echoed by the Center for Undergraduate Education in Science, Mathematics, Engineering and Technology (1999) and the National Academy panel studying AP mathematics and science courses (NAS, 2002). No systematic research documents the equivalence of AP and IB Programs to college courses, and the literature does not present evidence that exam scores predict success in upper-level college courses or that these courses provide the depth of understanding equivalent to that of introductory college courses (NAS, 2002). Further, in reviewing the mathematics and science curriculum offered in AP and IB Programs, the National Academy panel (NAS, 2002) concluded that there were shortcomings in these curricula in terms of the development of key ideas of the disciplines and metacognitive skills, and delineation of prior knowledge required. Finally, based on a self-report study of experienced AP science teachers, Herr (1992) concluded that AP teachers introduce a wider range of topics (than teachers in honors classes do) and cover them in greater detail, but they also adopt a predominately lecture format, fast pace of instruction, and don't respond to student interests because of the demands of coverage.

The offering of AP classes may result in a reduction in enrollment in other challenging science classes, particularly when schools offer extra grade point credit for AP Programs (Commission on Life Sciences, 1990; Herr, 1993). The Commission on

Life Sciences is also concerned that AP biology is modeled on biology courses that are poor educational experiences for many students.

The practice of ranking schools by the number of AP or IB exams administered has created a high stakes environment that may have detrimental effects on teachers and students, such as teachers teaching only to the test (NAS, 2002). Quality control issues relative to the course offerings, the competence of teachers, and the preparedness of students for the course offerings has been raised as an issue for the AP Program, but not for the IB Program (NAS, 2002). The NAS panel also warned that the ranking of schools on the basis of the number of AP or IB classes offered or exams taken may also discourage schools from developing or offering other options that may be better suited to the students.

Options Other Than Advanced Placement and International Baccalaureate

Consideration of options other than advanced placement seem to rest on either finding alternative ways of offering college equivalencies or finding alternatives to acceleration as an option for highly able learners. Other college equivalency options include teaching college courses within the high school setting and dual enrollment in college and high school.

Summary

The rapid growth of Advanced Placement and International Baccalaureate Programs in the United States is based on filling a gap in the provision of high level, challenging courses at the high school level. While developed for different purposes and for different constituencies, the courses in both educational options often come to be the basis for gifted educational programs in the secondary school. Their popularity can be attributed to many factors including government support; the availability of curricular guides, materials, and training; recommendations and commendations of the program by experts in gifted education, teachers of the courses, and students; increased use of the courses as gauges of school quality; and the positive regard of college and university admissions officers.

However, the research supporting and documenting the effects of the instruction are limited. There are studies that have investigated student and teacher satisfaction with the courses, and researchers have conducted limited investigations of the educational success of students who have participated in the programs. Further, the Commission on Life Sciences of the National Academy of Sciences and the Center for Undergraduate Education in Science, Mathematics, Engineering and Technology have raised some questions about the appropriateness of AP Programs in preparing students for college science success. Questions about equity issues, the appropriateness of the curriculum for all gifted students, and the degree to which either of these options become the only options available to high end learners at the secondary level continue to be raised.

As with many areas of gifted education, the lack of satisfactory research data comparing alternative options for the wide variety of students who are labeled gifted or who have the potential to develop as gifted adults appears to have resulted in limiting options for students rather than broadening them in defensible ways. This is not to suggest that AP and IB options are not viable, but further research is needed to document the effectiveness and appropriateness of these options as compared to other curricula.

Recommendations for Parents and Educators

Recommendation One: Before adopting any advanced courses for gifted students ensure that the options either provide for or allow for the adaptation of curriculum to ensure achievement of "deep conceptual understanding of the discipline's content and unifying concepts" (NAS, 2002, pp. 197-198).

Recommendation Two: Advanced Placement Programs and International Baccalaureate Programs do not necessarily lead to the achievement of the goals of deep conceptual understanding of the epistemology of the discipline or a full appreciation of the interrelations among concepts. Therefore, decision to adopt those courses should be accompanied by an assurance that teachers who are selected to teach in those courses have that knowledge and understanding themselves and have the pedagogical skills to translate their understanding into curriculum and instructional practices that will result in student understandings.

Recommendation Three: Ensure that equity of access is provided for all advanced level courses designed for gifted and talented students. Not only do we need to ensure that typically underserved populations have access, we should ensure that they are provided with the preparatory study necessary for success.

Recommendation Four: Closely examine the opportunities for preparation for all students that are not overly compressed such that time for the thoughtful and reflective study of the disciplines is lost (NAS, 2002).

Recommendation Five: Carefully evaluate all offerings for advanced learners at the secondary level to ensure that the curricular and instructional practices best reflect how people learn and incorporate the opportunity to develop metacognition (NAS, 2002). Do not assume that the college course model reflects those principles.

Recommendation Six: Provide guidance to students in making appropriate decisions about the advisability of accepting advanced placement rather than taking the introductory courses in college.

Recommendation Seven: Consider alternatives to AP and IB. The National Academy Panel recommends that "Approaches to advanced study other than AP and IB should be considered. Such alternatives can help increase access to advanced study for those not presently served and result in the emergence of novel and effective strategies" (NAS, 2002, p. 202).

Recommendation Eight: Remember that not all gifted students are like all other gifted students. Accordingly, consider alternatives to meet the needs of the widely divergent types of gifted students.

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Carolyn M. Callahan
University of Virginia
Charlottesville, Virginia

The evolution of Advanced Placement (AP) and International Baccalaureate (IB) Programs as the focus and fundamental core of offerings for gifted and talented students in America's high schools has been a relatively recent phenomenon. Prior to the introduction of these programs, educational opportunities for gifted students at the secondary level were limited in most cases to honors level courses that were independently developed and defined at each school, some geographically localized programs in conjunction with colleges and universities, and/or seminars and mentorship opportunities. Over the past two decades the vacuum created by "de-tracking" high schools has been filled with increased enrollment in AP and IB Programs. A historical perspective on the development of these courses and programs, the philosophy underlying the offerings, a review of the rapid growth of these options, and the research currently available on AP and IB options are the focus of this review.

General Background Information and the Philosophies of the Advanced Placement and International Baccalaureate Programs

Origins of the Advanced Placement Program

Initial development of the Advanced Placement Program was predicated on a perceived need to provide students with an opportunity to earn college credit while still in high school. The major impetus for the creation of the AP Programs and exams came from a group of educators convened to respond to concerns that an innovative program developed by the Ford Foundation that provided scholarships to high school sophomores to attend prestigious colleges was taking the most promising students away from their secondary schools. Noting that there was "a failure of the school and college to see their jobs as a continuous process" (General Education in School and College, 1952, as cited in Rothchild, 1995, p. 26), they recommended that able students take freshman college courses during their senior year in their home schools. In 1954, the Educational Testing Service was given a contract to develop exams to assess outcomes in experimental schools using college level syllabi and to compare results of the high school students' scores on the exams to those of freshmen in the 12 colleges involved in the effort. The resulting favorable comparison gave impetus to an expansion of efforts to further develop individual courses directed at providing an opportunity for motivated students, not necessarily gifted students, to earn credit in American colleges while still in high school.

Expansion of AP Offerings

The Educational Testing Service has responded with development of courses, course materials and examinations for courses across the traditional core disciplines of mathematics, science, English, the social sciences, and foreign languages. In addition, as demand for courses in areas such as computer science as well as art and music have emerged, the College Entrance Examination Board (CEEB) has responded. For each course in the current set of offerings, course syllabi, including topical outlines and recommended texts and readings, specifications of the emphases on particular topics on examinations, recommended laboratory time and exercises, and sample exam questions are provided for teachers. The courses are developed in consultation with college faculty and high school teachers who are experienced in AP teaching.

AP Exams

Students may elect to take the standardized examination for that course developed by the CEEB and scored by independent examiners. The examinations, like the courses, are developed in consultation with college faculty and high school teachers who are experienced in AP teaching. AP examinations are graded by independent, trained examiners. Each course is treated independently and all ratings are assigned without input from the teachers at the local school setting.

Scope of the AP Option

Students may elect any number of AP Programs and exams during their high school careers dependent on availability and timing of offerings in their school. Schools are not required to offer any specific number or sequence of courses, although a new AP Scholar Program awards certificate for completing increasing numbers of exams with greater proficiency. The award levels are designated by CEEB as follows:

AP Scholar

Granted to students who receive grades of 3 or higher on three or more AP exams on full-year courses (or the equivalent).

AP Scholar with Honor

Granted to students who receive an average grade of at least 3.25 on all AP exams taken, and grades of 3 or higher on four or more of these exams on full-year courses (or the equivalent).

AP Scholar with Distinction

Granted to students who receive an average grade of at least 3.5 on all AP exams taken, and grades of 3 or higher on five or more of these exams on full-year courses (or the equivalent).

National AP Scholar

> Granted to students in the United States who receive an average grade of at least 4 on all AP exams taken, and grades of 4 or higher on eight or more of these exams on full-year courses (or the equivalent). (College Board, n.d.)

In Texas, the state has created a Distinguished Achievement Program based on students completing the 24-credit recommended high school program. Within those credits, students must complete advanced measures at the college or professional level that are assessed by outside evaluators. The first of the options presented in completing four advanced measures is earning a score of 3 or above on a College Board AP exam or a score of 4 or above on an IB exam. Each exam can count as one measure (Texas Education Agency, 1996).

The AP Programs and examinations initially developed for 5% of high school seniors soon became available to wider groups of students (often 10-20% in many schools), and to juniors as course options increased, and eventually to even younger students (Rothchild, 1995). Casserly (1986) noted, "Over the years, secondary educators have become more experienced with the [AP] Program and more willing to offer appropriate challenges to their most able and ambitious students, whatever the students' ages" (p. 1). Currently courses are sometimes offered to students below the high school level. The Stanford Education Program for Gifted Youth has provided AP Programs in calculus and physics classes via computer to students in grades 8-10 and reports that in 1992-93, the Physics C[1] exam was taken by seven of these students. The 8th grader and two of the four 9th graders earned a score of 5 on the exam, the highest score a student can earn (Ravaglia, deBarros, & Suppes, 1995).

College Credit

The College Board does not assign college credits; rather credits are assigned according to the policy of the college or university to which the student applies for credit. A score of 3 or greater is described by the College Board as acceptable to most colleges for granting credit or advanced placement (Morgan & Ramist, 1998). The AP Program website advises students that a grade of 3 on an AP exam is equivalent to a C in an introductory college course and that a 5 is equivalent to an A (College Board, 2003). According to Camara, Dorans, Morgan, and Myford (2000), the scores are derived by having instructors in the 200 colleges that receive the most AP exam grades in the course under consideration administer the exam to their students under "motivated conditions" (not defined in the paper). "The lowest composite score that earns an AP grade of 5 is set to represent the average performance equivalent of college students who earn grades of A from their instructor" (p. 7). The descending levels of performance are similarly derived.

[1] There are two physics exams administered, Physics B and Physics C.

Lichten (2000) reports that even though two-thirds of test takers earn a score of 3 or higher, only 49% receive college credit based on AP exam of 3 or higher, many highly selective colleges and universities require at least a 4 and there is an increased tendency for institutions of higher education to require higher scores in some areas (e.g., English literature, foreign language) than in others.

International Baccalaureate

While the College Board does not specifically tailor its courses to gifted students, early descriptions of the IB Program asserted that the program was "a rigorous pre-university course of study, leading to examinations, that meets the needs of highly motivated and academically gifted secondary school students" (International Baccalaureate North America, 1986, p. 1). The initial aim of the program, as its name implies, is to provide "an international university entrance examination that could be taken in any country and recognized in any country" (International Baccalaureate North America, 1986, p. 1). However, the most recent literature of the diploma program describes its target as "highly motivated secondary students" (International Baccalaureate Organisation [IBO], 2000). The program was initiated by educators in international schools faced with multiple entrance exams required by the nations where their students were considering post-secondary education and also by concerns about the "increasing emphasis on education as the delivery of information, the fragmentation of knowledge, and the de-emphasis on aesthetic and creative education" (International Baccalaureate North America, 1986, p. 2). Current publications of the organization no longer include gifted as a descriptor of the target population (IBO, 2000).[2] The development of the program was initially funded by major grants from the Ford Foundation and the Twentieth Century Fund. It was supported until 1982 by annual grants from the U.S. Government. Since that time, many other foundations as well as governments of more than 20 other nations have provided financial support.

Organization and Philosophy

Because the origins of the IB lie in concerns of educators about standardizing a program across international school situations, it is not surprising that the IB Program reflects a different organization and philosophy than the AP Program. First, a distinguishing feature of the IB Program is that it is designed to be a *program* of studies with an expectation that the student will complete a course of study that includes specific requirements that include both the humanities and the sciences. In contrast, the AP courses are not tied to a program, but stand as individual educational pursuits. Further, the goals of the IB Program go beyond the achievement of particular content related goals to inclusion of the goal "to provide students with values and opportunities that will enable them to develop sound judgment, make wise choices, and respect others in the global community" (IBO, 2000, p. 1). To participate in the IB Program, a school must be approved through formal application and a review process. The application requires that the school offer all of the courses in the program.

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[2] Current publications state the program is "designed for highly motivated students ages 16 to 19."

Program Requirements

Students seeking the diploma must select one subject from each of six categories of study. However, students who declare themselves Certificate students (as opposed to Diploma students) are allowed, in special cases, to select courses from within the sequence of course offerings. Goals of the early developers of the program included "learning how to learn, how to analyze, and how to reach considered conclusions about people, their languages and literature, their ways in society, and the scientific forces of the environment" (International Baccalaureate North America, 1986, p. 1) which led to a program requiring students to build from six clusters of course selections that include:

- Group 1—language A1: In this group of courses the student is expected to develop "very good writing and oral skills and respect for the literary heritage" (IBO, 2000, p. 2) of his or her first language. In addition, the student is expected to "gain an international perspective through world literature studies" (IBO, 2000, p. 2). More than 80 languages have been offered for examination in this cluster.
- Group 2—second language: All diploma candidates must pass an exam focusing on written and oral communication in a second language with the aim of verifying that the student can use the language in a range of contexts and for many purposes.
- Group 3—individuals and societies: Subjects included in this group are: business and management, geography, history, history of the Islamic world, information technology in a global society, philosophy, psychology, and social anthropology.
- Group 4—experimental sciences: Group 4 includes biology, chemistry, physics, environmental systems, and design technology. The brochure describing the IB Program stresses that within this cluster students are expected to develop laboratory skills and "collaborative learning is encouraged through an interdisciplinary group project" (IBO, 2000, p. 2). Further, global and local issues are used as a basis for developing a "sense of social responsibility" and an "awareness of moral and ethical issues" (IBO, 2000, p. 2).
- Group 5—mathematics: Four courses in mathematics are available including Mathematical Studies and Mathematical Methods at the Higher Level. All students must complete at least one course in mathematics.
- Group 6—arts and electives including visual arts, music, and theater arts.[3]

To earn the IB diploma, students successfully complete at least three (but not more than four) subjects at the "Higher Level" (HL), which means two years (or a minimum of 240 teaching hours) of in-depth study before sitting for the examinations, and three subjects at the "Subsidiary Level" (SL), which are studied for one year (or a

[3] As of September, 2001, group 6 has been designated as "arts only" and includes dance and film. Classical languages, formerly in this group, has been moved to Group 2, and computer sciences, also formerly included in this group, has been moved to Group 5.

minimum of 150 instructional hours). While some students may elect four HL courses and two SL courses, the goal is to ensure both breadth and depth of study.

Theory of Knowledge is an additional course required of all students who wish to earn the diploma. Taken over the course of the two years of the program, this course is designed to "stimulate critical reflection on knowledge and experience gained inside and outside the classroom" (IBO, 2000, p. 1), to encourage questioning of assumptions of knowledge, to create an awareness of ideological biases, and to build competencies in the analysis of evidence. Two other requirements complete the spectrum of conditions required to earn the diploma. All diploma students must successfully complete an extended essay of approximately 4000-5000 words about an independent study of a self-selected topic and a "creative, aesthetic, or social service activity." There are currently 60 topics from which the students may choose in pursuing the investigation and a choice from 35 languages in which the essay may be written (IBO, 2003).

The required commitment of financial and personnel resources for the IB Program is considerably greater than those required for a school's participation in the AP Program structure. While schools provide AP teachers and may elect to send teachers for specific training and may purchase materials, participation in the IB Program requires an application fee, annual participation fees, participation in training which includes release time, travel and training fees, costs for authorized IB consultants, and funding of the position of IB Coordinator. Students in both programs are assessed examination fees.

Relationship Between AP and IB

Recognition of the relationship of AP Programs to the IB Program is noted in IB documents. For example, in describing the degree to which existing courses might be adapted to meet IB requirements, documents of the program note, "If the school has an honors class, such as the College Board Advanced Placement, the adaptation might be slight" (International Baccalaureate North America, 1986, p. 6).

Grading of IB Programs and Exams

Grading of the external examinations for courses for the IB is done by independent IB examiners; however, teacher examinations and project grading account for 20% of the final grade in a specific course for school records and student transcripts. Grades in AP courses in the high school are assigned by teachers with no input from the College Board. Only examination ratings are assigned by the College Board (with no input from the teacher of the course). As with AP credit, individual colleges and universities determine whether they will accept IB credit and what level of performance will be required for advanced standing or credit.

Growth of the Advanced Placement Program and International Baccalaureate Programs

Advanced Placement

The Advanced Placement Program was first implemented in schools in 1955-56 with 1,229 students from 104 participating school sites taking 2,199 exams. At that time, 130 colleges were listed as participants in the program. The number of participating high schools and participating students, the number of exams administered, and the number of participating colleges have grown at a steady pace over the past 45 years. In 2001, 820,880 students from the United States (844,00 total students) from 13,680 schools (out of approximately 22,000 high schools nationwide) took 1,139,516 exams (1,414,387 world wide.) Students submitted their scores to nearly 3,200 colleges and universities (College Board, 2002). (See Appendix A for graphs illustrating the growth in numbers of exams administered, number of schools participating, number of students taking exams and numbers of colleges accepting AP credit.) In the area of mathematics and science, courses and exams were offered in 2001 in biology, chemistry, computer science (A and AB), environmental science, calculus (AB and BC), physics B, physics C: mechanics, physics C: electrical and magnetic, and statistics. Students are not required by the College Board to take an exam if enrolled in an AP Program; however, individual schools may, and sometimes do, require enrolled students to take the exam. There are no predetermined number or pattern of courses or exams a student must take during his or her high school career. The number of exams administered in mathematics and science alone during 2001 is listed in Table 1. The numbers of students taking all AP exams in 2001 are presented in Appendix B.

Table 1

<u>Numbers of Students Taking Advanced Placement Exams in Science and Mathematics in 2001</u>

Discipline	Exams Administered
Biology	73,288
Chemistry	44,550
Computer Science A	12,905
Computer Science AB	6,318
Environmental Science	15,070
Calculus AB	117,518
Calculus BC	30,712
Physics B	27,006
Physics C: Mechanics	13,723
Physics C: Elec. and Magnet	6,434
Statistics	35,238

International Baccalaureate

First offered as an experimental project in 1967, the International Baccalaureate Program was offered to 20 schools in 1970. Currently, over 36,000 students are enrolled in IB Programs in more than 350 schools in the United States (Gehring, 2001). Nearly 800 colleges and universities in the United States are listed as recognizing/granting credit from the IB Program. Approximately 80% of candidates earn the diploma each year. Growth of the IB Program has been somewhat slower and more selective, probably as a result of the financial resource requirement and the demand for commitment to a full course of study rather than select courses.

Potential Explanations for Increased Enrollment in Advanced Placement Programs and International Baccalaureate Programs

Readily Available Curriculum and Training

One factor that certainly increases enrollment in Advanced Placement Programs is increased availability of the range of courses and number of course offerings in the schools. As Appendix A and the prior discussions illustrate, adoption of Advanced Placement and International Baccalaureate Programs in schools has been steadily increasing from year to year. The adoption of these ready-made programs and courses with accompanying teaching materials is far less stressful on a teaching staff than the creation of new curricula. Many teachers are not trained to develop curriculum and many do not have the grounding in advanced studies in a discipline that would allow for the creation of advanced level courses. In addition, both the College Board and the IB Program provide summer workshops and institutes to train teachers in the delivery of the curriculum. These workshops not only provide guidance in teaching strategies for delivering the curriculum; they also provide background and knowledge in the discipline itself.

Lack of Other Rigorous and Challenging Options

The availability of AP or IB Programs themselves would not necessarily create an increased enrollment were it not for the lack of other suitably challenging choices available to students in schools where these courses are offered. Quotes from interviews with students in AP Programs reported in a newsletter published by Johns Hopkins illustrate this point. One student commented, "I preferred the more challenging and therefore more intellectually stimulating and rewarding AP classes to the easier regular-track classes." Another said, "Otherwise I would have had to go to college early (which I didn't want to do) or be bored to tears in high school" (Hellerman, 1994b, p. 7).

Government Financial Support for Advanced Placement

The widespread adoption of AP Programs also reflects the actions and support of state-level leaders. For example, George W. Bush, while Governor of Texas, stated, "Making Advanced Placement available to students across Texas is one of the best ways to challenge students academically" (College Entrance Examination Board and Educational Testing Service, 1999a, p. 16). As evidence of that belief, Texas appropriated $21 million for the AP Program for the biennium 1999-2001 with the goal of having a minimum of between four and six AP Programs in every Texas high school by the year 2002 (College Entrance Examination Board and Educational Testing Service, 1999a). Twenty-three states use state funds to support AP Programs either through subsidizing exam fees, subsidizing the costs of teacher training, providing funds for materials and supplies for AP Programs, offering incentives for providing AP Programs or hosting training sessions, encouraging universities to accept AP credit, or encouraging the offering of professional development opportunities. For example, in Utah the schools are reimbursed $90 for every student who earns a 3 or higher on an AP exam. The California legislature has appropriated $80,000 for teachers in the Los Angeles Basin region to attend training sessions in either AP Calculus, AP Physics, or AP Chemistry. New Mexico has appropriated money for teacher training and supplies.

Federal and state governments have provided funds to pay either partial or full examination fees. The federal government allocated $3 million in fiscal year1998 and $4 million in fiscal year1999 to increase participation of minorities in AP and to cover costs of AP examination fees for low-income students. In announcing the availability of grants to states to pay for test fees, then Secretary of Education Riley stated, "I want everyone to know that college is possible. The funds will be available if you do the work and prepare for college level courses" (U.S. Department of Education, 1988, p. 1). Eighteen states provide direct assistance to students by paying for exam fees. Changes that occurred between 1998 and 1999 included: New Mexico increased funding to subsidize fees incurred by minority and low-income students; Michigan offered to pay the costs for the first 100 students who enroll for one of five new internet AP Programs; Georgia offered to subsidize AP exam fees; and California now pays all but $5 of the AP exam fee for low-income students. Individual school systems have also taken the initiative to pay for the examination (Matthews, 1999b).

National Trend Toward Increased Time to Complete the Baccalaureate Degree

One of the often cited potential benefits of completing AP and IB Programs is the opportunity to complete the bachelor's degree in a shorter time frame, saving money on tuition and also opening slots for other students (particularly in state institutions where demand exceeds space). (See, for example, the report of the Oregon University System, Oregon Department of Education, and Office of Community College Services, 1999). Dr. Eric Smith, Superintendent of Schools in Charlotte, North Carolina claims, "Many of these students will enter college as sophomores and have enough money saved from eliminating their freshman requirements to allow them to plan for graduate studies" (College Entrance Examination Board and Educational Testing Service, 1999a, p. 26). Whether or not students actually take advantage of the option of completing their college degrees early has not been documented. In newsletters provided to high school students, the advice given by college students to students still in high school is that using AP to shorten the time needed to attain a degree would not be advised (Hellerman, 1994b).

Beliefs About the Advantages in the College Admissions Process

Publications of the College Board, college and university web pages, and personal advice from other students often cite the potential positive edge to be gained from participation in these programs. In a brochure entitled "Facts About the Advanced Placement Program," benefits of participating in the AP Program are cited. "Students improve their chances of being accepted by the college of their choice. College admissions personnel view AP Programs as one indicator of future success at the college level. Participation in AP Programs is, therefore, a great advantage to a student who wishes to attend a highly selective college" (College Entrance Examination Board and Educational Testing Service, 1999b, p. 1). In a Johns Hopkins newsletter designed for pre-college gifted students, students are advised to "[t]ake the most advanced courses available—especially in your areas of strength—including *honors, Advanced Placement* (AP), and/or *International Baccalaureate* (IB) *options*" (Hellerman, 1994a, p. 3). They are also advised that "even when an AP score won't translate into credit you can use, it can still help you in other ways—by impressing admissions officers or convincing professors to let you take more advanced courses" (Hellerman, 1994b, p. 6). The veracity of these claims is affirmed on college websites and in articles in college admissions journals (Sindelar, 1988). For example, the University of Washington encourages and applauds students who have chosen IB Programs as part of their high school curriculum. "These courses, as well as honors courses, are challenging and demanding, and we believe they provide excellent preparation for University study" (University of Washington, Office of Admissions, 2002). A review of biology education in the United States concluded that AP Programs probably also help individual students in admission to college (Commission on Life Sciences, 1990). And the Center for Science, Mathematics, and Engineering Education advised college admissions officers that "Every effort should be made to encourage students to undertake a rigorous high school program of studies, including Advanced Placement" (1999, p. 23). Belief in the importance of AP Programs in the college admissions process has even been the basis underlying a lawsuit in California claiming bias because fewer AP Programs are offered in schools with higher percentages of minority and low-income students (Matthews, 1999a).

AP and IB Programs as Indicators of School Quality

The AP and IB Programs have become markers of quality in high school programs. In the popular media, the number of AP and IB Programs in place in a high school has been used to judge quality of high school programs and even to rank high schools (Matthews, 1998, 1999b).

State assessments of educational success have also utilized enrollment in AP Programs, success on AP exams and enrollment in IB Programs as indicators of quality (Articulation and Coordinating Committee, 1994). And some leaders in the field of gifted education have publicly judged the quality of high schools in part by their AP offerings. "Good high school programs offer College Board Advanced Placement courses, . . . honors courses which deal with advanced and complex content at a rapid pace, and specialized electives for extended study in English, social studies, sciences, mathematics and business subjects" (Feldhusen, 1995, pp. 60-61).

Recommendations to Gifted and Talented Learners

Not only did the IB Program identify its constituency as gifted and talented learners, the IB and AP options are presented in the literature (both in gifted education and general education) as viable options for gifted and talented learners. In journals for secondary school principals, these options are ranked among the most favorable educational options for high achieving and gifted learners (Cox & Daniel, 1985; Daniel & Cox, 1992). In publications for secondary school principals about world-class schools, the IB Program is cited as a leading example of ways to transform schools into institutions reflecting world-class standards (Marnholtz, 1994). In journals and book chapters for gifted educators, the AP and IB Programs are favorably reviewed as *one* option for gifted and talented learners (Feldhusen, 1995; Pyryt, Masharov, & Feng, 1993). Articles for educational researchers reflect the same endorsements (Jacoby, 1992).

Quality of Curriculum, Level of Challenge, and Learning Environment

The most frequently cited reason for the increased growth of AP and IB Programs has been the rigor and challenge associated with the course offerings. Not only does the challenge exist at the time of taking the courses; it also allows successful candidates to begin taking more advanced courses at the beginning of their college careers and to select more elective courses. The *Oregon Early Options Study* (Oregon University System, Oregon Department of Education, & Office of Community College Services, 1999), which includes an examination of AP and IB Programs cites "acceleration of progress" and "relief of high school boredom" among the benefits of AP, IB, and other early college credit options.

Students also report feeling better prepared for college. Students are quoted as claiming, "The APs [sic] do provide some advanced preparation for college courses;" "AP credit allows you to go straight into upper level courses, and that is definitely a bonus because many intro-level courses are large and tedious"; "The main reason for taking an AP class should be that you are looking for a more interesting class and a more challenging environment in which to learn" (Hellerman, 1994b, p. 7). The *perceived* challenge has been documented in more formal research studies described below. However, the degree to which the courses actually provide preparation for advanced college-level courses is not clearly agreed upon. For example, the Commission on Life Sciences of the National Academy concluded, "Students often report that they found themselves well prepared for the sequence of advanced college-level courses in which they could enroll, but that view is not universally shared by college faculty" (Commission on Life Sciences, 1990, p. 84). In fact, the *Oregon Early Options Study* questioned whether the college-level courses offered in high school are, in fact, college level (Oregon University System, Oregon Department of Education, & Office of Community College Services, 1999).

The Commission on Life Sciences (1990) concluded from its review of AP biology that, "If recommendations of the College Board are followed by a properly prepared teacher with adequate laboratory facilities, the AP biology program could provide the equivalent of an introductory college biology course. . . . The presence of AP biology provides an incentive for students with an interest in science" (p. 84).

Enrollment Requirements

Student enrollment in Advanced Placement Programs and the International Baccalaureate Program are not regulated by the College Board or the International Baccalaureate Organization except as required for IB certification. Neither program specifies that enrollment should be dependent on prior identification as gifted and talented. However, enrollment in AP calculus is predicated on having completed the traditional mathematics program at a faster pace and enrollment in AP chemistry and biology generally requires prior completion of the traditional high school classes in those subjects.

Student selection of AP Programs is very dependent on the advice of high school counselors, and in some cases, grades and recommendations of teachers in the course immediately preceding the AP option. However, for students who have been identified as gifted and talented, the AP options often are the only placement option when the regular curricular options provide neither an accelerated pace of learning nor in-depth and complex learning tasks. Similarly, acceptance in the IB Program is based on a locally determined screening process conducted at the local school level (but specified and included part of the IB approval/certification process) and does not require prior identification as a gifted student.

Equity Issues

Equity issues stem from concerns with access. In the area of AP and IB these concerns stem from circumstances within schools and across schools. While neither AP nor IB Programs require that the student be identified as gifted and talented, preconceived notions of who will succeed in such programs may limit recommendations and encouragement of students to enroll. For example, in those school districts where intellectual ability is considered a general unitary ability, students with specific talents in mathematics or science may not be identified as gifted or talented because of average or below average verbal abilities. As a consequence, they may not be counseled to pursue AP or IB Programs. In schools where giftedness is recognized across individual disciplines and talent areas, these students may be more likely to have been recognized and recommended for such programs.

The nature of the school may also preclude opportunities for some students. Rural schools and schools that serve students from impoverished environments are far less likely to offer AP and IB Programs than suburban schools (unless designated as magnet schools), although even within suburban schools there is considerable variability in offerings (Aluri, Winecoff, & Lyday, 1991; California State University Institute for Educational Reform, 1999; Matthews, 1998). While technology and distance learning are likely to affect opportunity to access, without concurrent development of ability to recognize and encourage talent, it is unlikely that maximum opportunity would be available. And increased support for teacher training and examination fees will make the costs to schools and individual students less of a barrier. Businesses are investing in efforts to make AP options more universally available as illustrated by the venture capitalist investments of more than $20 million in a company offering on-line AP Programs in calculus, statistics, U.S. government and economics (Seattle University, 2000).

Finally, less tangible and more debatable issues underlie the equity concerns. We often presume that it is only lack of availability of courses, lack of money to take exams, and/or poor attitudes that underlie the lower participation rates of minority or low SES students in AP or IB Programs. One presumption is that if we just made the courses available and the money available, we could alter the situation. A second is that if we just started preparing students earlier (in middle school and early high school), the problem would be solved (hence the development and institution of pre-AP Programs) (Cox, 1984). Underlying these premises is the assumption that mathematics is mathematics, physics is physics, chemistry is chemistry, and we should not examine the structure of what we teach or how we teach it. Just prepare the students early so they can "get it" when we teach it the way we always have. The startling and renowned success of Jaime Escalante with minority students forms the basis for this assumption. What is not examined is the way in which he taught the calculus—using strategies, approaches and an organizational scheme that addressed the particular learning styles of the students he was working with and the ways in which he altered the organization and strategies for teaching to reach highly able minority and poor students. These strategies were aligned with the recommendations for an emphasis on learning with understanding, active learning, responding to prior knowledge, and background of the students as it affects their structural knowledge of the discipline, etc. (Bransford, Brown, & Cocking, 1999). The process of starting with an understanding of how students conceived and misconceived mathematical concepts, the ways in which they learned, the support they needed, and the motivations that would influence each student individually was key to Escalante's ability to teach these students successfully. While we might suggest close examination of the content of AP, we might also question whether the structure of AP lends itself to these modifications or if we should seek other ways to develop the mathematical and scientific thinking of talented students from these populations.

While female participation in AP science and mathematics courses is increasing, inequities continue to exist in enrollment and achievement of females in the advanced calculus AP Program, all physics areas, chemistry, and computer science (College Entrance Examination Board and Educational Testing Service, 1999a). Inequities in achievement in the physics and chemistry courses of the IB Program were documented by Feldhusen and Poelzer (1996), suggesting that the ways in which these courses are taught and/or options available to females in the learning of advanced science and mathematics need to be examined. Systematic research on these issues is not available.

These debates will, of course, also revolve around separate but unequal arguments. If we provide other options, do we reduce the favorable advantage that more privileged or male students gain from the recognition given for AP and IB enrollments and examination success?

Research on the Advanced Placement Program and the International Baccalaureate Program

Advanced Placement

Surveys of Student Satisfaction

As early as 1968, Casserly was reporting in College Board publications that student satisfaction with Advanced Placement Programs was high. Overall, students in a California sample gave a mean rating of 4.05 out of a possible 5 on a scale rating the challenge of the courses. However, the relatively large standard deviations on each rating (close to 1 in most cases) and frequency distributions indicated that while the mean reflects the positive end of the scale, considerable numbers of students gave ratings at the middle and below the middle of the scale. No recent independent research has studied student satisfaction with the AP Program offerings.

Research studies on outcomes of enrollment in AP Programs have focused primarily on documenting that AP students succeed in college courses. For example, Curry, MacDonald, and Morgan, (1999) reported a "good" correlation between scores on AP and subsequent grades in related college courses and that AP students do as well or (often) better than the non-AP college students taking the equivalent college course. Morgan and Crone (1993) found that AP students continue to pursue knowledge in the subject area of their exams at greater rates than other students. This is not a surprising finding since one would be less likely to take AP classes in an area of no interest. They also found that students with AP grades of 3 or higher received higher grades than students who had not received AP credit in the same class. Recently, Morgan and Ramist (1998) also compared "upper-level" students who had received AP credit to peers who were in their classes but who had take the introductory college class instead. They also found that in most areas the AP students earned significantly higher grades than their fellow students. A re-analysis of the same data by Breland and Oltman (2001) came to the same conclusion for students in AP comparative government and politics and AP economics. A review of the methodology of these two most recent and most comprehensive studies and a re-analysis of the data by the panel of the National Academy of Sciences (NAS, 2002) concluded that the most precise interpretation of the data is that:

> students with qualifying AP scores who were exempted from first-year courses in college appeared, on average, to earn grades in second-year courses that were no lower than those earned by student who took the introductory courses in college. . . . [T]he methodology used in conducting the studies makes it difficult to determine how often and under what circumstances there is a positive advantage

> for AP students relative to non-AP students in second level courses. . . . [The methodological flaws also] make it difficult to determine whether any apparent advantage held by AP students over non-AP students is a function of the colleges they attend, the classes they enter, their own academic backgrounds and abilities, or the quality of the AP courses they took in high school . . . . It is possible that some AP students were at a disadvantage in some classes or at some colleges. (p. 193)

Teacher Opinion

In 1986, the College Board reported that 92% of a national sample of teachers rated the program excellent or good, and 78% agreed that the courses challenge both teachers and students. Similarly, 92% of teachers in a limited 1985 sample of California rate AP Programs as good or excellent. Data were not analyzed by courses.

International Baccalaureate

As with the AP Program, independent research on the impacts of the program has been limited. Further, like the AP research, lack of control for aptitude and motivational variables often inhibits understanding of the results. Feldhusen and Poelzer (1996) studied the achievement of students in Alberta; comparing students enrolled in HL International Baccalaureate Programs in physics, biology, and chemistry; students enrolled in SL courses in the same subjects; and students enrolled in regular school courses. Even though sample sizes were small, a MANOVA repeated measure pre-post comparison showed students in the HL (studying the subject two years before sitting for the examination) and SL courses (studying the subject for one year before sitting for the examination) outperforming students in the other courses on AP tests. The result is not surprising since students in the IB Program were selected based on prior high achievement and teacher recommendations and that the teachers in the study reported that the IB students were more motivated and "demonstrated greater task commitment, questioning, independence, intelligence, ability to see connections among concepts, desire to understand, management skills, and taking responsibilities for their own learning" (p. 33). The first surprising finding was that the increase in achievement for students in the HL and SL biology classes and physics was equal. Second, while the increase in male scores in HL IB chemistry was greater than that of females in HL IB and males and females in SL IB, females in HL IB showed gains only equal to those of the males and females in SL IB. Finally, the mean score of IB physics students (27%) was well below the mean for AP students (43%).

A study of IB students at the University of Virginia documented that the grade point averages of IB students during their college years exceed those of AP students by .2 points and exceed students who were in neither IB nor AP Programs by .3 points (Grexa, 1988). The author concluded, weakly, that "IB students perform at least as well as their counter-parts from the same or other schools that do not offer IB" (p. 5).

Match of Gifted Student Learning Needs With Advanced Placement and International Baccalaureate Offerings

The examination of the appropriateness of Advanced Placement and International Baccalaureate offerings for the most talented learners in our schools rests on the consideration of several variables. In this paper, the learning needs of these students in mathematics and science in particular will be considered.

The first consideration in evaluating the quality of any curricular offering is the choice and organization of content. Underlying the AP Program and most of the IB offerings, particularly in science and mathematics, is an assumption that the most appropriate avenue for study for the most talented and motivated is the acceleration of learning to provide high school students with college level courses and experiences. This assumption presumes that the student is capable of thought processes that characterize the young adult, such as abstract and logical reasoning abilities at least at the formal operational stage as described by Piaget. The literature on adolescents, and gifted adolescents in particular, leads one to reasonably assume that gifted adolescents are capable of the logical, formal thought required for success in learning the science and mathematics concepts of AP and IB Programs.

AP instruction also presumes that these students benefit from a style of instruction that dominates the college classroom. If one assumes that this is the best alternative, then the question becomes one of determining whether the syllabi provided by the College Board and/or the International Baccalaureate reflect the big ideas, important concepts, fundamental understandings and skills of introductory college level courses in those disciplines *as delivered* in most colleges and universities. The College Board uses systematic review of the syllabi and materials by college faculty and high school teachers to address that issue and all documents stress an emphasis on teaching conceptual understanding of the discipline. That question would seem resolved, but in actuality it is open for review and will be discussed later.

If the assumption that college level instruction is most appropriate for gifted and talented learners in high school is open for debate, then the question becomes one of determining whether college level content is most appropriate for all gifted students or particular categories of gifted students. Further, we should examine whether the instructional strategies and the structure of these courses reflect the kind of learning experiences that will result in the learning outcomes most appropriate for gifted and talented (or other highly motivated) students.

The Secondary School Learner

While literature on the young child, the elementary school learner and the middle school learner abound, the literature specifically focusing on the high school learner is much less prevalent. In looking for evidence of the learning of these individuals, a search of the index of such publications as *How People Learn* (Bransford et al., 1999) does not even include adolescent, adolescence, or the high school learner. Constructivist theories of learning abound in discussions of teaching science and mathematics, but no studies of the relationship of these theories to the highly able learner are found in the literature.

Similarly, while texts and research abound in the area of psychosocial changes that occur during adolescence, little examination has been made of the ways in which gifted adolescents learn differently from pre-adolescent or adult gifted learners. The most common statements made about highly able learners in adolescence reflect the generalizations made about gifted learners at all levels: learn at a faster pace, understand advanced and complex concepts, more independent in learning, insights into solutions to problems, exhibit greater efficiency in problem-solving (Saul, 1999).

Mathematics

Specific writing in the area of mathematics suggests that misperceptions that characterize the young mathematical thinker also characterize the calculus learner in areas such as the notion of a limit and functions (Tall, 1992). The conclusion drawn by Tall is that "even at the advanced level of mathematics instruction, presenting definitions and theorems only by means of logical development teaches the product of advanced mathematical thought, not the process of advanced mathematical thinking" (p. 509). His writing and that of other mathematics educators suggests that pre-conceptions and knowledge of able students influence their learning, albeit at a higher level, in ways similar to those of all learners. It also suggests that the didactic and logical sequential argument approach to mathematics instruction may not be appropriate for all learners in mathematics.

General Cognitive Abilities

Mönks and Von Boxtel (1985) note a differentiation of cognitive abilities wherein students become more capable of reflecting on their thinking processes and are more able to engage in meta-cognition. They also point out that gifted adolescents exhibit motivation to reach high standards of achievement and they become more realistic and knowledgeable about their own abilities as those abilities become more manifest over time in more specialized areas. At this time, as with all adolescents, gifted learners become more independent. The increase in autonomy associated with adolescence in general is related to increased cognitive capacity to judge the value of learning experiences.

Definition of Giftedness and the Appropriateness of AP or IB Programs

One unresolved debate in the field of gifted education that impacts the discussion of all curricular or programming options available for gifted learners is the conception of giftedness that underlies decision-making regarding who is gifted and how those individuals should be identified and served. The options that might be appropriate for the several constituencies that make up the group known as gifted and talented students would take into account the agreed upon conception of giftedness as well as agreed upon goals for curriculum offered to these students. These constituencies change based on the definition of gifted and talented students that one adopts, the gender of students, the socio-economic status of students, and the language and experiential backgrounds of particular groups of students.

While whole texts are devoted to the topic of conceptions of giftedness (e.g., Sternberg & Davidson, 1986), there are several conceptions that most directly apply to this discussion. The first, identified by Mönks and Mason (1993), is the cognitive component model such as that espoused as part of the Study of Mathematically Precocious Youth at Johns Hopkins University, which represents the trait of giftedness functionally rather than by intelligence test scores. In models such as this, the exceptional level of mathematics performance guides identification and bases programming on the faster pace of learning characterizing these students. For these students, the model espoused by AP has been recommended as an appropriate fit.

A second, dominant conception is one of achievement orientation. Authors representing achievement oriented definitions regard other non-cognitive factors as having equal importance in defining giftedness and talent. For example, Renzulli (1978) bases his definition on a review of the literature on gifted adults that led him to the conclusion that giftedness is a dynamic interaction among three traits. He defines giftedness as an interaction among the traits of above average abilities, high levels of task commitment (a refined and focused form of achievement motivation in which energy is brought to bear on a specific problem in a specific performance area), and high levels of creativity. Renzulli distinguishes this type of giftedness (which he calls creative productive giftedness) from "schoolhouse giftedness" in which the student is a consumer of the knowledge already produced in the discipline. Renzulli acknowledges the role of the AP Program as appropriate for the second type of gifted learner, but questions the ability of the AP Program to nurture the creative productive gifted learner, particularly when the goals of course instruction focus on exam success. He judges the opportunity for extended independent investigation in the IB Program as more closely aligned with his beliefs about appropriate opportunities for gifted learners that lead to the study of real problems, using the methodology of the discipline with products produced for real audiences.

Specific Research on Talented Teenagers

Perhaps the most comprehensive studies of talent development among talented adolescents have been done by Csikszentmihalyi, Rathunde, and Whalen (1993) and Bloom (1985). Czikszentmihalyi et al. found great discrepancies between the motivational factors influencing learning and the practices of teachers in the classroom. While they found the focus of talented adolescents in classrooms to be greater than that of other students, their motivation was low. "Three fourths of the time when talented teens reported from the classroom they did not want to be doing what they were doing" (p. 180). Even in classes where teenagers were experiencing great academic success, they typically did not want to be there. The overarching theme that described teachers successful in working with talented teenagers was their ability to attend to the students as emerging adults and go beyond the standardized curriculum to respond to the particular developmental stages and interests of the student. What appears identified as "motivators—and made them memorable to their students—is their ability to transcend institutional roles in favor of a more personal approach to teaching" (p. 181). In one particular case study used as an example, Gwen, a student, points out that "most teachers don't share her interest in concrete, everyday applications [of] mathematics. They'll give you the material, but they can't help you with why or when you use it." (p. 183).

Three particular dimensions seem to characterize classrooms that were described as fostering "flow in learning." First, the teachers in these classrooms never abandon their own commitment and passion for learning. Second, these teachers seek to create classroom conditions that minimize the pressures from "competition, grades, needless rules, and bureaucratic procedures. Instead they do all they can to center students' attention on the challenges and inherent satisfaction of learning something new" (Czikszentmihalyi et al., 1993, p. 191). Czikszentmihalyi et al. note that when feedback focuses on external rewards, students cease to develop the self-reinforcing skills necessary for sustained concentration on a problem and focused and extended immersion in challenging tasks. Finally, these teachers have an ability to judge the changing needs of learners and alter the pace of learning, the degree of scaffolding necessary for individual student learning, and to provide choice in activities to students. They are able to adjust learning experiences to student interests and learning style as well as to provide choice in materials and themes of study. "Perhaps because schooling has traditionally militated against individual expression, a measure of choice is arguably the most crucial to the realization of intrinsic rewards in the classroom" (p. 193).

Researchers' views of talented adolescents are quite different than what we often hear as characteristics of the teenage population. "What came through clearly in our study was an avid willingness to accept challenges and overcome obstacles when the problems were interesting and the necessary skills were within the individual's reach" (Czikszentmihalyi et al., 1993, p. 187).

While there are no necessarily negative characteristics of AP or IB that would either contribute to or mitigate against a match between the development of talented adolescents as described above, the structure of AP Programs and the IB option and the subsequent interpretation and implementation may reflect characteristics that are in contrast to the conditions described as maximizing development. For example, the specifically delineated content and high stakes evaluation may create pressure to "cover" the material within a certain time frame (before the exam), resulting in a tendency for teachers to ignore the particular developmental stages and interests of the students, to resist altering the pace of instruction and choice in efforts to adhere to the curricular framework. Undue emphasis on the test may maximize rather than minimize the stress from competition and grades.

Issues With Math and Science Instruction

While the students in the talented teenager study just described recognized a high level of challenge and clear goals in their math and science classes, they complained most about the rigidity of the structured curriculum and the reluctance of teachers to deviate from highly structured programs. They complained of little opportunity for choice, especially with regard to the pace of instruction. Data collected from students while in class revealed unusually high levels of concentration, but also unusually high levels of tension and confusion accompanied by dramatic drops in self-esteem. The authors concluded that their data indicate:

> The problem with our technologically inspired views of education is that we have come to expect learning to be a function of the rationality of the information provided. In other words, we expect that if the material is well organized and logically presented, students will learn it. Nothing is farther from the fact. Students will learn only if they are motivated. Unless a person enjoys the pursuit of knowledge, learning will remain a tool to be put aside as it is no longer needed. (Czikszentmihalyi et al., 1993, p. 195)

The numbers of times that students reported flow experiences in school in art, athletics, and music were more than double the rate of science and mathematics.

Bloom and his colleagues (1985) found that talented mathematicians had engaged in independent work in mathematics while in high school, usually on their own without school support when they found the courses in school uninteresting or too low-level. The teachers and courses that impressed these individuals were those where the teachers were actively involved in learning and able to transmit the excitement of the learning process. Content that intrigued these students was described in one case as follows:

> It was developed by starting with a few axioms, and then, rather than memorizing, we would derive the basic algebraic rules. And then there was the question of proving various theorems. . . . I went to that first year of high school thinking I wanted to be an engineer, but at the end of the year I wanted to be a mathematician. (pp. 306-307)

Extracurricular experiences were extremely important to these mathematicians because:

> the content of these experiences was very different from what they had in class. It was more challenging and interesting to them. They had the opportunity to explore topics with which they were fascinated and develop their own techniques for solving problems. Math became special through these experiences, as did the mathematicians. (pp. 308-309)

Another significant aspect of the extracurricular activities was the peer interaction. One student found that "you learn from your peers and not your teachers" (Bloom, 1985, p. 311). Given the documented over-extension of breadth of study incorporated into AP Programs (NAS, 2002), the likely scenario may be for teachers to focus on "covering," through lecture and teacher-guided discussion, the vast content of the course syllabi rather than to provide opportunities for students to interact with the content as co-learners. The IB cross-disciplinary requirements projects are more structured to demand student interactions with content with their peers.

Advantages and Disadvantages of AP and IB Noted in the Literature

Benefits Noted by Students

In a student-written review of the International Baccalaureate (Choudbury, 1994), the list of advantages include:

- Learning skills including "practice in taking notes at warp speed, preparing voluminous papers in almost every class (even math!), writing up lengthy labs, and taking exams that covered *everything*."
- Preparation for college which resulted in feeling "less stressed by college."
- The "ability to think critically about my world." (p. 5)

The student also noted that the Extended Essay provided for great flexibility. "For our math project, some chose to work with fractals or chaos theory. . . . I did a statistical project studying attitudes; I planned, carried out, analyzed, and wrote up my first psychological study before entering my senior year of high school" (Choudbury, 1994, p. 5). She also noted an emphasis on student discovery of knowledge within the program. "Our teachers presented problems and asked questions, and we students discussed them until we came up with a solution" (p. 5).

Disadvantages Noted by Students

A student verified the findings of the NAS (2002) that among the disadvantages of taking Advanced Placement Programs is the emphasis on the exam, "I wasted time and money taking the AP exams, because I don't really want to graduate in three years" (p. 6) (early graduation being the only AP option for applying AP credit at her college) (Hellerman, 1994b). Another student warned against a false sense of preparedness. "I would caution against blindly letting an AP score be your basis for enrolling in a higher course. Often the AP is NOT the equivalent of a college course. You only need 60% of the points on an AP exam to get the highest score and I can assure you that 60% of the credit in a Harvard course will not earn you an A" (p. 7).

Disadvantages Noted by College and University Faculty

The student sentiment that warns against a false sense of preparedness is echoed by the Center for Undergraduate Education in Science, Mathematics, Engineering and Technology (1999). "Even high scores on the examinations [AP science] cannot necessarily be equated with this desired level of understanding" (p. 24). Part of the concern about the preparedness of students for college courses stems from the conclusion that the College Board courses are based on "*typical* [emphasis in the original] college introductory courses, rather than the best college courses or educational practices based on learning and pedagogy" (NAS, 2002, p. 64). The National Academy panel studying AP mathematics and science courses challenged the "assumption that AP courses uniformly reflect the content coverage and conceptual understanding that is developed in good college courses" (NAS, 2002, p. 192). The IB Program does not claim that its courses are based on college introductory courses, yet many colleges and universities (more than 750 (NAS, 2002)) grant credit for courses based on scores on the IB exams. No systematic research documents the equivalence of AP and IB Programs, and the literature does not present evidence that the IB exam score predicts success in upper-level college courses or that the preparation in IB Programs provides the depth of understanding equivalent to that of introductory college courses (NAS, 2002).

Pedagogical Concerns Stemming From Learning Research

In reviewing the mathematics and science curriculum offered in AP and IB Programs, the National Academy panel (NAS, 2002) concluded that there were shortcomings in these curricula:

- The curricula fail to develop understandings of concepts and key ideas from the disciplines. "Excessive breadth of coverage (especially in 1-year science programs) and insufficient emphasis on key concepts in final assessments contribute to the problem in all science fields . . . . [I]n mathematics, further improvement is needed." (p. 8)
- There is no clear delineation of the specific prior knowledge need for success in the sciences.
- Many of the programs and courses are not effective in helping students develop metacognitve skills.

Other Concerns and Recommendations

Based on a self-report study of teachers who were experienced AP science teachers, Herr (1992) concluded that AP teachers introduce a wider range of topics (than teachers in honors classes do) and cover them in greater detail. But because of the need to cover topics to be tested, they adopt a "strong lecture format and minimize time-consuming, student-centered activities such as laboratory experiments, student projects, and student presentations" (p. 530). Further, one third of AP science teachers judged the pace of AP to be too fast and indicated a preference to switch to honors if given a choice. They also indicated that they fail to spend time on topics that pique the interests of students because of demands of coverage.

Herr (1993) also notes that the offering of AP biology may result in a reduction in high school physics enrollments, particularly when schools offer extra grade point credit for AP Programs. This belief is reaffirmed in the report on biology education in U.S. schools (Commission on Life Sciences, 1990). According to the Commission, counselors feel there are valuable, rigorous non-AP Programs that students pass by to take AP Programs and the Commission is also concerned that AP biology is modeled on biology courses that are poor educational experiences for many students.

> The time has come to stop designing curricula by the process of serial dilution, in which the high school course is a thin version of the college course. . . . Secondary schools need to provide opportunities for able students to become passionate about their interests. . . . The present policy of modeling the AP course after a composite view of college courses is missing opportunities for generating a unique high school experience, providing a more realistic introduction to experimentation, and providing better college preparation . . . . Whatever their form, AP and or other advanced biology courses should not be taken instead of chemistry, physics, or mathematics. . . . We suggest that the terminal year biology course provide intensive treatment of a few topics of molecular biology, cell biology, physiology, evolution, and ecology. Emphasis should be on experimental design, experimentation and observation, data analysis, and critical reading. . . . Colleges and high schools should both recognize the value of a second course in *experimental* science taken at the end of high school. Such a course need not be sponsored by the College Board or be designated "advanced placement." (pp. 85-87)

The practice of ranking schools by the number of AP or IB exams administered has created a high stakes environment that may have detrimental effects on teachers and students. The NAS panel (2002) cautioned that decisions made about teacher effectiveness based on test scores may result in teachers discouraging students from taking the AP or IB Programs they may not pass or may counsel students against taking the exams. The panel also noted the literature that supports the contention that teachers who are judged based on test results are likely to teach to the test. Noting their evaluation that the science and mathematics tests they reviewed are narrow in scope and teach at a surface level of understanding, the panel concludes that teaching to the test in this case will not lead to the

> development of the level of conceptual understanding that should be the goal of advanced study. . . . In sum, teaching to AP and IB tests for the purpose of raising test scores can lead to superficial coverage of a broad base of content knowledge, to teachers ignoring the importance of meaningful inquiry-based and laboratory experiences (AP only) and to students feeling that what they are learning in school has little application to the real world. (pp. 186-187)

Quality control issues relative to the course offerings, the competence of teachers, and the preparedness of students for the course offerings have been raised as an issue for the AP Program, but not for the IB Program that monitors and certifies offerings offered under the IBO imprimatur (NAS, 2002).

The NAS panel also warned that the ranking of schools on the basis of the number of AP or IB classes offered or exams taken may also discourage schools from developing or offering other options that may be better suited to the students who attend a particular school.

Options Other Than Advanced Placement and International Baccalaureate

Consideration of options other than advanced placement seem to rest on either finding alternative ways of offering college equivalencies or finding alternatives to calculus and acceleration as an option for highly able learners.

Other College Equivalency Options

College Courses Taught Within the High School Setting

Individual states have encouraged colleges to develop and support courses within the high school setting that are taught by high school teachers to be used to earn high school credit and college credit simultaneously within that state (Oregon University System, Oregon Department of Education, & Office of Community College Services, 1999). College High, developed in the 1970s, involves cooperative agreements between individual colleges and high schools that provide the opportunity for students to earn credit. At present 14 community colleges and three Oregon University System institutions participate. Each institution is responsible for developing course content and maintaining standards, administrative support, and program monitoring.

Dual Enrollment in College and High School

Students who have exhausted high school options are sometimes given the option of enrolling in community colleges, colleges, and universities for credit toward both the college and high school degree. In many states, student tuition is paid; in others, students pay their own tuition and fees. The opportunities for gifted or highly motivated college-bound students to participate in either dual enrollment or college courses taught in the high school are obviously limited by access to institutions of higher education. Also the quality of course offerings will vary considerably by the quality of the institution and/or the degree of monitoring of course offerings. Hence, options for applying the credit toward a degree may be limited in some cases to the institution that offered the course. However, Oregon and Utah report increasing demand for these options (Oregon University System, Oregon State Department of Education, & Office of Community College Services, 1999). (For a summary of policies on college equivalency options, see Appendix B.)

While many of the schools of mathematics, science, and technology offer AP Programs, they have also developed a repertoire of courses that supplement, extend, or replace those courses. For example, the North Carolina School of Science and Mathematics reports that some of its courses cover the same topics as those covered in AP Programs and that some students elect to take the exams. However, the school disavows the goal of exempting students from college courses and also emphasizes the importance of offering interdisciplinary options. Hence, courses in biophysics, bioethics, and human sexuality are also offered. Further, special research courses and mentorships at nearby universities and laboratories are offered (Eilber & Warshaw, 1988). Similarly, the Thomas Jefferson High School for Science and Technology in Fairfax, VA (a public consortium high school) offers courses in supercomputing, quantum physics, artificial intelligence, linear algebra, marine biology, medical technology, etc. in addition to traditional AP Programs (S. Bloomquist, personal communication, March 16, 2000). While these courses are designed for special schools, there are many equally able students who do not attend these schools who might benefit from similar instruction.

Apprenticeship Programs

While the Rutgers University apprenticeship program in astrophysics was offered only during the summer and for a limited scope of topics, the initial evaluation of the program suggested that it was more effective in teaching concepts assessed on the AP physics exam than the traditional AP instruction and that it was judged more engaging and motivating by students (Etkina, Lawrence, & Charney, 1999). The students in the program first developed and defended models of observed physics and astronomical phenomena. Then they worked on an actual science investigation with a research scientist. Not only were quantitative data supportive of achievement gains, but also qualitative analysis of discussion groups and journals revealed changes in student thinking and questioning that paralleled that of the scientists who instructed the program. In this program, students "acquired an authentic scientific sense that study of this new material generated more questions than answers—a very different experience from the textbook-based known bodies of knowledge that had been the foundation of their educational experience" (p. 505).

Other Course Options

An alternative entry-level college course in mathematics with potential for highly able high school students has been developed by the Consortium for Mathematics and Its Applications (Arney et al., 1997). Designed as a two-semester college alternative to calculus and using themes such as growth and change, it presents students with a program of studies emphasizing breadth in the coverage of the field of mathematics and a variety of studies emphasizing modern mathematical applications and strategies for mathematical inquiry.

One other alternative to fast-pace options in highly structured mathematics courses has been to offer greater depth (Saul, 1999). Stressing the need for highly able students to understand complex concepts in depth and the dangers of not allowing students to discover structure, Saul recommends such alternatives as introductory calculus going beyond discussions of the limit of a function and allowing students to explore the notion of the limits of sequence intuitively. Another response is to create project-based courses such as a physics-calculus interdisciplinary course in which students use the concepts, principles, and generalizations to solve real-world problems (Ramey, 1999).

Summary

The rapid growth of Advanced Placement and International Baccalaureate Programs in the United States is clearly based on filling a gap in the provision of high level, challenging courses at the high school level. While developed for different purposes and for different constituencies, the courses in both educational options often come to be the basis for gifted educational programs in the secondary school. Their popularity can be attributed to many factors including government support; the availability of curricular guides, materials, and training; recommendations and commendations of the program by experts in gifted education, teachers of the courses, and students; increased use of the courses as gauges of school quality; and the positive regard of college and university admissions officers.

However, the research supporting and documenting the effects of the instruction are very limited. There are studies that have investigated student and teacher satisfaction with the courses and researchers have conducted limited investigations of the educational success of students who have participated in the programs. Further, the Commission on Life Sciences of the National Academy of Sciences and the Center for Undergraduate Education in Science, Mathematics, Engineering, and Technology have raised some serious questions about the appropriateness of AP Programs in preparing students for college science success. Further questions are raised about equity issues, the appropriateness of the curriculum for all gifted students, and the concurrent concerns about the degree to which either of these options becomes the only option available to high end learners at the secondary level.

As with many areas of gifted education, the lack of satisfactory research data comparing alternative options for the wide variety of students who are labeled gifted or who have the potential to develop as gifted adults appears to have resulted in limiting options for students rather than broadening them in defensible ways. This is not to suggest that AP and IB options are not viable, but further research is needed to document the effectiveness and appropriateness of these options as compared to other curricula that have been developed or might be developed for secondary gifted students.

Recommendations for Parents and Educators

Recommendation One: Before adopting any advanced courses for gifted students ensure that the options either provide for or allow for the adaptation of curriculum to ensure achievement of "deep conceptual understanding of the discipline's content and unifying concepts" (NAS, 2002, pp. 197-198).

Recommendation Two: Advanced Placement Programs and International Baccalaureate Programs do not necessarily lead to the achievement of the goals of deep conceptual understanding of the epistemology of the discipline or a full appreciation of the interrelations among concepts. Therefore decision to adopt those courses should be accompanied by an assurance that teachers who are selected to teach in those courses have that knowledge and understanding themselves and have the pedagogical skills to translate their understanding into curriculum and instructional practices that will result in student understandings.

Recommendation Three: Ensure that equity of access is provided for all advanced level courses designed for gifted and talented students. Not only do we need to ensure that typically underserved populations have access, we should ensure that they are provided with the preparatory study necessary for success.

Recommendation Four: Closely examine the opportunities for preparation for all students that are not overly compressed such that time for the thoughtful and reflective study of the disciplines is lost (NAS, 2002).

Recommendation Five: Carefully evaluate all offerings for advanced learners at the secondary level to ensure that the curricular and instructional practices best reflect how people learn and incorporate the opportunity to develop metacognition (NAS, 2002). Do not assume that the college course model reflects those principles.

Recommendation Six: Provide guidance to students in making appropriate decisions about the advisability of accepting advanced placement rather than taking the introductory courses in college.

Recommendation Seven: Consider alternatives to AP and IB. The National Academy Panel recommends that "Approaches to advanced study other than AP and IB should be considered. Such alternatives can help increase access to advanced study for those not presently served and result in the emergence of novel and effective strategies" (NAS, 2002, p. 202).

Recommendation Eight: Remember that not all gifted students are like all other gifted students. Accordingly, consider alternatives to meet the needs of the widely divergent types of gifted students.

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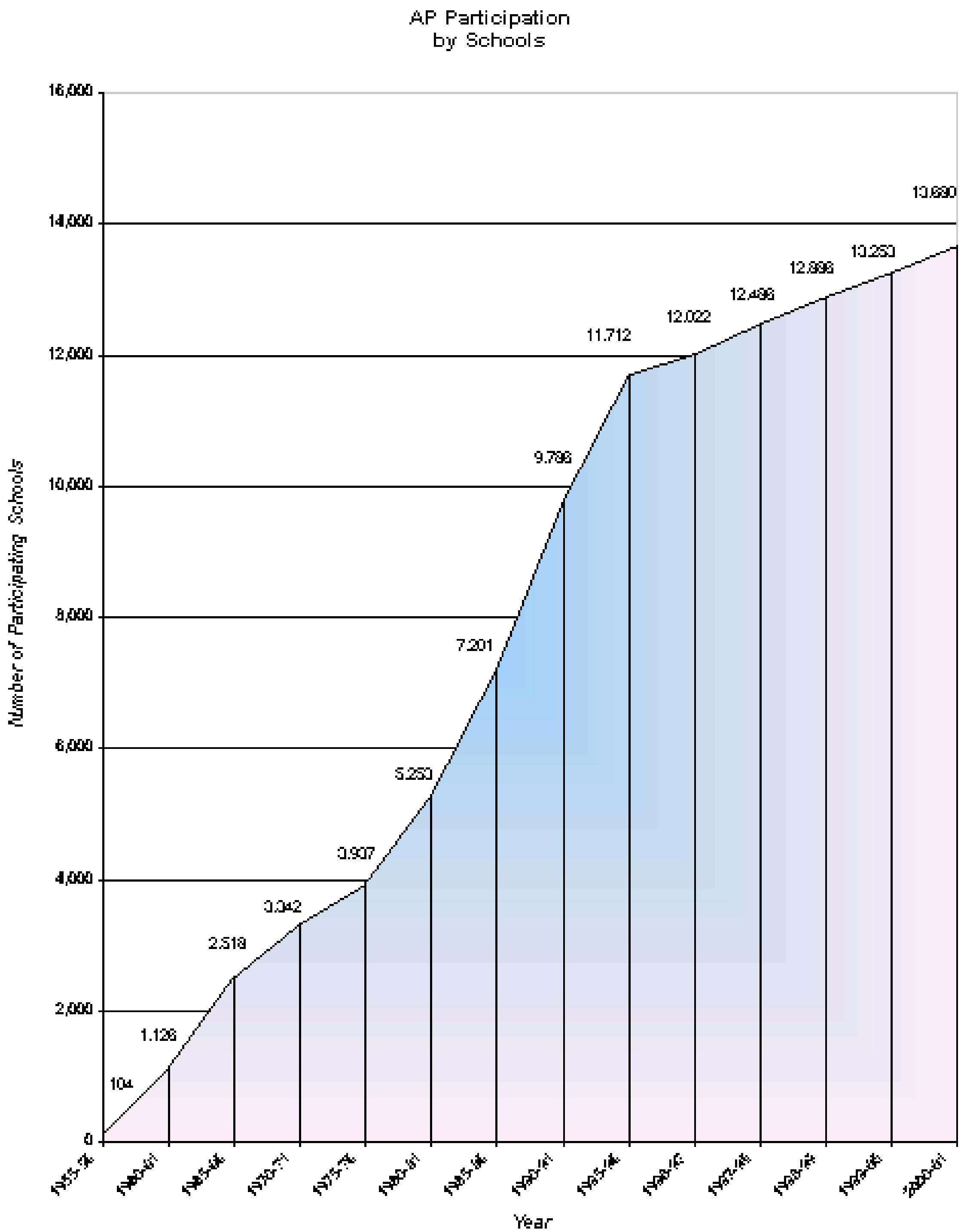
Appendix A
Growth of Advanced Placement Programs

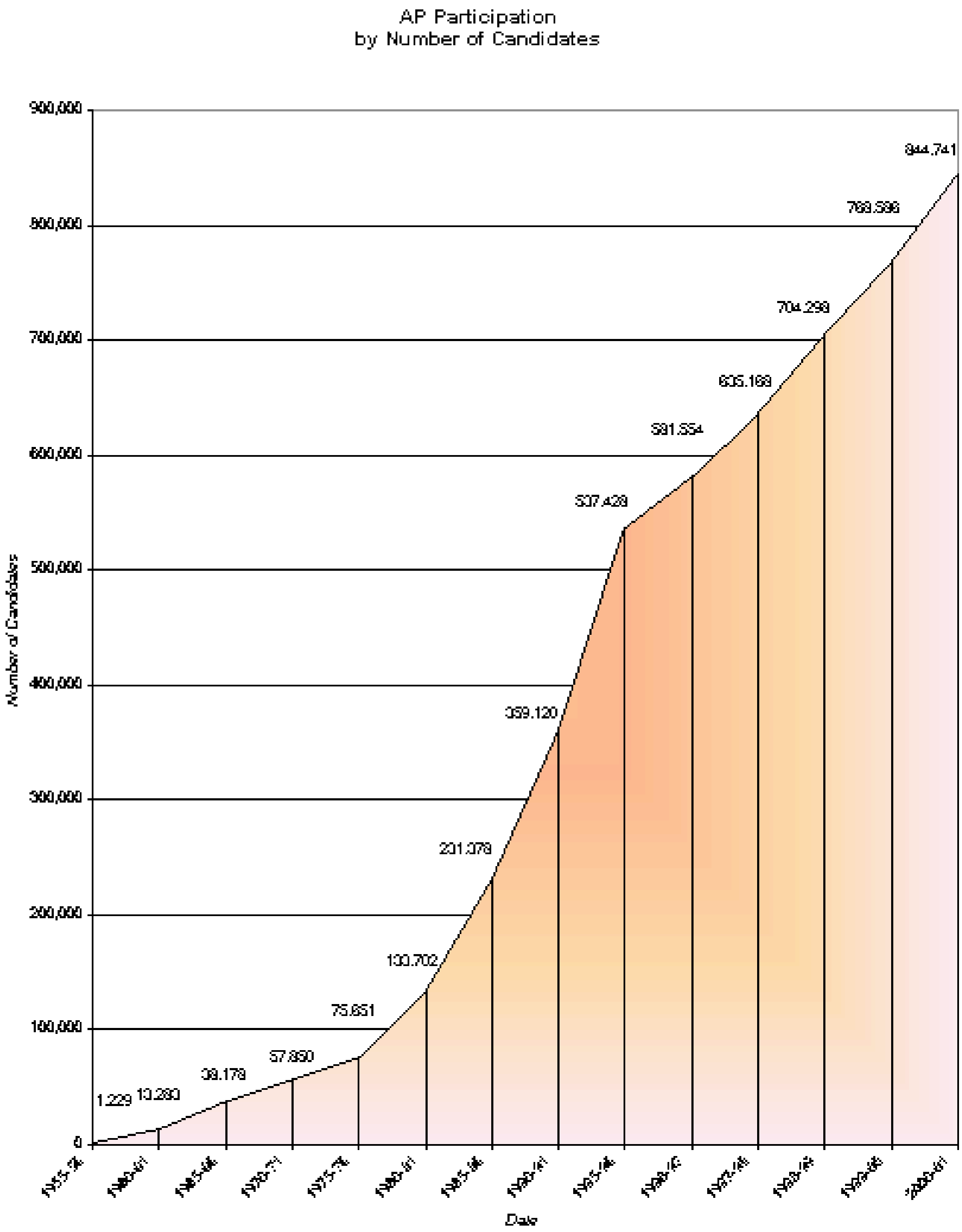
AP Participation by School

Year	AP Schools
1955-56	104
1960-61	1,126
1965-66	2,518
1970-71	3,342
1975-76	3,937
1980-81	5,253
1985-86	7,201
1990-91	9,786
1995-96	11,712
1996-97	12,022
1997-98	12,486
1998-99	12,886
1999-00	13,253
2000-01	13,680


AP Participation
by Schools
Number of Participating Schools
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
104
1.126
2.518
3.342
3.907
5.253
7.201
9.786
11.712
12.022
12.486
12.886
13.253
13.680
Year

AP Participation by Number of Candidates

Year	Candidates
1955-56	1,229
1960-61	13,283
1965-66	38,178
1970-71	57,850
1975-76	75,651
1980-81	133,702
1985-86	231,378
1990-91	359,120
1995-96	537,428
1996-97	581,554
1997-98	635,168
1998-99	704,298
1999-00	768,586
2000-01	844,741


AP Participation
by Number of Candidates
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Number of Candidates
1.229
13.283
38.178
57.850
75.651
133.702
231.378
359.120
537.428
581.554
635.168
704.298
768.586
844,741
Date

AP Participation by Number of Exams Taken[*]

Year	Exams Taken
1955-56	2,199
1960-61	17,603
1965-66	50,104
1970-71	74,409
1975-76	98,898
1980-81	178,159
1985-86	319,224
1990-91	535,186
1995-96	843,423
1996-97	921,601
1997-98	1,016,657
1998-99	1,149,515
1999-00	1,272,317
2000-01	1,414,387

[*] "This month more than a million students in 14,000 high schools took 1,750,000 AP exams, a 10 percent increase over last year and twice the number of these college-level tests taken in 1996" (p. 50).
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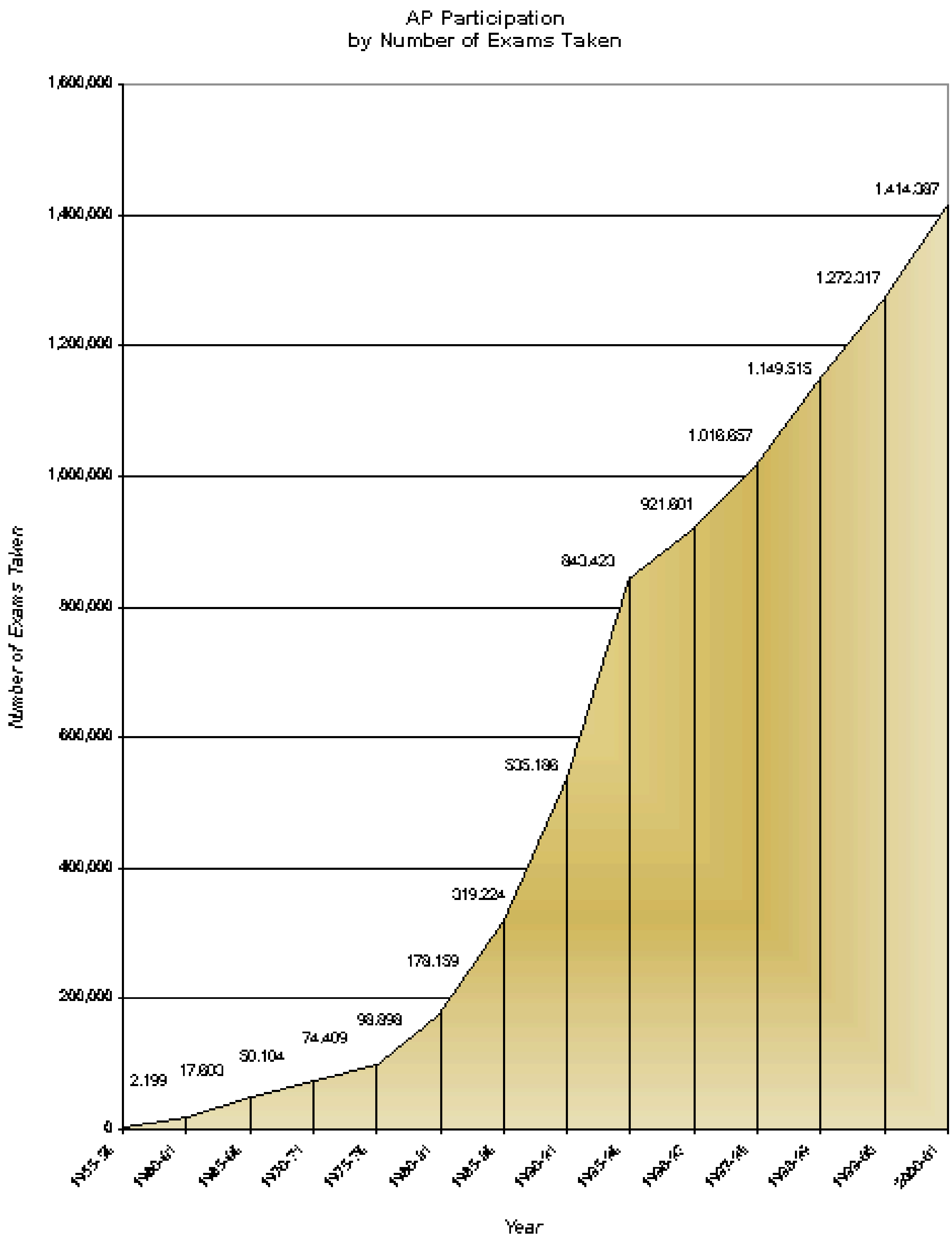
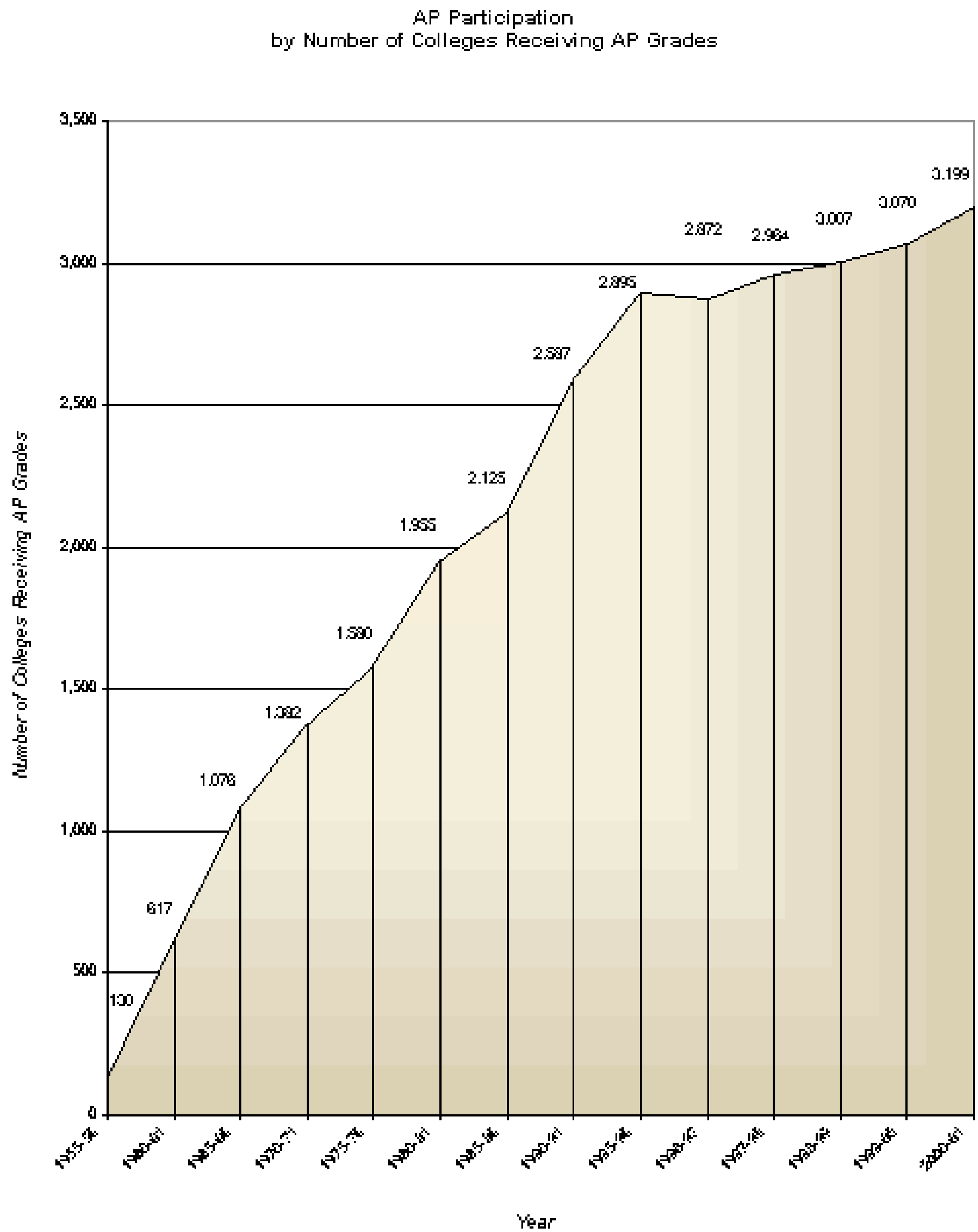

AP Participation
by Number of Exams Taken
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Number of Exams Taken
2.199
17.600
50.104
74.409
98.898
178.159
319.224
535.186
843.420
921.601
1.016.657
1.149.515
1.272.317
1.414.387
Year

AP Participation by Number of Colleges Receiving AP Grades

Year	Colleges Receiving AP Grades
1955-56	130
1960-61	617
1965-66	1,076
1970-71	1,382
1975-76	1,580
1980-81	1,955
1985-86	2,125
1990-91	2,587
1995-96	2,895
1996-97	2,872
1997-98	2,964
1998-99	3,007
1999-00	3,070
2000-01	3,199


AP Participation
by Number of Colleges Receiving AP Grades
Number of Colleges Receiving AP Grades
3,500
3,000
2,500
2,000
1,500
1,000
500
0
130
617
1.076
1.382
1.580
1.955
2.125
2.597
2.895
2.872
2.964
3.007
3.070
3.199
Year

Appendix B
Total Numbers of Students Taking Advanced Placement Exams in Specific Courses

TOTAL EXAMS ADMINISTERED	1,139,516
ART: HISTORY	7,993
ART: STUDIO DRAWING	4,555
ART: STUDIO GENERAL	7,970
BIOLOGY	73,288
CALCULUS AB	117,518
CALCULUS BC	30,712
CHEMISTRY	44,550
COMPUTER SCIENCE A	12,905
COMPUTER SCIENCE AB	6,318
ECONOMICS: MACRO	23,218
ECONOMICS: MICRO	14,859
ENGLISH LANG & COMPOSITION	112,954
ENGLISH LIT & COMPOSITION	161,014
ENVIRONMENTAL SCIENCE	15,070
EUROPEAN HISTORY	51,968
FRENCH: LANGUAGE	10,743
FRENCH: LITERATURE	707
GERMAN: LANGUAGE	3,143
GOVERNMENT POLITICS COMP.	7,710
GOVERNMENT POLITICS U.S.	66,208
HUMAN GEOGRAPHY	2,751
INTERNATIONAL ENGLISH LANG	16
LATIN: LITERATURE	1,256
LATIN: VERGIL	1,900
MUSIC THEORY	5,133
PHYSICS B	27,006
PHYSICS C: ELEC. & MAGNET.	6,434
PHYSICS C: MECHANICS	13,723
PSYCHOLOGY	37,385
SPANISH LANGUAGE	58,636
SPANISH LITERATURE	7872
STATISTICS	35,238
US HISTORY	168,763

Research Monograph

The National Research Center on the Gifted and Talented
University of Connecticut
2131 Hillside Road Unit 3007
Storrs, CT 06269-3007
www.gifted.uconn.edu

Editor
E. Jean Gubbins

Production Assistant
Siamak Vahidi

Reviewers
Thomas Hays
Rachel Sytsma

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The National Research Center on the Gifted and Talented Research Teams

University of Connecticut

Dr. Joseph S. Renzulli, Director
Dr. E. Jean Gubbins, Associate Director
Dr. Sally M. Reis, Associate Director
University of Connecticut
2131 Hillside Road Unit 3007
Storrs, CT 06269-3007
860-486-4676

Dr. Del Siegle

University of Virginia

Dr. Carolyn M. Callahan, Associate Director
Curry School of Education
University of Virginia
P.O. Box 400277
Charlottesville, VA 22904-4277
804-982-2849

Dr. Mary Landrum
Dr. Tonya Moon
Dr. Carol A. Tomlinson
Dr. Catherine M. Brighton
Holly L. Hertberg

Yale University

Dr. Robert J. Sternberg, Associate Director
Yale University
Center for the Psychology of Abilities, Competencies, and Expertise
340 Edwards Street, P.O. Box 208358
New Haven, CT 06520-8358

Dr. Elena L. Grigorenko