Advanced Biology for Talented High School Students

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The authors describe an experimental advanced biology course and its impact on the subsequent college careers of the participants

The development of various curricular materials for talented high school students in biology (e.g., BSCS second-level course) reflects the national concern for providing enrichment opportunities for these students. A great diversity of course innovations also are being attempted by many individual high schools to enhance the development of students with high scientific potential. The difficulties encountered in curriculum development at the community level are of vital concern to biology teachers. Yet relatively little attention has been given to discussion of the problems and nature of this type of course development.

Reasons for the initiation of advanced biology courses at local schools have been reported by Lightner. (1) In his survey of 1217 high schools in the United States, he found that 171 schools offered advanced biology courses (i.e., a one or two semester biology course requiring as a minimum prerequisite the completion of a course in general biology). Of 135 teachers of advanced biology responding to his questionnaire only 6 indicated that the Advanced Placement Program was the course they offered. Since the Second-Level BSCS course was not available at that time, it is apparent that the vast majority of advanced programs were probably developed in relation to local school needs and interests. Even with new materials created by BSCS, it is likely that local needs and interests will dictate the most effective utilization of such materials.

The purpose of this article is to discuss the formulation and implementation of an advanced animal biology course, including case studies of the participating students and the effects of this course on their college performance in biology. Also included will be implications and suggestions for general improvement of advanced biology courses.

Formulation of the Course

The course in advanced biology discussed here was taught at Guilderland Central Senior High School, Guilderland Center, New York. This is a moderate-sized suburban high school having a student population of approximately 900 students in 1961. A comprehensive curriculum is offered with programs available in college preparation, business education, fine arts, and practical arts. Guilderland Central High School has a science curriculum that offers a full year of seventh and eighth grade science, a full year of ninth grade science, with Earth Science as an elective subject for capable students. Biology is offered at the tenth grade level with the student being able to elect Physics and Chemistry in the eleventh or twelfth grade. One additional science course in advanced physical science is offered for seniors as an elective. It was evident from student inquiries and from career interest questionnaires that approximately 5–10% of the 900 student population wanted advanced training in science. Of these students many expressed a definite interest in the animal aspects of biology with particular emphasis on those topics which would help them towards a professional career in medicine, zoological research, and related fields.

Obviously, no single type of course can be designated as "the" course for talented science students. The approaches that may be most stimulating for one group of talented minds may not be as suitable for another group. For example, in one situation it may be desirable to develop a course along molecular lines involving open ended experimentation; in another situation, the most beneficial type of course may involve a more classical study of vertebrate structure and function.

With the above philosophy in mind, and recognizing the backgrounds, abilities and career interests of the group, it was decided to organize the program as outlined in the following course description:

> "This science enrichment course is divided into three major segments which will cover one complete academic year of two semesters. The first segment is a very rapid review of the animal kingdom with lectures on Systematics. Laboratories on biostatistics and malarial parasites are included as introductory material. Lectures are given on the taxonomy of the chordates with detailed study of the borderline forms being stressed. Detailed dissection of the bullfrog (*Rana catesbiana*) and the cat (*Felis domesticus*) follow with emphasis placed on the learning of the vertebrate body plan. Lectures of major body systems such as integumentary, skeletal, circulatory, endocrine, etc., coincide with the laboratory work. Keeping of laboratory manuals and some laboratory diagrams is emphasized. The students also are given practical experience by taking examinations on the representative organisms.
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> The second semester of the course consists of microanatomy with emphasis placed upon the student learning the technique of obtaining, preparing, embedding, sectioning, and staining of various animal tissues. Experience with the microscope and microtome will be provided. On one tissue of his choice each student also prepares an illustrated lecture which is presented to the class. This includes the preparation by the student of his tissue and photomicrographs of it. Experience with reference material is provided as time permits. The last phase of the course is spent on radiation biology with a basic treatment of physics of radiation giving major emphasis to the biological effects of radiation. Detailed study of the effects of X-irradiation is made using the white rat as an experimental animal. Use is made of the count-rate meter and tracers. Uses of radiation in biology are studied.
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> Since the class enrollment in Advanced Biology is limited, preference is given to seniors who meet the qualifications. Juniors who have had biology and are taking chemistry will be considered. More than successful completion of the basic biology course is also required. The course is designed for those students contemplating a career in the biological sciences, particularly in the fields of medicine, dentistry, and zoology.
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> Several college texts are used with materials taken from current literature to supplement. Prerequisites; Biology, Physics and/or Chemistry, and approval of instructor."

Due to space limitations, all of the course details cannot be presented here. Information concerning course content, laboratory materials, textbooks, equipment, and schedule of events, week by week lesson plans, etc., are available in detail for interested readers. (2)

Problems

Some of the problems encountered early in the development of the program concerned time, space, and acquisition of equipment and instructional materials.

Scheduling the course posed some difficulty. The course consisted of two semesters, eighteen weeks per semester. Each week involved five lecture-discussion sessions of 55 minutes each. In order to fit advanced laboratory work into an already crowded student schedule, it was necessary to have the laboratory sessions after the regular school day. These consisted of one three-hour session per week.

Time for teacher preparation was another problem. The preparation for this course required a great amount of time beyond the normal teaching requirement, which was five periods of a seven period day. Although one teaching period was freed for working on the course, preparation involved many evening hours.

Obtaining a laboratory suitable for the course was a problem. A laboratory room reserved solely for this class would have been ideal. However, it was necessary to use a laboratory that was in regular use by different classes each day. Thus, the students in the advanced class had to pick up their materials after each session and it was difficult to plan sustaining experiments.

Another item of importance was the selection of appropriate texts and laboratory manuals. Due to the diverse nature of this course, it was impossible to select one text that would serve the purpose. After examining many as to content, literary style, vocabulary, illustrations, and mechanical makeup, six books were selected which were appropriate for the course. Many supplementary, mimeographed laboratory exercises were provided. Even though a wealth of textbooks and manuals are available, judicious selection from these sources is essential for satisfying individual needs.

A course of this nature requires equipment that is expensive. For example, approximately $500 was necessary to purchase a rotary microtome and an additional $300 was expended for photographic materials. Other expensive items included quality binocular microscopes and a good quality count-rate meter. In addition to these major items, numerous expendable supplies were required.

In terms of the small number of students using the equipment it would seem that the expense was very high. This question was raised by the administration and it was pointed out by way of justification that these items could be used by many future classes. Obviously, administrative cooperation in the procurement of equipment is essential to the ultimate success of this type of program.

Student Participants

The total number of students selected to participate in this program was twelve. The course was offered for two years with six students participating each year.

The criteria considered for selection were I.Q., reading ability, individual interest, previous performance on New York State Regents Biology Exam, and personal appraisal of student performance in the first biology course. Gifted students normally make up the top 20% of the population and will have I.Q.'s above 120. (3) In Guilderland, the I.Q. range, based upon the California Test of Mental Maturity given in grade twelve, was from 104-147 with a mean I.Q. for the group of 120. On the California Reading Test the group range was 13.5–15.9 with a mean score of 14.9, and on the New York State Regents Biology examination the range was 85–100, with an average of 94.

Since the instructor of the advanced course had 8 of the 12 students in the beginning course a personal estimate of the students' ability and interest was readily available. Evaluations of the remaining four students were obtained from the instructor's colleagues.

Case Studies

To determine the value of the course to the participants, the case study method was employed. This involved a personal interview and questionnaire administered to the individual student after his first college level biology course. Parents and the college instructor of each student were interviewed whenever possible. Since we were concerned about laboratory performance an attempt was made to interview the laboratory instructor. The majority of these instructors were graduate students, extremely busy, and their impressions of individuals were rather hazy and, in general, proved unsatisfactory.

The parents were interviewed while the student was involved in the advanced course in high school. They generally did not know much about the major aspects of the program and their impressions were not very helpful.

A student questionnaire was designed to obtain the following information: 1). College attended, 2). College major, 3). Year in college, 4). College courses in biology and grades received, and 5). Value of the advanced high school course in relation to college courses.

As a result of the questionnaire and personal interviews, it seemed that all twelve students were benefited in their beginning college biology courses. One indicated he did not benefit greatly because of the nature of his college course which was totally taxonomically oriented.

The major ways in which the program benefited these students was as follows:

1. Familiarity with technical vocabulary and concepts.
2. Exposure to topics and preparation in the ways the modern biologist thinks.
3. Learning valuable laboratory techniques; such as photomicrography and histological techniques.
4. Comparative and evolutionary approach to the study of anatomy.
5. Significance of embryonic study of the development of living organisms.
6. Exposure to "college type" examinations, and laboratory practicals.
7. Stimulation of interest in biology and related fields.
8. Providing the correct skills of study and methods of preparation necessary for success in college.
9. Exposure to a scientific attitude of self-discipline toward problem-solving and life in general.
10. The background information acquired provided the necessary confidence for college success.

Conclusions:

Although many of the aspects of the development and implementation of this course in advanced animal biology cannot be included here, certain conclusions based on this experience may prove valuable to the reader. They are:

1. Students of the type involved in this program are capable of handling content material of substantial complexity at a relatively rapid rate provided that the material is presented in a way that is meaningful to them.
2. This curriculum development was teacher-originated and depended upon teacher-dedication to be successful.
3. Favorable administrative attitude, encouragement, and interest are vital components of a successful venture and one should truly be aware of the administrative attitude before the work is undertaken.
4. Parental attitude is of small significance to the program's success.
5. An advanced course can have both good and adverse effects on participating students. Though the good effects far outweigh the bad, we saw a student fall into the trap of complacency and do great harm to himself. On the other hand, we have seen how students have used this academic advantage to further their own accomplishments. Each student should be made aware of this pitfall.
6. Courses of this nature should be highly laboratory oriented. Of all the benefits indicated by the students, laboratory experience was the most frequently cited.
7. An advanced biology course should provide freedom to allow a student to pursue his individual interest to some extent.
8. An advanced course should be demanding. The student expects and enjoys such an approach, providing it is reasonable and meaningful to him.

Thoughts for the Future

Obviously, there is much to be done in the future in order to improve the teaching of advanced biology courses in high school. Some of the problems that seem worthy of further investigation are:

1. Devising objective methods for evaluating such courses and determining the effects upon the students.
2. Determining what specific teacher qualities and training are necessary for successful implementation of such a course.
3. Objectively evaluating the relative effectiveness of laboratory versus lecture approaches to the teaching of advanced biology.
4. Designing and testing syllabi and instructional materials and references for advanced biology.
5. Integrating the high school advanced biology course with college placement in biology.
6. Establishing self-sustaining advanced biology programs that are not wholly dependent upon single individuals for proper and effective implementation.
7. Maximizing efforts to reconcile the attitudes of administrators and teachers towards achievement of common educational goals.

References

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Carbon Dioxide In Photosynthesis and Respiration

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A laboratory exercise designed to show that CO_2 is consumed during photosynthesis and liberated during cellular respiration. It only requires materials that usually are stocked in all high school laboratories.

The plant used in this experiment is the fresh water green plant called elodea. Elodea grows free from any root or rhizoid attachment to substrate. Elodea has many flat leaves which contain hundreds of cells which in turn contain thousands of chloroplasts. In this experiment, elodea is suspended in a water solution, free from any attachments, and displays its capacity for photosynthesis. It is in such a situation that CO_2 consumption and liberation can best be studied. As CO_2 is absorbed by water, carbonic acid is formed; thus CO_2 concentration in water can be measured very exactly in terms of pH levels.

Procedure: To prepare for this experiment, a slightly basic solution at pH 9.0 containing a very sensitive pH indicator should be prepared in advance. This solution will be used later to test for the carbonic acid content of the water in which the elodea is immersed. To make this solution, place 100 ml of distilled water into a 100 ml beaker. Add approximately 2.2 ml of 0.1 molar NaOH solution, drop by drop, until this solution has a pH of 9.0. Then add 0.1 grams of phenolphthalein powder to the water. Place the beaker on a hot plate and boil gently for 20 minutes, or until the solution turns a deep red in color.

If a 0.1 molar NaOH solution is not available, it may be prepared by adding 0.4 grams of sodium hydroxide to 100 ml of distilled water. Sodium bicarbonate may be substituted for sodium hydroxide by slowly sprinkling baking powder into the water until pH 9.0 is reached.

While waiting for the test solution to slowly boil, take 300 ml of water from the aquarium in which the elodea is growing. Place this water into a 500 ml beaker and bubble CO_2 from your breath into the water with a 10 inch piece of glass tubing. If a tank of CO_2 is available in your laboratory, a length of rubber tubing may be attached to the nozzle of the tank, and in this way CO_2 may be slowly bubbled into the water from the aquarium. Regardless of either method used, CO_2 should be slowly bubbled into the water until the pH of the water is lowered to 6.0. As CO_2 is bubbled in the water, carbonic acid is formed. The formula expressing this chemical reaction is $CO_2 + H_2O \rightleftarrows H_2CO_3$. It is not recommended that any other method be used to place CO_2 into the water, otherwise other ions, acids, buffers, etc., may be introduced which may offset your final results during the laboratory portion of this experiment. PH paper, or a standard pH meter may be used to check pH levels in the water during the execution of the experiment.

At this point in the experiment 20 grams of fresh green elodea sprigs, approximately 3 inches long, should be removed from the aquarium. Then three 100 ml graduated