INTRODUCING APPLICATIONS OF BIOTECHNOLOGY TO HIGH SCHOOL STUDENTS

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It increasingly appears that high school students who have the opportunity to take science and mathematics courses which lead to careers in technology fail to do so. This national dilemma may stem, in part, from the fact that students simply have no idea of the socially positive nature of technological contributions. Those students who avoid taking the most challenging mathematics and science courses while in high school may not know how exciting the practical results of their knowledge can be, or how useful their contributions could be. Briefly, high school students need to be given a more pragmatic grasp and understanding of technology in addition to guidance concerning their career paths. With some practical understanding of technology, these same students might then pursue advanced science and math courses while in high school.

EXPLORATORY PROGRAM

We have been investigating ways to introduce applications of modern biotechnology to high school students, with the objective of incorporating these applications into high school science courses. To date we have carried out two quarters of a pilot program, meeting after school with local ninth and tenth graders. The sessions in the first quarter were one hour long and were of a "show and tell" nature. (About twenty-five students began this first group and about twenty completed the quarter). For the second quarter, we held two-hour sessions in which we introduced a topic and then conducted a demonstration which included some measurement. This was followed by an "experiment" conducted with groups of three to four students. In all cases, the sessions closed with a written quiz and a discussion of the results of the quiz.

This second-quarter pilot program involved two groups of students, and fifty-two out of sixty-four students completed the program and received a certificate. Moreover, fifteen of the students volunteered to continue with a summer internship project. We now believe it is important to also work closely with the teachers and are planning a summer session for high school science teachers.

Our objective in conducting this exploratory project was to learn how to introduce technology into high schools. Biotechnology was selected as our theme because of the background of several of our engineering faculty in this field, and because this technology has recently attracted media attention and, we as-

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sumed, student interest. Moreover, biotechnology cuts across essentially all standard career fields and is most often interdisciplinary in practical implementation.

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PROGRAM INITIATION

The first quarter of the pilot program was initiated through an established program at Northeastern University which provides academic support to, primarily, minority students. This first quarter of our "Applications of Biotechnology" program was offered to tenth graders, and our one-hour session on the topic was followed by one hour of mathematics for the same students. Our retention through the quarter of about twenty students out of the beginning twenty-five was exceptional when compared to other attempts to present topical issues to high school students.

Our pilot program for the second quarter was initiated when two professors visited a biology teacher and one of his ninth grade classes at a local high school. After discussing our plans for a second after-school pilot course, the biology teacher (with the approval of his Headmaster) agreed to hand out an application form and questionnaire. We had hoped to have as many as fifteen students enroll but had anticipated perhaps twelve. We were all surprised when sixty-four students applied. The biology teacher and others at the school tried to, but could not, pinpoint the "key" words in the application that attracted the interest of so many students.

At this point, because of the large number of applicants, the Headmaster wanted to know what our criteria would be for accepting the planned-for 12-15 students and rejecting the others. We then decided to accept all of the applicants and to divide our second pilot project into two classes to accommodate them. Each class would have identical presentations and would meet after school for two hours on Monday and Tuesday.

CONDUCTING A SESSION

Our plan was to present approximately a one-hour informal lecture on a topical subject, with as much question-and-answer participation as possible. While some of the classroom discussions also included show-and-tell demonstrations, most of this first portion of the two-hour session was used to introduce the technical topic of the day. As noted previously, we prepared a typed quiz for the students to take. To save time, the snack-break was coupled with the written quiz, enabling an immediate review of the quiz. The second portion of the session was then devoted to some type of "hands-on" experimental work which involved some aspect of quantitative measurement.

A discussion of one particular session will be useful here. In the session on pharmaceuticals, we demonstrated "pan agglomeration" or "prilling" of "tiny time capsules" to the class in the first portion of the session. In the second portion, students were divided into groups of three students each, and each group was given three pairs of pre-pressed tablets, *i.e.*, six tablets, along with a beaker of water. The tablets contained sodium bicarbonate and citric acid, so the reaction, when dropped into water, was a visible effervescent carbon dioxide. It surprised the students to learn that the tablets had been prepared under 2,000, 4,000, and 6,000 p.s.i. compression, and therefore they had significantly different "release" times.

After measuring the timed release of these tablets, we passed out similar tablets, but with a biopolymer coating (also demonstrated by spray coating), to demonstrate a long-acting, or "controlled release," system. As expected, these time-capsules had a much longer "lifetime."

TOPICS

A list of the topics covered in each session during our pilot program follows.

• Session 1 •
Bioconversion of Municipal Solid Waste

In this session we discussed the bioconversion of municipal solid waste. Under appropriate conditions certain microorganisms degrade wastes and produce fuel gas, a valuable by-product. The magnitude of the problem of disposing of municipal solid waste was reviewed using 35mm slides of "dump sites" in different places throughout the world. Students seemed impressed that substitute natural gas, used in some of their own homes, could be produced from wastes—through the action of microorganisms.

• Session 2 •
Medical Applications of Plastics

In this session we discussed medical applications of biopolymers. Biopolymers are special plastics that are used, for example, as surgical staples, bone "grout" (a putty-like material used for bone repair), heart valves, bone splints, *etc.* We focused, in particular, on biodegradable plastics used as implantable long-acting controlled release drug delivery systems. For this application, a conventional drug (for example, an antimalarial drug) is blended with a biodegradable plastic. This drug/polymer matrix is then extruded into a small thin rod, about the size of a pencil lead. When this rod is implanted, the drug slowly diffuses out and, as the polymer biodegrades, a continuous release of drug occurs, providing protection (in this example case) against malaria. We used 35mm slides to illustrate a number of controlled release drug delivery systems in model animal situations.

• Session 3 •
Biopolymers in Concrete

The purpose of this session was to introduce a novel application of biopolymers, *i.e.*, using a biopolymer in concrete with the objective of reducing water permeability. The reasoning was that using a water soluble plastic in making concrete would reduce water penetration, resulting in an improved material for pothole repair. Students, in groups of three, carried out the preparation of concrete in the laboratory. Samples were prepared with and without biopolymer. Using similar samples of concrete (prepared earlier for this class), students observed and recorded compression strength testing on the Instron tester. Most students were not aware of the technology involved in considering an improved concrete.

• Session 4 •
Production of Bread Yeast

Technology for producing yeast used in making bread is similar to the technology for producing antibiotics and other pharmaceuticals and biologicals. Using bakers yeast as a model, students carried out the initial plating of the yeast (many came back the following week to show their cultures), and they observed the yeast growing in shake flasks and the production of yeast in a pilot-plant fermenter. To stress the importance of being able to measure key parameters, samples of yeast in the active growth phase were taken, and students monitored the oxygen uptake rates. The students showed an interest in actually observing microorganism-growing situations.

• Session 5 •
Prevention of Acid Rain

"Acid rain" is generally believed to be caused by burning coal which contains substantial amounts of sulfur. Research work is under way to use enzymes to clean the organic sulfur from coal. We presented a demonstration of enzyme activity as well as measurement of sulfur removal. The students recognize the importance of reducing acid rain and were impressed by the catalytic activity of enzymes.

• Session 6 •
Preparing Pharmaceutical "Tiny Time Capsules"

The technology of pan agglomeration, or "prilling," was demonstrated, showing how "tiny time capsules" are produced from a mixture of powdered pharmaceutical chemicals. Components of commercial Alka Seltzer® (citric acid and sodium bicarbonate) were used as a model system. After "prilling," the small beads were coated or encapsulated with biopolymer, thus providing for a longer-acting release of the active ingredients. Prior to the class we had also prepared (by compression) tablets of citric acid and sodium bicarbonate, and each student group of three received three tablets. After placing a tablet into a beaker of water, the group would determine the time required for complete dissolution. Since we had prepared the tablets under different pressues (2000, 4000, and 6000 psi), the time for dissolution varied. The tablets coated with a polymer were found to have much longer lifetimes. The students were interested in observing and learning how selected conventional pharmaceuticals are produced.

• Session 7 •
Field Trip to Sewage Treatment Plant

We took a field trip to the Massachusetts Water Resources Authority sewage treatment plant located on Deer Island. Plans for the new Boston harbor cleanup, to be carried out from this facility, were also reviewed. The tour was directed by a person intimately familiar with all operations of the plant and it involved site visits to all major aspects of the facility. Students were impressed with the size of both the treatment plant and the new composting pilot plant (for converting sewage sludge residuals into a material for organic gardening).

• Session 8 •
Food Technology Applications

Three undergraduate chemical engineering students presented brief overviews of their special assignment dealing with food technology. One student presented the procedures for concentrating orange juice, the central step of which is freeze crystallization. Comparisons were made between preparing concentrated orange juice (freezing from water) and shipping "not from concentrate." Another student considered freeze drying of meat such as that used in making certain soup mixes. There was a lively discussion about food preservation techniques, including the use of chemical preservatives and methods used in other countries.

• Session 9 •
Unit Operations

In this session, the students were introduced to process systems and "scale-up," *i.e.*, the consideration of how chemical and biochemical products are manufactured on a larger, more practical scale. Unit operations consist of singular processing units which, when combined, make up essentially all chemical/biochemical production plants. The classroom discussion stressed the importance of measurements of fluid flow, temperature, *etc.* The laboratory experiment, using a completely computer-controlled humidification unit, involved groups of students monitoring changes in input variables and subsequent changes in the system output.

• Session 10 •
"CMA" Deicing Salt

Calcium magnesium acetate, or "CMA," is a non-corrosion, non-polluting organic deicing salt (developed under sponsorship of the Federal Highway Administration) that is produced from dolomitic limestone and acetic acid. In this session we first reviewed how microorganisms may be used to directly produce many organic chemicals (lactic acid, ethanol, methane/carbon dioxide, acetic acid, *etc.*). Using CMA as an example, we discussed how further processing of the fermentation product (acetic acid, in this case) may be required. Following an overall description of the conversion of organic wastes to CMA, liquid-liquid extraction of acetic acid from fermenter broth was demonstrated in the classroom. Then each group of three students received a sample of the extracted acetic acid along with some powdered calcium carbonate. Students were able to observe the formation of product calcium acetate. We concluded by discussing the advantages and disadvantages of both sodium chloride and CMA as road salts. Students appeared unanimous that reducing the cost of CMA was the most effective way to achieve wide acceptance.

• Session 11 •
"Focused" Microwave Applications

It is not often that you can bring together a striking example of both chemical and electrical engineering, but we did this in our session on "focused" microwave applications. Specifically, we addressed the problem of non-invasive cancer treatment, as well as microwave sterilization. This topic was presented by giving an overview of the technology, and following up with a demonstration. The technology of cancer treatment by microwaves centers on the fact that cancer cells have high electrical conductivity and are more sensitive to temperature increase than normal tissue. Thus, techniques for focusing, or directing, the microwaves enables heating of the cancer cells to the point of cell death, without serious damage to adjacent normal cells. We demonstrated this technique (using a home microwave oven) by first showing that different fluids (salt water, tap water, ethanol, salad oil, aqueous solutions of the water soluble polymer polyvinylalcohol) have different electrical conductivities. We then placed a small beaker of one fluid (saline, modeling a tumor) in a larger flat tray containing another fluid (salad oil, with much lower conductivity). We saw how the fluid in the beaker could be elevated to a temperature substantially higher than the one in the flat tray. We also explored how an air-foamed material (whipped cream) absorbs microwaves, comparing that to beakers of selected fluids placed in the foam.

• Session 12 •
Organ Transplants

One of the leading researchers on immunosuppression for organ transplants gave an overview of this topic, pointing out both the problems and the progress in this area. We discussed the concepts of organ acceptance and rejection between donor and recipient. A number of 35mm slides were used to illustrate, for example, both healthy kidneys and those that had been rejected. Because it is illegal to demonstrate examples on live animals to high school students, we could not illustrate the standard "skin patch" test. However, we did take the students to the university research operating room and showed them mice at various stages of skin patch testing.

• Session 13 •
Genetic Engineering and Production of Seaweeds

This session addressed the many uses of seaweeds and the need for genetic engineering of new seaweed strains. In addition to describing the objectives and the methodology behind genetic engineering technology in general, the global perspective of growing and harvesting seaweeds (especially in developing countries) was presented. We demonstrated the "thickening" characteristics of agar and presented examples of edible seaweed products. The session concluded with a tour of the laboratory in which seaweeds are cultured and grown.

EVALUATION OF THE SESSIONS

Unfortunately, we did not survey the students before or after conducting our first pilot quarter. However, we did so for the second quarter. As noted above, an application/questionnaire was given at the initiation/conclusion of these sessions. Some overall observations follow.

First, on the original application, only six students indicated a serious interest in pursuing a career in science or engineering (no one mentioned the word "engineering"). On the concluding questionnaire, only six students did *not* indicate the pursuit of science or engineering as a career goal. Moreover, from their responses on the final course evaluation form and on the separate application form for a summer internship program (completed by fifteen students), it appeared that the students were more focused on technical interests. While we cannot say if there was an earlier unexpressed interest in the topical issues presented, it is clear that these ninth (and some tenth) grade students were sufficiently sophisticated to decide that genetic engineering of seaweeds was exciting and that investigating the use of biopolymers in concrete was not exciting—or the reverse. Moreover, some students expressed an interest in having demonstrations and experiments with animals and in further pursuing research on the topics we had discussed. (Note: Other than showing an animal to the high school students, demonstrating experiments by using live animals is illegal in Massachusetts.)

At the conclusion of our second quarter pilot program we devoted the last session to a buffet, followed by the awarding of certificates. (An award was made to students who missed three or fewer sessions.) Two faculty members who had graduated from this school spoke briefly, as did the dean of the college of engineering. The students seemed to be pleased both with the special awards session and with the opportunity to complete a course evaluation form. In general, throughout the pilot project we treated the students as adults and found that they acted like adults.

FUTURE PLANS

Our future plans call for bringing together high school science teachers and university professors to plan the introduction of applications of modern biotechnology into high school science courses. In our first summer session, we anticipate that high school science teachers will wish to learn more about modern biotechnology, and especially its social applications. Thus, a series of informal lectures and hands-on participative demonstrations will be given by professors who are well-established in selected areas of modern biotechnology. Further, since the professors will need to gain an understanding of what high school science teachers believe is appropriate for presentatin to high school students, the high school teachers will present informal seminars dealing with their experiences in introducing the newer aspects of science and technology into their courses.

Looking ahead, we also plan to initiate some of the key recommendations from this summer study program into a pilot program to be initiated during the following academic year. This pilot program will involve the introduction of key recommendations from the summer study sessions into the high school classrooms and laboratories. We also anticipate that the professors will give demonstrations and will involve students in "show-and-tell" type experimental themes coupled with measurement orientations (*i.e.*, we wish to integrate quantitation into all demonstrations). Further, the pilot program will include regularly scheduled monthly meetings with the professors and the high school teachers in order to assess progress and to discuss problems. □

REVIEW: Hazardous Waste

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teaching and research, consulting, and governmental experience to supplement his BS, MS, and PhD in chemical engineering, and his MBA. Thus, he has real design and management experience in waste treatment technologies and has taught the material in the classroom to engineering students. Moreover, he has organized countless professional meetings dealing with the HWM area for AIChE.

The text covers the entire field in 450 pages. It begins with the basic definition of hazardous waste in general terms and provides an historical background for the field, both in the United States and Europe. The latter is an important perspective because European concerns predate ours in many respects. Several important case studies are provided to place the field in its political context and to provide introductory technical insight. Next, the process of risk assessment is introduced with case studies. Then the author provides two chapters which discuss the driving force behind the HWM area: federal legislation.