FEATURE ARTICLE

APPLE for the Teacher – Scientists in the Classroom: From Grassroots to Productive Orchard

RECOMMENDED FOR AP Biology

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Abstract

We describe the implementation of "APPLE for the Teacher," an alternative education outreach program that augments teacher efforts in presenting specific AP Biology laboratory exercises and at the same time involves the community in the educational process. The program is 5 years old and is staffed primarily by volunteers. We discuss the experiences of participants and lessons learned during the program's implementation and growth.

Key Words: *Community outreach; education enhancement; AP Biology.*

The enzyme activity has been measured and the spectrophotometers have been packed up and loaded into the van. It is the end of another of our *APPLE* (Advancement Placement Program for Learning Enhancement) *for the Teacher* visits. As usual, we were all inspired by the experience and the response of the students and teachers. This visit was to Athens High School, Alabama, a 30-minute drive west of the HudsonAlpha Institute for Biotechnology, and was unique in that the "class" that we visited was actually a group of students that volunteered to stay after school in order to participate in this laboratory experience. The students were thus exceptional in their interest and motivation, and it was clear that they had great respect for their teacher, who contacted us to request the visit. The exhilaration caused us to reflect on the journey that we have taken with the *APPLE for the Teacher* program over the past 5 years.

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○ What Is *APPLE for the Teacher*?

APPLE had its genesis in the early spring of 2005 at a meeting of the Alabama Partnership for Biotechnology Research (PBR), a regional grassroots professional organization. The mission of the PBR is to promote the growth of biotechnology in the region through events for professional networking and educational endeavors. During those early developmental days of the PBR, we wanted to establish educational programs that would help to train future biotechnologists. The initial concept was simple. We would form teams of four or five scientists, teachers, and other appropriate professionals that would visit local schools and aid in the presentation of biology laboratory exercises.

We decided to focus on high school students as our target audience, specifically those taking AP Biology. In order to assure ourselves that we were targeting a sector with a need and to get guidance on the type of help that we could offer, we drafted a questionnaire and distributed it to the AP Biology teachers at the seven public high schools in our county. We then held meetings with each of the responding teachers to obtain direct feedback regarding some of our strategies. Between the information provided by the questionnaire and the personal interviews it was clear to us that the teachers were in need of help in two specific areas. We could help by providing access to the instrumentation and equipment required for some of the experiments in the AP Biology Laboratory Manual (College Board, 2001). Additionally, we could provide the specific expertise necessary to optimize the implementation of some of the exercises. Using the input from the teachers and guided by our own experiences, we decided to focus on two of the laboratories from the manual where we could provide the most help – Exercise 2: Enzyme Catalysis and Exercise 6: Molecular Biology (College Board, 2001).

Even early on, we felt strongly that having professionals in the biotechnology field directly visiting high school classes would have a positive impact. Besides having an increased "teacher"/student ratio for the laboratory exercises that we would implement, the students would be exposed to a number of different professional opportunities both in academia and industry. All of these aspects were discussed with the interested teachers before we committed to begin our visits. The feedback that we received on these ideas was very positive. An additional benefit for teachers was the opportunity to use their normal laboratory preparation time in a more productive fashion.

We knew that the high schools that we planned to visit differed in their class scheduling. Some schools have the more traditional seven-period day with approximately 50 minutes per period. Others are

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organized on a block schedule that devotes about 90 minutes to each of four class sessions per day. Of course, there are other individual modifications of these basic schedules in some schools. Regardless of the particular laboratory, we recognized that it would be a significant challenge to effectively present and perform any laboratory exercise in the schools with the shorter class sessions.

Although all of us had significant experience teaching biology-related laboratory and lecture courses at the university level, none of us had taught at a high school. In order to orient ourselves with respect to how these laboratories have been implemented in the past, we asked high school teachers about their experiences. We also performed the laboratories as they had been historically presented to the students and immediately noticed a number of areas where improvements could be made.

The enzyme catalysis laboratory was traditionally taught using catalase as the enzyme. The reaction that is catalyzed by this enzyme is the conversion of hydrogen peroxide to water and oxygen. The procedure required that multiple reactions be set up at one time and that individual reactions were terminated by the addition of sulfuric acid at designated time points. The reaction was allowed to proceed for 6 minutes. At that point, each student or group of students would have eight small cups. These cups would contain a reaction that had proceeded for zero, 10, 30, 60, 90, 120, 180, and 360 seconds. Once this was completed, the progress of the reaction was monitored by measuring the amount of residual hydrogen peroxide in a 5-mL aliquot of each of the stopped reactions. The hydrogen peroxide was determined by titration with potassium permanganate. The potassium permanganate was added until the aliquot reached the endpoint, which was determined by the appearance of a slight pink color (College Board, 2001).

Thus, in order to complete this laboratory, the following processes had to be completed:

1. Labeling the containers
2. Setting up the reactions
3. Stopping the reactions
4. Titration of aliquots of each of the reactions stopped at the eight time points
5. Calculation of the residual hydrogen peroxide

This appeared to be a logistic nightmare, but we tried to set up and run this lab anyway. Even though we didn't require a pre-laboratory presentation to explain the basic concepts, nor did we need training on any of the specific techniques, we were still in the process of titration after 2 hours. It was also extremely difficult to organize everything. Students would need significant help on both fronts, requiring additional class time. Although our model of increasing the teacher/student ratio would help to alleviate these problems somewhat, our concern about successfully implementing this exercise in the classroom setting with 25 to 30 students was substantial. The consulting teachers were not surprised to hear of our experience with this lab. Because of this experience and the resultant concerns, we decided to create a protocol that would accomplish the same objectives as the original lab but could be finished in a single laboratory period. We were confident that this would not be too hard. We set out to find an enzyme assay that would require less instruction on the methods and that had simpler associated logistics and organization.

The use of an enzyme assay that was colorimetric and could be monitored in real time with a spectrophotometer was suggested by one of us. There was concern raised regarding the requirement for the instruments and the associated costs. Through some investigation, however, we learned that most high schools in Alabama had access to the needed instruments through the Alabama Science in Motion program (Allison et al., 2008). In addition, the HudsonAlpha Institute for Biotechnology in Huntsville provided a set of spectrophotometers and pipettes, ensuring access to the needed equipment. Further discussions with our consulting teachers indicated that they felt that the exposure to the spectrophotometers would be a great experience for the students. It took only a few more meetings to work out the detailed protocol and ensure that the exercise was consistent with the stated objectives.

The reaction that was finally chosen was the alkaline phosphatase-catalyzed dephosphorylation of *p*-nitrophenyl phosphate to *p*-nitrophenol (Jenkins & D'Ari, 1966). Because the phosphorylated compound is colorless and the dephosphorylated product is yellow, the progress of the reaction could be easily measured using a spectrophotometer. The basic setup and procedure for the laboratory that we designed is outlined in Table 1. There are only a few reagents that are necessary and, although they are not difficult to make, their preparation can take a significant amount of time for one who infrequently works in the laboratory. Additionally, access to balances and pH meters is often limited in high schools. Thus, our APPLE group prepares and tests the reagents prior to using them in the field. This helps to ensure the success of the exercise in the classroom setting.

○ The First APPLE Visit

Once the first exercise to present was chosen, the teachers were again consulted and with their approval we proceeded with implementation. We were all very excited and were feeling quite confident. All we had to do was prepare the reagents, write the handout for the lab, choose who would play the lead, and decide on the classroom setup and implementation.

Preparation for the first visit was very time-consuming. We weren't well organized, and because of our desire for a professional production, all of us were a bit too much "in control." Even as we were preparing to leave, one of us was at the copier making the handouts that we planned on using. We loaded up the car and headed off to Huntsville High School. At that school, the laboratory was adjacent to the classroom and, thus, we could set up as the teacher was taking attendance and dealing with assignments and other general issues. The setup went smoothly. Within 10 minutes, four stations were prepared, the spectrophotometers were turned on, and initial adjustments were made.

A 15-minute presentation was given to describe the basic concepts regarding enzymes and to summarize the exercise protocol. The students were divided into four groups of five students, and each of us served as the leader for one of the four groups. During the remaining time, each of us guided a group of students through the laboratory exercise, instructing them on the use of the micropipettors and the spectrophotometer. The allotted lab period (50 minutes) allowed ample time for completing the protocol and helping the students use their collected data to perform the required calculations. With some of the groups, there was even time near the end of the class period for some group discussion covering varied topics, ranging from college choices to who would win that week's football game.

There were two sections of the AP Biology class at Huntsville High that year: each station had to be reset and another lab run immediately after the first. The second lab also went smoothly. The time went by very quickly – "Wow, we did it!" – and the event proved to be exceedingly fun for all: students, teachers, and us. "When can we do this again?" was echoing in our minds.

Table 1. The basic alkaline-phosphatase-colorimetric enzyme assay (sources for each chemical and catalogue number are indicated in parentheses).

Instruments & Other Materials	
1000-mL micropipettors	
Disposable tips for above	
Spectronic 20D spectrophotometers (or equivalent)	
13 × 100 mm test tubes	
KimWipes	
Digital timers (optional)	
We have been in classrooms where students have used their cell phones as timers. We have noticed that in our region, nobody in that age group wears a watch. However, if your students do wear watches, use them.	
Linear graph paper	
Solutions	
Diluent buffer:	
10 mM Tris	(Sigma, cat# T6066)
1 mM $MgCl_2$	(Sigma, cat# M8266)
pH 8.0	
Substrate buffer:	
4-paranitrophenylphosphate (PNPP)	(Aldrich, cat# N22002)
0.03 mM in diluent buffer (see above)	
Enzyme:	(Sigma, cat# P5931)
Phosphatase, Alkaline (from *Escherichia coli*)	
Inhibitor:	
Sodium phosphate	(Sigma, cat# S3264)
5 mM in diluent buffer	
General Protocol	
• Adjust the spectrophotometer for 405 nm.	
• Verify that the correct filter is in place for the wavelength selected.	
• Verify that there is no tube in the chamber.	
• Set the instrument for zero percent transmittance.	
• Set the mode of the instrument to the absorbance mode.	
• Transfer 2.8 mL of substrate into a clean tube.	
• Place the tube in the chamber and close the lid.	
• Adjust the absorbance to zero.	
• Remove the tube and add 0.2 mL of enzyme to the tube	
• Have one student hold the tube and prepare to mix the tube.	
• Have a second student pipet the enzyme into the tube containing the substrate.	
• Have a third student begin timing as soon as the enzyme is added—this is the zero time point.	
• Record absorbance readings every 20 seconds for 3 minutes.	

○ Continuing & Expanding

Motivated by this first success, we reworked a second AP Biology laboratory exercise, Exercise 6: Molecular Biology. In a similar fashion to our first approach, the focus centered on altering the protocols and providing reagents and equipment that would allow the students to perform the exercise successfully in the time allotted.

During the first year of the *APPLE for the Teacher* program, we visited two of the local high schools. Both the Enzyme Catalysis Laboratory and the Molecular Biology Laboratory were presented in the fall and spring semester at one school. The second school was on the traditional schedule, and we presented the laboratories once each at that school.

At the end of that first year, we met with the two teachers as a group and shared our impressions of the program. The teachers indicated that the visits appeared to pique the interest of a number of the students. They mentioned that the exposure to commonly used laboratory instruments and techniques was exciting to the students, and also that the conversation that sometimes ensued within the small groups was particularly "cool."

The interest from other local high schools increased over the following years. We soon realized that we would need help if the program was to accommodate the growing demand. To solve this problem, the "APPLEttes" were created. These are volunteer individuals from the community, including chemistry and biology undergraduate and graduate students, former teachers, and professionals in one of the biotechnology-related companies in the area. The size of the APPLEtte pool varies over time. We currently draw from a group of 35 individuals. Given that one of our goals is to be of real service to the teachers, we need to be sensitive to their teaching schedules. Having the additional APPLEtte group as a resource makes the scheduling of visits much easier. We usually have no problem finding enough individuals for any one visit. With this larger pool it is even possible to identify one extra person to serve as an alternative in case of illness or some other conflicting issue.

Very frequently when we go out to schools, there is much interest generated not only among the students but also among other faculty and administrators. What are these crazy people doing in our school? Often, when they see what occurs when we go into action, they are very complimentary and encourage us to continue our efforts.

○ The Work Is Not Done

We maintain continuing discussions with the consulting teachers. All participating teachers are interviewed informally after each visit and we welcome suggestions for modification and improvement of each of the laboratory exercises or the program in general. The APPLE core group routinely meets to review each of the visits. The topics of these meetings are varied but always focused on the quality and function of the program. How can we modify the exercises, the logistics, and the pre-labs? How much should APPLE be involved in the pre-lab and post-lab discussions with the students? How do we maintain a pool of dependable volunteers to draw on for help?

Thus, starting with a group of four interested individuals, the seed of an idea, interactions with local high school teachers, and support of the PBR and the HudsonAlpha Institute for Biotechnology, the *APPLE for the Teacher* program has weathered 5 years. The program has grown from servicing two schools per year to providing APPLE visits to eight schools, with requests from more to add them to the schedule. Local and school newspapers have run stories describing some of our visits. So far, we have touched the lives of over 450 students. Some of us have seen these students again in the college courses that we teach and the internship programs in which we are involved. We hope that, through this article, we have inspired some of the readership of this journal to begin their own local or regional APPLE programs. We offer our help in providing as much advice and guidance as is reasonably possible. A few suggestions to help you get started are presented in Table 2.

○ Final Comments

Biotechnology touches our lives in ever increasing ways – from the foods we eat to the medications we take to the energy that powers our cities. It is important to engage students to help connect scientific concepts taught in the classroom with real-world applications that are based on those concepts. *APPLE for the Teacher* provides an outstanding venue to make those connections. This program also connects the community and local industry with education and sends the message that everyone has a stake in ensuring the success of tomorrow's workforce.

For students, APPLE offers the chance to work with new cutting-edge equipment and obtain usable data to reinforce their understanding of biological concepts. APPLE also allows students to interact with researchers on the front lines of biotechnology in Huntsville. Students realize that there is nothing magical or unattainable about scientists – we are everyday people with a passion for biology and answering the unanswered questions. The time the students spend with the APPLE team provides opportunities to talk about the science and applications of the activity in an informal small-group setting. The scientists also serve as informal mentors for students considering careers in science, offering them course guidance, opportunities for internships, and college choices.

The education of our children is a central concern of modern societies. The children are our loved ones, they are the future, and they deserve to be helped in any way possible to enjoy the lives that we hold so precious. Those of us in higher education, in professional fields, and all of us who share this concern have an obligation to take an active part in the educational process.

Table 2. Six steps in organizing an *APPLE for the Teacher* group for biology in high schools in your community.

1.	Contact the biology department chairs at nearby community colleges and universities to identify specific faculty members that would be interested in leading an APPLE group.
2.	Form a small core group that will be committed to the success of the program.
3.	Contact the appropriate high school teachers to confirm that they could use the program.
4.	If your group decides that you will provide the equipment, identify sources of funding for this. There are a number of online sites where used equipment is available. Alternatively, it is possible that your partnering college or university may have appropriate instruments and/or equipment. Note that although we try to have one complete set of materials/instruments for each group of four students, we have had to adjust this ratio to accommodate the larger classes. If you must start with a suboptimal amount of needed equipment, initiate the program anyway. It is easier to get support for continuation and building once the program is in place and functional.
5.	Be patient, persistent, creative, and flexible in implementing your program. It has taken us 4 years to assemble a reliable base of volunteers to meet the growing demand for our program. Many of the ways that we originally planned to operate have been altered in response to practical issues.
6.	Be constantly mindful of the true reason for your program – the enrichment of education of the student. We believe that a good APPLE program will provide both the physical tools and the people power necessary to help build a high-quality laboratory educational experience for students in our communities.

APPLE was conceived to fill what we saw as a great need in the AP Biology classes. The equipment available at that time was unreliable, the experiments too tedious and lengthy to work in the classroom, and results were not guaranteed. The chance to mentor the younger generation in our chosen careers was irresistible. It allowed us to take the art and science of molecular biology, craft a 50-minute précis of what we knew so intimately, and then enable the students to experience it all first hand. As R.D. noted, "The interest and delight on the their faces when they were able to see DNA on an electrophoresis gel and to observe these molecules in action was one of the highlights of my career."

APPLE is one mechanism that we have found which meets a true need in education. The visits are inspiring, the connections that we make with the students are fulfilling, and the response that we have received from students and teachers makes us proud and energized to continue.

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