INCORPORATING HIGH SCHOOL OUTREACH INTO ChE COURSES

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Three years ago, an undergraduate-level Introduction to Biomedical Engineering elective was created at the University of Maryland, Baltimore County (UMBC). One goal of the course was to include a group project that allowed an opportunity for the students to delve deeply into an area of interest that was not covered in the lecture material. A second objective was to provide a forum for the students to hone their presentation and group interaction skills.

We decided to try something new and different that would challenge the students in a way they had not yet experienced. The idea was to integrate a high school outreach presentation into the course that required the students to participate in problem-based learning. In addition, using the high school setting for the presentation challenged the undergraduates to present highly technical material to an audience with little technical knowledge. We believe this latter skill is critical for success in the "real world." Based on the success of the outreach projects in the elective course, the idea was also tailored to a required course in heat and mass transfer.

THE PROJECTS

While the content of the projects varies between the two classes, many aspects of the exercise are the same. The presentations are planned for a high school class period that lasts for approximately 45 minutes. In most cases, presentations are given to an upper-level science or math class. Typically, a segment of the presentation is in a lecture format to introduce students to the topic. Interactive components are critical to the success of the presentations, however, so lecture time is kept to a minimum. Exercises to get the high school students involved are an important part of the project and have encompassed such ideas as games ("Who Wants to be a Biomedical Engineer?", "Engineering Jeopardy"), skits ("The Doctor, the Scientist, and the Engineer"), demonstrations (geyser eruption, air freshener diffusion, conduction and convection experiments, electroplating), and puzzles. Student participation is encouraged by using small treats (approved by the teacher) for those who volunteer answers or participate in activities in front of the class.

At the end of the presentation, the group members give the high school students information on their backgrounds, how they chose engineering as a career, and any summer industrial or research experiences they have had. The undergraduates also describe their future plans, if known. The high school students are then given time to ask career-related questions. Before concluding, a survey is performed to help the group determine the effectiveness of its presentation. Finally, information related to the presentation topic is left in the classroom for any student who wants to learn more. Examples of "leave behinds" are bookmarks with definitions and web addresses, a bulletin board that stays up in the classroom, informational CDs, and web sites with links related to the projects.

ORGANIZATIONAL DETAILS

In each class, the projects carry significant weight in the final course grade (15% in Heat and Mass Transfer and 40% in Introduction to Biomedical Engineering). The projects last

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for a full semester and points are distributed throughout the semester for reaching milestones leading up to the actual outreach presentation. Groups are chosen by the students within the first week of class, and project topics are assigned. Groups contain a minimum of three students and a maximum of four, depending on the class size (we have integrated these projects into classes with up to 25 students). We found it very important for each group to have at least one member who attended high school in the U.S, and it was also helpful if at least one group member had a car. All group members are required to spend equal time leading the presentation.

In the Introduction to Biomedical Engineering course, topics that are current or emerging research areas in which chemical engineers participate are chosen. Examples include tissue engineering, bioinformatics, biosensors, metabolic engineering, and controlled release. In this case, the projects are an exercise in problem-based learning because the outreach topics are not covered in the course content.

In the Heat and Mass Transfer course, the projects must include demonstrations and activities that demonstrate the fundamentals of transport phenomena. Part of one class period at UMBC is taken to demonstrate what the projects could include. The following are example demonstrations.

- The session is begun by asking the students to discuss how they can tell when air pressure changes. *(Possible answers may include flying in an airplane, going up a mountain and feeling your ears pop, etc.)*
- The students are divided into pairs and given a straw, two pieces of string, and two balloons. Ask them to blow up the balloons to equal sizes and tie them to the ends of the strings. The trailing ends of the strings should then be tied to the straw, so that the two balloons are near each other on the straw, but not touching. One student in the pair will be told to hold the straw and the other student will blow so that his/her breath goes directly between the balloons. Ask the students to predict what will happen. *(The students usually expect the balloons to separate further, but the opposite is true...the balloons move together! Blowing between the balloons creates a stream of air that is moving faster than the surrounding air. The pressure between the balloons is lower than the pressure of the air surrounding them, so they come together.)*
- The students are given a clear plastic cup filled with water, along with two straws (one 3-inch and one 4-inch straw), and are challenged to blow across the top of a straw in the water and cause water to come out of it. *(In order for the water to spray out of the straw that is in the water, the students must put the 3-inch straw into the water in such a way that it does not touch the bottom of the cup, and then take the other straw and hold it near the opening and perpendicular to the top of the straw that is being held in the water. Blowing through the longer straw across the top of the immersed straw causes a spray of water to come out of the straw in the water. The faster the blast of moving air from the student's mouth, the lower the pressure exerted around the blast. When the blast flows across the top of the lower straw, the pressure on the liquid in that straw is reduced, and since elsewhere on the water's surface the air pressure is atmospheric, the water is pushed upward through the upright straw toward the low-pressure area. When the water gets into the air stream, it is pushed and scattered by the quickly moving air.)*
- Give the students a Ping-Pong ball, two small paper cups (2 to 3 inches tall), and some masking tape. Ask them to tape the cups onto the top of a table, one behind the other, four inches apart. Put the Ping-Pong ball in the first cup and challenge the students to get it out of the first cup and into the second cup—neither the cups nor the ball can be touched by any solid or liquid. *(Blowing across the top of the cup will produce lift on the ball and it will pop up out of the cup when the air speed is high enough. Controlling the ball's motion to get it to land in the second cup is not easy!)*
- Give the students a round piece of cereal and a bendable drinking straw and challenge them to get the cereal to hover above the straw. *(Bend the straw to a right angle and insert it into the mouth like a pipe. Take a deep breath and, with the cereal held above the straw opening, gently and with control, blow air at the cereal. Let go of the cereal once you start blowing. This takes practice! The cereal will stay roughly at the same height because forces upward [the air stream] and downward [gravity] on the cereal are balanced. This is more easily demonstrated using toy blow pipes or with a hair dryer and a Ping-Pong ball—the angle of the air dryer can be varied to further demonstrate the effect of velocity, air pressure, and gravity.)*

These are just a few examples of hands-on experiments that can be used to demonstrate Bernoulli's principle (which the heat and mass transfer students have studied the previous semester in fluid mechanics). Then, the students are encouraged to explain what math and science skills they learned in high school to study Bernoulli's principle and how it relates to industrial applications (design of pumps, airplanes, etc.)

The first milestone of a project is to find a high school classroom that is within 30 miles of campus for the presentation (5% of the project grade). In general, the UMBC students find schools and classes on their own, with some choosing to return to a group member's own high school. Other common choices include schools that are near UMBC or that target a specific demographic (such as an all-girls school or a predominantly minority inner-city school). To date, presentations have been made in six different counties in the greater Baltimore area. A compiled list is kept of classes we have previously visited, along with contact information to be given to groups that encounter difficulties finding a venue for the projects.

To meet the first milestone, groups must turn in the name of the high school, the course name and time, the teacher name and contact information, the number of students enrolled, and the grade level of the students. We have found high school teachers to be quite accommodating and enthusiastic about our participation in their classrooms.

Within the first month of the semester, the groups are required to meet with the professor for a preliminary meeting (5% of the project grade). At this meeting, the group must present preliminary ideas for the presentation and have a general idea of the information they will present. Each group must turn in one typed page outlining their ideas. We have found this initial part of the project to be very challenging for the students because it requires significant independent reading and synthesis of information. The topics assigned are purposefully broad so that this step requires a significant effort.

At this point, students must make choices as to what material would be both interesting to high school students and at an appropriate level. Approximately two weeks later, the students are required to have a second meeting with the professor (5% of the project grade) to present a full outline of the project presentation, including specific details about what material will be presented and how it will be presented. The plan at this point must incorporate feedback given after the preliminary meeting.

Approximately two weeks before the outreach presentation takes place, at least one member of the group is required to visit the school classroom to meet the teacher, verify the date and time for the project, and to assess if the room is adequate for the planned exercise (5% of project grade). We have found this step to be critical for a successful outreach project. It was added after the first year of the projects when we experienced several classrooms that were not adequate or appropriate for our presentation. Examples of classrooms that were inadequate or inappropriate included classrooms without screens for the projection of the presentation, open classrooms that made hearing difficult, lack of seating for all the observers, and lack of lab space for the demonstration.

At least two weeks before the presentation date, each group is required to present the outreach project to the professor (5% of the project grade). This presentation is expected to mimic exactly what is planned for the high school classroom, to be carefully timed, and to include any props, games, and handout material. The groups must also turn in the "leave behind" information that has been developed, along with a copy of the student and teacher surveys they plan to use for assessment. This meeting typically results in significant feedback on content level, clarity of explanations, and quality of presentation materials (overheads, slides, etc.). In addition, the meeting commonly identifies any problems that arise with the organization of planned activities or games. At the end of the practice presentation, groups are either given permission to go ahead with their presentation or are required to practice again in front of the professor.

The outreach presentations are typically held within the last several weeks of the semester and account for 60% of the project grade. The UMBC students are asked to dress in typical "everyday" clothes for the presentation to help the high school students relate to them. In the Introduction to Biomedical Engineering course, one lecture is cancelled for each outreach presentation.

In addition to performing an outreach project, all students are required to attend one other outreach presentation as observers. We have found this to be especially helpful for students who are nervous about presenting in front of a group or who did not attend high school in the United States and are unsure of what to expect. The student groups are solely responsible for running the project presentation. The professor does not participate, instead observes and evaluates the presentation. See Table 1 for a typical evaluation sheet.

Assessment is a vital aspect of the project (15% of grade). Each group must collect survey information from

TABLE 1
Sample Outreach Project Evaluation

Date ______________

Group Members

____

School

____

Duration

____

\# High School Students in Attendance

____

	Poor 1	*2*	*3*	*4*	*5*	*Excellent*
Clarity of speech - overall	1	2	3	4	5	
______________________	1	2	3	4	5	
______________________	1	2	3	4	5	
______________________	1	2	3	4	5	
______________________	1	2	3	4	5	
Volume of speech - overall						
______________________	1	2	3	4	5	
______________________	1	2	3	4	5	
______________________	1	2	3	4	5	
______________________	1	2	3	4	5	
Organization	1	2	3	4	5	
Flow	1	2	3	4	5	
Group participation	1	2	3	4	5	
Student participation	1	2	3	4	5	
Slides/Overheads	1	2	3	4	5	N/A
Game	1	2	3	4	5	N/A
"Leave behind"	1	2	3	4	5	
Professionalism	1	2	3	4	5	
Ability to relate to audience	1	2	3	4	5	
Enthusiasm	1	2	3	4	5	
Technical content						
Technically correct	1	2	3	4	5	
Clearly explained	1	2	3	4	5	
Appropriate to topic	1	2	3	4	5	
Appropriate level	1	2	3	4	5	
Terminology	1	2	3	4	5	
Held student interest	1	2	3	4	5	

both the high school teacher and the students. All teacher surveys must include the question "Would you be willing to have another group perform an outreach project in your class in future years?" The response to that question is turned in to the professor for use in building a list of contacts for groups in future years that may have difficulty finding a classroom.

The remainder of the survey is not turned in, but rather serves as feedback for the group. Information from the survey is expected to be incorporated into the group's self-assessment statement to provide support for conclusions that are drawn. The self-assessment statement is a critical assessment of the efficacy of the outreach project (three typed pages maximum, one statement per group, with signatures of each group member). The statement must address several issues: What was done well? What could have been done better? Was the presentation effective? How do you know? What would you do differently if you were to do it again? How well did your group function together? How could you improve the way your group functioned? What overall grade would you give yourself?

Points are distributed for "accuracy" of the assessment as judged by the professor and for writing clarity (not for strength of the project itself). For example, a project with major difficulties that were accurately assessed would receive a low project score, but a high score for self-assessment. We believe this element of the project is critical because it forces the students to begin self-evaluation. The professor's evaluation of the project is given back to the students after the self-assessment is turned in so the students can gauge how well they identified their own strengths and weaknesses.

We have estimated that we spend approximately 2 to 3 hours per group in order to implement this program. This time investment has certainly been worthwhile considering the positive feedback we have received from the high school teachers and students and the UMBC participants.

OUTCOMES

We have witnessed several desirable outcomes from our outreach presentations. In nearly every case, the level of enthusiasm of UMBC students has been very high. They have been highly motivated to put on an interesting presentation and participation within the groups has been surprisingly uniform. We have witnessed only a few cases where one or two group members performed all the work. To the contrary, since each member is required to spend an equal amount of time leading the presentation, in most cases all group members have contributed equally to the project. The comments relating to the projects on the end-of-semester course evaluations have been overwhelmingly positive.

The initial reaction to the project at the beginning of the semester has typically been, "This will be really easy," followed shortly by, "This is going to be really hard!" In particular, the students have been challenged by learning a new topic on their own, narrowing the topic, and choosing what material to present. In addition, it has been challenging for them to determine the level of their audience and to tailor a presentation to that level. While these skills can be critical in the "real world," they are often overlooked in the undergraduate experience. We believe the outreach format can successfully target and enhance these skills.

Since each group is required to develop its own survey, no standardized results can be reported here. Each group did have to survey the teachers and students on the effectiveness of their presentation, however, and in all cases the surveys indicated the students' understanding of the topic had significantly improved. They also indicated that they had a better understanding of what chemical or biochemical engineers do.

An unexpected outcome for the UMBC students has been an increased pride in what they are doing and a sense of accomplishment. As a result of returning to the high school setting, many students have an increased awareness of how much they have learned and how far they have come during their undergraduate experience. They often speak with pride about their impending graduation and future plans for work or graduate school. In one case, at the end of a presentation three group members described their plans to pursue PhD degrees (two at M.I.T. and one at Georgia Tech). Quite unexpectedly and without prompting, the class of thirty high school students stood up and applauded. After the presentation, the group members expressed pride at what they had accomplished and expressed an understanding for the first time that they were role models for the high school students.

Providing role models to high school students has been an ongoing goal for the outreach projects. In our experience, the high school students have been very interested to learn more about the experiences of the undergraduates. In particular, UMBC attracts a significant pool of highly talented minority students (graduating classes in chemical engineering have averaged 47% minority students and 47% women in the last three years). We believe that these students in particular project powerful images to young high school students. It is not unusual to hear the high school students comment, "You don't look like engineers." We believe that this type of direct contact can powerfully combat stereotypical images of the engineering profession.

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