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Richard Zollars, Washington State University

Dr. Zollars is a professor in, and director of, the School of Chemical Engineering and Bioengineering at Washington State University. He received his Ph.D. from the University of Colorado. He has been teaching engineering for 28 years. His interests are colloidal/interfacial phenomena, reactor design and engineering education.

Donald Orlich, Washington State University

Don Orlich graduated from the University of Montana in 1953 with a B.A. in Education. He received a Masters of Science Education in 1959 from the University of Utah and an Ed.D. in 1963 from the University of Montana. He taught five years as an elementary and junior high science teacher in Butte, MT before taking a faculty position at Idaho State University. From 1967 to 1994 he was a faculty member in the Department of Education at Washington State University. He currently works at the Science, Mathematics, Engineering Education Center at Washington State University.

William Thomson, Washington State University

Bill Thomson graduated from the Pratt Institute in 1960 with a Bachelor's degree in Chemical Engineering. After receiving an M.S. in Chemical Engineering from Stanford University in 1962 he received his Ph.D. from the University of Idaho in 1969. He was on the Chemical Engineering faculty at the University of Idaho from 1969 to 1981 rising to the rank of full professor. In 1981 he became the Department Chair in Chemical Engineering at Washington State University, a position he held until 1993. In addition he has worked with Esso Research, AVCO Research, the Union Oil Research Company and the Stanford Research Institute. He currently is a professor (emeritus) at Washington State University.

A SWEET Program Review

Background

A problem facing the United States is the declining numbers of students expressing an interest, or majoring, in engineering. Recently the American College Testing organization reported that between 1992 and 2003 the percentage of high school students expressing an interest in majoring in engineering dropped from 9% to 6%[1]. In addition to the lack of numbers there is also the recurring problem of the lack of preparedness among US students in math and science[2].

To address these issues a proposal was submitted and funded by the National Science Foundation, Division of Elementary, Secondary, and Informal Education (ESI-9254358). This was followed in the years 2004 – 2006 with a Research Experiences for Teachers (RET) grant (EEC-0338868). In both cases the activity arose from a conversation amongst chemical engineering faculty members on what influenced them to major in engineering. Almost uniformly the conclusion was that it was an influential teacher (usually in math or science) that got them started. While the influence of this teacher led to an interest in science how this ultimately resulted in majoring in engineering was never as clear cut. To eliminate this uncertainty we sought to bring math or science teachers to the WSU campus for a summer to work along side engineers in their research laboratories to get a clear idea of what engineers do. The teachers, in addition to strengthening their math and science backgrounds, then would serve as spokespersons for engineering in their respective classrooms. During the five years that the earlier program was in operation a total of 67 teachers from throughout the United States participated. Of the approximately 100 engineering faculty at WSU 19 served as mentors (some multiple times) during the teacher's stay.

New Program

The experiences gained in the earlier NSF grant helped guide the development of the Summer at WSU – Engineering Experiences for Teachers (SWEET) program. There are three primary goals for the program: 1) enhance the math/science skills of the teachers in the K-12 system, 2) increase the number of students interested in engineering as a major, especially amongst underrepresented groups, and 3) provide a means by which faculty at all levels who are concerned about this problem can communicate. While the first item had clearly been addressed in our prior activity we did not feel that the latter two issues had been adequately resolved. The steps we took to improve on this situation will be outlined below.

Conduct of Program

One of the most important aspects of a successful activity is the recruitment of the teachers who will participate. The first item to consider is the grade level for the teachers. We focused on science and mathematics teachers at the 6 – 12 grade level. We felt that it was important to have students exposed to engineering concepts as soon as possible in their education because majoring in engineering requires a strong mathematics background. Since the student's decision on the level of the mathematics classes they will be taking often occurs as early as the 7^{th} or 8^{th} grade having them exposed to engineering starting at the 6^{th} grade level seemed appropriate. Involving teachers below the sixth grade level did not seem appropriate as students should have developed some mathematics and science skills before the exposure to engineering concepts would have its full effect.

In addition, teachers at the 6 – 12 grade level have had very similar education in science and mathematics. Thus teachers at the 6 – 12 grade level should have equal preparation for participation in the research activities that are part of the program. Our experience has shown this to be true.

We start our teacher recruitment activity in October, usually at the Washington Science Teacher's Association (WSTA) meeting by hosting a booth. This is followed up by an ad placed in the WSTA newsletter and letters sent to prior participants. Prospective participants are asked to complete an application form along with a reference form to be completed by their principal or supervisor.

This program also sought to include pre-service teachers so that they could learn both from the engineering faculty as well as experienced teachers. These were recruited by contacting science education programs at the University of Idaho, Washington State University and a number of other four-year institutions in the area, especially Heritage College, an institution in Toppenish, WA serving a mainly Hispanic population.

Because one of our goals was to increase the number of students from underrepresented groups we also focused our recruiting efforts on selected schools from within the state. Greater recruiting efforts were focused on those schools with a higher than average enrollment of students from underrepresented groups, primarily Hispanic and Native American. The targeted schools were selected from lists supplied by our Mathematics Engineering Science Achievement (MESA) office as well as the Office of the Superintendent of Public Instruction for the state.

Applications from both pre-service and in-service teachers were due by February 1. The three authors meet shortly after this deadline to select the teachers to participate for the following summer. While not selecting for either a math or science specialization we do aim to have eight in-service and four pre-service teachers as participants. Teachers selected for participation were notified by March 1 and had to reconfirm their intention to participate no later than April 15. This latter action was found necessary in order to insure that we had our full compliment of 12 teachers during the summer.

At the same time that the teachers were being recruited so too were the engineering faculty who would serve as the mentors for the teachers. Unlike our prior program for which no focus was planned, the RET program used biologically related engineering topics as its focus. This topic is both current as well as being of interest to the K-12 students. Six faculty are recruited for each summer session, with each faculty member mentoring two teachers, either an in-service and a pre-service teacher or two in-service teachers.

The first activity in the program is a one-day meeting that was held in May involving the teacher participants and the faculty mentors. The purpose of this meeting is to start forming relationships among all of the participants to address the desire to form a community (item #3 mentioned above), firm up housing arrangements for the summer, distribute information on the research projects that would be available for the summer, and tour the campus and laboratories. All of the teachers, whether they were able to visit the campus or not, then were asked to return a listing of the top three projects on which they would like to work. By the end of May all teachers had been assigned projects, with two teachers assigned to each project and each pre-service teacher paired with an in-service teacher. This allowed about two weeks for the teachers to communicate with each other, and with their mentor, prior to the start of the on-campus portion of the program. We found this two week period to be extremely important for the teacher's preparation as it allows them to start their preparation prior to arriving on campus. Furthermore, details such as housing arrangements, meals, parking, and continuing education or academic credits can be cleared up before the start of the program. This allows the full duration of the program to be focused on the research activity.

The on-campus portion of the program starts in late June so as not to conflict with the calendar for the K-12 schools. The duration of the on-campus activity is six weeks, ending in late July or early August. The duration was largely set by the desire to have the research activity last as long as possible, so that the teachers could make a meaningful contribution, but not so long as to conflict with the school year for either the K-12 system or the university. During the six weeks there was a daily, one-hour lecture covering basic concepts of engineering, grant writing, and teaching module preparation as well as some off campus visits to engineering businesses. These sessions were conducted by faculty from either the engineering college or the science education program on this campus.

An example of one of the class sessions in engineering was a discussion of using sources other than petroleum for future fuel needs. We did this by first determining the total energy currently consumed by the transportation sector of the US. Using the energy content of various alternative fuels (hydrogen, biodiesel, ethanol) the teachers computed the amount of these alternative fuels needed to replace petroleum on a joule for joule replacement strategy. Knowing how much of each fuel would be required then allowed the teachers to determine the resource necessary to produce this amount (KW of electrical energy for the production of hydrogen from electrolysis, acres of canola for the production of biodiesel). Comparing these results with current levels of the resource then gave the teachers an understanding of the size of the task required to replace petroleum. While doing this it also allowed us to introduce such concepts as the first law of thermodynamics (energy balances).

During the three years of the RET program the teachers have participated in a number of research projects including projects focused on: protein separations, sensors for water analysis, biomechanics, food processing, cancer treatments, and biocompatible materials. A question frequently asked is how cutting edge research in a university setting can be transferred to a middle school or high school setting. An excellent example of this is a project using lasers as a means of destroying cancer cells. The concept of the research project is that by selecting the correct wave length of the laser the laser beam will pass through the skin with little to no interaction. A dye could be injected into the body attached to an antibody that will interact only with the cancer cells and not with other cells of the body. The dyes are selected such that they will interact with the laser. Thus, when the laser is focus on a particular spot of the body there will be no interactions except where the dye is concentrated (at the cancer cells). This produces a localized heating, thus killing the cells in that region (the cancer cells).

This type of experiment is obviously beyond the scope of a middle school or high school. However, the underlying concept, that light of different wave lengths interacts differently depending upon the properties of the target, translates easily. The experiment to be conducted at the high school level consists of focusing a high powered halogen light through a colored filter onto a colored candle. For example, the light passing through a blue filter is mainly in the blue wave lengths. However, a candle that appears blue does so because it absorbs all of the other wave lengths except blue. Thus a blue candle exposed to blue light absorbs little energy. However a blue candle exposed to red light will absorb a great deal of energy and melt quickly. The equipment needed to conduct this type of experiment can be built for under $100 and used in virtually any classroom.

Social events, to build esprit-de-corps, have also been found to be essential to build the desired sense of community. These start with a welcoming picnic prior to the first day of the program. This is followed by a one-day training session using the ropes course at the WSU Student Recreation Center. This is an excellent way of getting the teachers introduced to each other and starting to form lasting partnerships. Later events (whitewater rafting, mountain biking) are attended by a majority of the participants and often their families. All of this is intended to form lasting relationships between the teachers and their mentors.

In addition, the teachers were required to develop a teaching module, based upon their research experience that could be brought back to their classrooms. To aid in developing this module Don Orlich, from the Science, Mathematics, Engineering Education Center (SMEEC), conducted many of the classroom sessions during the latter portion of the program. During the final week of the program local middle school and high school students, selected by the participating teachers, came to campus to test the modules that had been developed.

External assessment is also an essential component to make sure that the goals of the program are being met. To accomplish this a faculty member from the Department of Education at Lewis-Clark State College, Dr. Ken Wareham, is hired as a consultant.

Outcomes

There were three goals for this program that were mentioned earlier; improved skills for the teachers, increased interest in engineering by their students, and improved communications between the teachers and the faculty mentors. One of the major tools in achieving these goals is the teaching modules that are developed during the summer. Fifty-two teaching modules, available for use by any teacher, were developed during our prior program and are still available on line at www.che.wsu.edu/home/modules/index.html. The modules developed during the summers of 2004, 2005, and 2006 are also available on-line at http://eerc.wsu.edu/SWEET/. These modules are often intended for multi-class period implementation so their length precludes presenting them here.

The interactions between the high school/middle school teacher and their university mentor have been valuable to both parties, as well as to the graduate students who inevitably get involved. The teachers do make valuable contributions to the research effort, albeit at a level roughly equivalent to an undergraduate engineering/science student. The graduate students gain a deeper understanding of their projects as they must guide a person with little experience in the laboratory though the six weeks spent in the lab. The faculty also gain valuable insights as well as a possible pipeline to highly qualified and motivated future students.

Maintaining communications between teachers and between teachers and mentors is one of the most difficult goals to meet. To overcome this impediment an interactive meeting capacity using high-end, Internet based technology has been developed. Dr. Maring used this technology in a project (co-TEACH) where graduate students and faculty in the Department of Teaching and Learning at WSU were able to mentor teachers and students at a number of schools scattered around the Northwest. We developed equipment to do this and more. While Dr. Maring's equipment was largely stationary (everyone had to go to a fixed location to make use of the technology) our equipment is mobile. The equipment consists of two units, one at WSU and one that is brought into the K-12 classroom. By linking the two via the Internet we can provide real-time audio and visual between the two sites. Thus a teacher and their class could have a virtual face-to-face interaction with the faculty member at WSU, similar to what was done in co-TEACH. The K-12 students can also be brought into the faculty member's research laboratory to let them see activities and equipment that would not be accessible to them at their school.

To assess goal #2, increased interest in engineering as a major, we developed an instrument to measure the student's attitudes towards engineering. This instrument is used in the classrooms of the participating teachers before and after they have used the modules they developed in their classroom. The use of the teaching module, coupled with mandatory visits by the WSU faculty member to the teacher's classroom, will provide a stronger link between the teachers, their students, and the engineering program at WSU, hopefully leading to the attainment of goals 2 and 3. We have, however, done a similar survey of the teachers to see whether their attitudes and opinions about engineering had changed. When asked whether this experience would change the manner in which they teach their science classes (using a Likert scale assessment with 5 being a strong influence and 1 being no influence) the teacher's rating of 4.3 showed a definite change in their teaching approach. When asked whether they would recommend this experience to a colleague the average rating of 4.9 (with 5 being a definite recommendation and 1 being not to recommend) further demonstrated the impact that this program had on their attitudes.

The most successful part of the RET program has been the involvement of underrepresented groups. Our recruiting efforts have focused strongly on schools with higher percentages of Hispanic and Native American students. As a result 12 of the 24 in-service teachers who have participated in the RET program have been from underrepresented groups (7 women, 4 Hispanic and 1 Filipino-American), including three from schools with large Hispanic enrollments and one from a charter school established by a nearby Native American tribe. Students from underrepresented groups were also actively recruited for the one-day module testing conducted at WSU. Of the 71 students to participate in this activity 48 were from underrepresented groups (37 female and 11 Hispanic). Participation in this module testing activity was highly sought after by students and was highlighted in a local newspaper from the area in which most of the Hispanic students were drawn.

Conclusions

As a result of these past activities we have reached certain conclusions concerning activities, where laboratory experiences are used to convey the essence of engineering to K-12 teachers. We found that six weeks was necessary for the conduct of the on-campus portion of the program. Although many teachers initially felt that this was too long, most felt that they were just starting to contribute to their projects by the time that the six weeks was ending. Shorter periods of time would not allow the teachers to become contributing members of their research groups. In addition, without a substantial involvement in the project the teachers would feel less confident in presenting this material to their class, thus reducing the impact of the program at the K-12 level. A longer period of time (8 weeks) was viewed as too long by both the university mentors and the teachers in addition to presenting significant scheduling barriers.

A preliminary meeting was essential in maximizing the usage of the six-week, on-campus period. This first meeting gave us the opportunity to take care of many important items prior to the teacher's arrival in the summer, including project/mentor selection, preliminary research, housing, academic or continuing education credit, and laboratory safety.

Having the teachers work in pairs on their research projects is a powerful tool. They have a compatriot with whom they can share experiences, and they develop a close relationship with another teacher with whom they could interact in the future. This helps in implementing the module they have developed into their classroom as they will have a person with intimate knowledge of the module with whom they could talk. The close contact with another teacher was an especially valuable experience for the pre-service teachers.

Follow-up between teachers and between teachers and mentors is probably the hardest issue to address. This is particularly true for our situation because of the distances involved between WSU and the various schools where the participating teachers work. The two-way, Internet conferencing capability will be monitored to see if this can provide a useful tool in addressing this issue.

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