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ABSTRACT
The Dave C. Swalm School of Chemical Engineering, in conjunction with the Mississippi Science and Mathematics School, in Columbus, MS (approximately 25 miles from the Mississippi State campus) has joined in a program for providing research experiences for junior and senior high school students. Three students participated in the program in the fall 2005 semester. The goals of the program include recruiting high school students to consider programs of study in chemical engineering or related fields at Mississippi State and to increase students' technological literacy by participating in active research projects. Of the three participants for fall 2005, one has declared his intention of studying chemical engineering at Mississippi State. The authors felt that the program objectives were met for helping students to become more familiar with our program and curriculum and for helping high school students to learn about conducting research with "real-world" applications. Future offerings of the program will be modified to optimize student schedules and increase the efficiency of their time on the Mississippi State campus.

I. Introduction

Recruiting students with top academic standing is a highly competitive activity necessitating creative strategies for engaging them as they choose a university and major field of study. Such students may be academically prepared for entrance into an engineering program and informed about educational opportunities, but may lack the experience to accurately judge which field best fits their interests. It is important to provide these students with additional "data" and positive experiences. Providing an interactive experience can enlarge their view of engineering and of their potential for playing a significant role in a particular field. Attributes of providing a research experience through a local university include exposing students to the college environment, promoting interactions with successful undergraduates, and providing personal points of contact among faculty at an institution.

The authors have worked cooperatively with a counselor at an accelerated mathematics and science high school to introduce high school juniors and seniors to a chemical engineering research environment. Students participating in this program investigate scientific literature and conduct experimental work under faculty guidance. Their research experience culminates with a project report and presentation for class credit. The high school students spend 3 to 4 hours per week on campus engaged in research related activities. We anticipate reaching the goal of recruiting more, high quality, students to MSU's chemical engineering program (or other engineering and science programs) by fostering interactions with faculty, graduate and undergraduate students through teamwork in the laboratory, discussions at meetings and by enjoying social interactions.

Strengths and weaknesses of this program will be discussed, including the development of the mentor/protégé relationship, exposure to new concepts, laboratory training, and providing a meaningful experience within time constraints. This discussion will conclude with an assessment of the number of students that can be involved in the program as well as logistical and travel constraints for student participants.

II. The value of high school students performing engineering and science research

"In the end, the fate of children depends on our ability to use technology constructively and carefully…Technological decisions made today will determine, perhaps irrevocably, the kind of physical and social world we bequeath them and the kind of people they become"[1]

Kenneth Keniston, 1977

Advanced technology surrounds students throughout K-12 education. They readily use an immense variety of items ranging from media devices (e.g. cell phones and iPods™) to complex toothpaste formulations. However comfortable they may be with their use, for many, the underlying principles and concepts giving rise to these ingenious inventions remain a total mystery. They proceed through mathematics and sciences courses of increasing difficulty, yet they often do not make the necessary connections between the concepts encountered and resultant applications. This gap in between student performance in science and mathematics translates into lower enrollments in higher educations engineering and science programs.

From the discovery and use of macro-scale materials in ancient civilizations to the current conquests of technology ranging from the mega-scale to nano-scale, technological advances have borne an ever-increasing and pervasive influence on the forms of society.[2] At a recent education/engineering dean's summit on educational reform, the importance of technological literacy for the general population was emphasized. Of the many ideas developed at the education/engineering dean's summit, several major themes were identified including:

- encouraging the association of engineering schools teaching/learning centers
- supporting the introduction of design and engineering in pre-college curricula
- and promoting collaborative efforts between schools of engineering and education to develop joint courses focused on pedagogy and technological literacy.[3]

A working definition of *technological literacy* is having enough technical knowledge to make informed assessments and decisions. Technological literacy is increasingly important in our technologically driven society. As technology impinges upon every aspect of daily living, it is vital that future industry, business and political leaders and policy-makers achieve a level of technical literacy commensurate with their responsibility for gauging and guiding the movement of technology into society.

A strong foundation in math and science education not only forms the essence of a technologically advanced and innovative society, enabling individuals to make reasonable and optimal use of technological advances for the betterment of the human condition. Recent assessments comparing U. S. student performance in multi-national groups reveals serious faults in this foundation.

Society's leaders and pundits consistently emphasize the role engineering and science educators serve in building technical literacy[4-6]. Methods, techniques and strategies abound for engaging students in the quest for technical knowledge and understanding[7-8]. The authors have engaged in a variety of activities to try and bridge the technological literacy gap, including working with K-12 pre-service teachers[9-11].

While outreach programs serve an important role informing students of available programs and fields of study, a detailed involvement of students in the day-to-day functions of an engineering school can enhance their understanding and provide a link between their perceived career goals and the fields of engineering. The research experience has proven invaluable for engaging students in active learning, building relationships surrounding a drive to discover and maintaining motivation for achieving intellectual goals[12-14]. The key elements of engineering research—posing a technical question, gathering supporting information, designing and building computational or experimental models and gathering data to test hypotheses - all provide a rich learning environment with which to engage 10-12th grade students in this process of engineering study. This key experience also furthers their knowledge of math, science and engineering principles and concepts.

III. Partnership between Mississippi State University and the Mississippi School for Mathematics and Science (MSMS)

The focus of this paper is our current partnership between Mississippi State University and Mississippi Science and Mathematics School, in Columbus, MS. Here, our focus is on our activities in the Dave. C. Swalm School of Chemical Engineering to engage high school juniors and seniors in our ongoing research programs with a goal, not only of improving their technical literacy, but of opening their eyes to the possibility of pursuing engineering (or related) field of study at Mississippi State.
The Mississippi School for Mathematics and Science (MSMS) is a public, residential, co-educational high school for academically talented juniors and seniors. Created by legislative enactment on July 1, 1987, MSMS is located on the campus of the Mississippi University for Women (MUW) in Columbus, Mississippi, and is governed by the State Board of Education. MSMS is unique in that it is a campus within a campus. This is a benefit for MSMS students who are allowed to participate in various college extension opportunities and MUW programs. The MSMS course is designed to introduce the student to the methodologies employed in research. Extensive out-of-class work is required for successful completion of this course. It is expected that the research performed by the student will lead to a written paper and an oral presentation. Research opportunities exist in numerous departments at Mississippi State University in addition to on-site research at MSMS. Students are required to enroll in a minimum of two semesters of research. Up to 2 credits of research can be earned at MSMS. However, only the 2nd ½ credit will count toward the 13 MSMS required courses. Approval for enrolling is required of the Director for School Advancement at MSMS.

Through this partnership, students interested in pursuing a research “internship” for school credit are encouraged to visit with faculty at Mississippi State. Students may select a project from among those provided by faculty members and subsequently work with those faculty members and their research teams for one or more semesters. Students provide feedback to both their supervising faculty/administrators on the MSMS campus and to the directing faculty members at Mississippi State. The close proximity of the MSMS campus to the Mississippi State main campus allows ready access to our facilities (i.e. offices, laboratories, library, etc.). Students typically make two or more visits per week for several hours of interaction on the Mississippi State campus. At the end of the term, each participant submits a summary report of their activities and accomplishments.

Project descriptions and activities

To illustrate the program currently in place, the following motivation and description of a research project assigned in 2005 is provided. This information was given to the student working with Dr. Minerick. The project description gives an overview of the technology and its supporting scientific concepts followed by a summary of learning objectives.

The motivation and importance of the research is provided in order to excite the student and to further develop the link between math and science and the advanced technologies coming onto the market.

> "Researchers have been working to develop hand held medical diagnostic devices that can be used at home to monitor diseases such as diabetes. Many of these devices rely on microfluidics, the flow of nanoliters of fluid through channels that are the size of a human hair. A force has to be used at this small scale in order to get the fluid (or in our case biological sample) to flow down the channels. A pressure pump can be used, but it is bulky and does not scale down well to be included on a hand held device. Electricity is another force that can be used to move fluids in these small channels; this area of research is known as electrokinetics. Electric fields currently have one drawback; the flow of electrons from the metal electrodes in contact with the biological sample causes a reaction known as electrolysis. Electrolysis is the splitting of water into hydrogen and oxygen; it occurs via an oxidation, reduction coupled reaction pathway. The result of this is that the free hydrogen (H+) and oxygen ions (OH-) impact the pH of the fluid within the microdevice. Changes in the H+ concentration are not good for biological samples and sometimes have an impact on the analyte (like glucose) that the hand held device is measuring.
>
> Your project is to use a fluorescent molecule whose light emission changes based on the pH around it to measure local pH within a 20 micron capillary (cylindrical channel). Using fluorescence video microscopy, you will show development of the pH gradients over time in capillaries 20 microns in diameter for electric fields ranging from 12 to 50 Volts per centimeter. If time permits, you will also image these gradients as a function of electrolyte concentration beginning with phosphate buffer solution (NaCl = 0.143mM). The microscope you will be using can construct 3D images to illustrate the pH profiles. This is accomplished by taking a series of 2D pictures along the length of the capillary and at different heights within the capillary.
>
> The skills you will learn during the course of this project are: lab techniques, scientific control techniques, microdevice operation, fluorescent imaging, data analysis, and

problem solving.   You will need to learn lab preparations and are responsible for lab cleanup after your experiments."

Similarly, projects were offered by chemical engineering faculty to two other students participating in the fall 2005 semester offering of this program. These two projects dealt with the development of renewable energy resources through the use of biotechnology. Students were introduced to the fundamentals of working with microbial cultures (e.g. asceptic techniques, safety and materials handling when working with biologically-active materials, etc.)   Faculty members, research associates and graduate/undergraduate students active in these research programs each provided guidance and input to the participating high school students. Advantages of this multi-faceted mentoring approach are that the student leaves with a well-rounded impression of the different aspects of life in an engineering curriculum.

As with any research, success is not a foregone conclusion. Some students elect to not continue the experience for another term or find their interests lie in another field. The logistics of running a laboratory and the unpredictability of research introduce challenges when directing high school students with limited availability for work on campus. However, by providing clear guidance during the programmed activities, the experience can be optimized for student participants. We plan more directed activities with somewhat more predictable outcomes for future students participating in our research.

Objectives and Outcomes

The following objectives are desired for the student participants:

- Read and critique a technical article in the research area
- Perform standard laboratory procedures in the research area
- Maintain a laboratory notebook
- Gain familiarity with types of topics covered in the ChE curriculum.
- Learn about the roles of undergraduate laboratory assistants, graduate student and post doctorate researchers, and faculty members directing the research
- Become more familiar with college environment
- Practice writing project report summaries
- Make project presentations
- Become more excited about science and engineering
- Establish friendly contacts at a large university who can continue to mentor the student through their freshman year and beyond
- Connect the math and science from classes with the advanced technology used everyday.

For our student participants in the fall 2005 semester, most of these objectives were met in a satisfactory manner, assessed by regular interaction with the student participants and by their final reporting/presentations. We will work to strengthen the effort on the part of faculty and Mississippi State staff to strengthen the familiarity of the students with the chemical engineering curriculum and the many possibilities of using such a chemical engineering degree to achieve career objectives.

IV. Conclusions

Program strengths/weaknesses

As the semester progressed, the high school students developed a level of comfort with the tasks they had been assigned to do. However, the limited time that each student can spend on the campus restricts the pace of advancement. We believe the program works well to achieve the objectives related to recruiting (i.e. familiarity with the campus and chemical engineering program and learning about the university environment). One of the three participants expressed a growing interest in our program and, prior to completion of the fall semester, declared his intentions to enroll at Mississippi State University in chemical engineering.

Most students developed some independence and began optimizing the procedures or brainstorming ideas to solve problems encountered. Discussions between the high school students and faculty members participating in the program enabled students to discuss the learning process and voice their understanding (or lack) of their assigned projects/tasks. However, lack of contact time between the students and faculty members is noted as a weakness of the program. This is governed by students' availability to come to campus and by the faculty members' availability upon their arrival. The time constraint can be addressed by improving the scheduling of meetings and by more directly instructing the students in specific tasks. These tasks must be associated with short-term goals clearly outlined and readily achievable in the time allotted for their participation.

The growth of the mentor/protégé relationship was clear throughout this program. Students quickly grew familiar with their surrounds and readily joined in laboratory activities. The practice of new laboratory techniques was met with enthusiasm and a desire to understand the underlying purpose of the techniques and the projects' goals.

Constraints that must be evaluated for the future include the number of participants that can be accommodated, optimizing travel to campus and continuous time available to work on the project and the logistics for getting the student participants on the campus, into the secured laboratory areas and trained for efficiently getting started on their research.

Further data is being acquired on the impact of this particular directed research mentoring program as a recruiting tool. Recruitment of these students is a highly competitive activity and this program provides the experience to accurately judge which field best fits their interests and assess aspects of the college student life. This particular interactive experience succeeded in enlarging the student's view of engineering and research. The cooperative relationship with the MSMS high school counselor has strengthened and will continue to enable high school juniors and seniors to be introduced to a chemical engineering research environment.

Time constraints on faculty members and their research team are a real consideration. In the cycle reported here, high school participants were integrated into the ongoing activities of researchers' active teams. The number of future participants will be gauged by the availability of research projects amenable to the incorporation of such short-term participation by these students. With a current chemical engineering faculty of 13, it is anticipated that a minimum of 5-7 students could easily be accommodated each term for this program.

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