Experiences in Advancing Materials Engineering Education in Public High School via Teachers' Training

Jeannette Santos [1], Wendy Crone [2], Greta Marie Zenner [3], O. Marcelo Suárez [4]

Abstract - Valuable outreach to public high-school students, as prospective materials engineers, starts by training their science teachers. Accordingly a main goal of our Partnership for Research and Education in Materials (PREM) program is to facilitate the preparation of public high-school teachers in Materials Science and Engineering (MSE). For five weeks during the summer, teachers are trained in PREM-supported laboratories while they concurrently prepare educational modules based on those experiences. The content of these modules is dictated both by economic restrictions common in public schools and by educational regulations from the local school district. This article summarizes these teacher professional development activities and the accompanying logistics coordinated under the PREM umbrella.

Keywords - High school teachers, teaching modules, teachers' training, materials science and engineering

Experiencias en la Promoción de la Educación en Ingeniería de Materiales en las Escuelas Superiores a través del Entrenamiento de Maestros

Resumen - Una extensión valiosa hacia los estudiantes de escuelas públicas, como potenciales ingenieros de materiales, comienza con el entrenamiento de maestros. En este sentido, la principal meta de nuestro programa Alianza para la Investigación y Educación de Materiales (PREM) es apoyar la preparación de maestros de escuelas superiores públicas en Ciencias e Ingeniería de Materiales (MSE). Durante cinco semanas de verano los maestros son entrenados en laboratorios apoyados por PREM al tiempo que preparan módulos educacionales basados en esas experiencias. El contenido de dichos módulos está adaptado a las restricciones económicas, comunes en escuelas públicas y regulaciones educacionales que dependen del distrito escolar local. Este artículo resume estas actividades de desarrollo profesional de los maestros y la logística necesaria coordinada para la protección de PREM.

Palabras claves - Entrenamiento de maestros, ciencias e ingeniería de materiales, maestros de escuela superior, módulos de enseñanza.

INTRODUCTION

Several strategies have been shown to be effective in motivating high-school students to pursue engineering careers, including contests (Verner and Ahlgren, 2002), partnerships (DeGrazia et al., 2001), one-day programs, summer programs (Symans, 2000), and teacher professional development (Conley et al., 2000). All of these initiatives aim at increasing the pool of qualified engineers needed to satisfy the future demand of this profession. It is hoped that these initiatives will help to prevent a future shortage of engineers, as is predicted by institutions such as the National Science Foundation (NSF, 2003). Universities are becoming involved in the advancement of K-12 (K-12 is a short form normally used in the US for the publicly-supported school grades prior to college (Kindergarten through the 12th grade) mathematics, science, and engineering with the goal of reversing the trend of dwindling numbers of engineers (National Academy of Engineering, 2005; Grose, 2006). These numbers are even more discomforting when specific categories of engineers are considered, such as materials professionals, post-graduates,

[1] Professor, University of Puerto Rico, Mayagüez, Puerto Rico, USA, jsantos@ece.uprm.edu
[2] Associate Professor, Director, MRSEC IEG, University of Wisconsin, Madison, Wisconsin, USA, crone@engr.wisc.edu
[3] Assistant Director, MRSEC IEG, University of Wisconsin, Madison, Wisconsin, USA, gmzenner@wisc.edu
[4] Associate Professor, University of Puerto Rico, Mayagüez, Puerto Rico, USA, msuarez@ece.uprm.edu
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minorities, and women. The current national K-12 educational system (May, 2003) does a particularly poor job of preparing women and underrepresented minorities in science, mathematics, engineering (Grose, 2006), and technology. Nevertheless, career opportunities for engineers in general and materials engineers in particular are on the rise. In particular, materials engineers are among the best remunerated engineers in the US, according to a recent survey (Roncone, 2005). The smaller numbers of engineering graduates indicate, therefore, that information about opportunities and salaries is not reaching the high school population at the appropriate levels. In particular, underrepresented minority students enrolled in public high schools are even less exposed to that information and the challenges and excitement of engineering. This article describes our experiences as part of a project at the University of Puerto Rico-Mayagüez (UPRM) that aims to increase student awareness of and appreciation for the potential career opportunities for Hispanics in materials engineering. However, rather than focusing our efforts on the student population, we propose a professional development program that introduces teachers to material science and engineering (MSE). The preparation of teachers is a strategy for continual and lasting impact on students.

THEORETICAL FRAMEWORK

The University of Puerto Rico-Mayagüez is the US institution with the largest number of Hispanic engineering graduates (Bird Picó, 2003). UPRM was ranked sixth in the nation for the number of engineering bachelor's degrees awarded to women in 2004-2005 and second for the percentage of female graduates in engineering (Gibbons, 2006). With a student body of 12,000 (almost 5,000 of which are in engineering), this is the only public university on the island that grants engineering degrees.

In April 2004, UPRM established a broad collaboration with the University of Wisconsin-Madison (UW) via a Partnership for Research and Education in Materials (PREM) program sponsored by NSF. A main participant of the partnership is UW's NSF-funded Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces. In particular, one of the undertakings of the MRSEC, the Research Experiences for Teachers (RET) program, focuses on preparing teachers in nanoscale science and engineering topics related to MSE. This UW-based RET program served as a model for the Summer Research Experience for public high-school teachers from the Mayagüez School District, a program run by the UPRM's PREM Office of Education and Outreach (OEO). The experience of the UW MRSEC group provided a first-class resource for the success of this UPRM initiative.

RET programs are common in many universities and have proven to be a practical strategy in helping to reinforce the science background of teachers and prepare them in emerging sciences and technologies. New and rapid developments in science and technology make such teacher professional development programs an urgent necessity.

At the moment, several initiatives are being conducted throughout the University of Puerto Rico System with parallel goals that address facilitating the professional development of K-12 teachers. The largest of such initiatives is AlaCima, an island-wide program. The program description can be found in the given reference (AlaCima, 2006). AlaCima has established Resource Centers in several of the participating schools that facilitate the incorporation of new modules and materials into the classroom. Another such program is AFAMaC, which offers middle-school teachers professional development training in mathematics and science (AFAMaC, 2006). The PREM Summer Research Experience program for teachers presented here broadens the impact of pre-existing initiatives by incorporating a rapidly-expanding area of knowledge: materials science and engineering.

SCOPE OF THE SUMMER RESEARCH EXPERIENCE PROGRAM

The primary goal of the UPRM Summer Research Experience program is to provide teachers with research practice in a professional environment. Participants learn about a number of MSE topics, develop a project, produce presentations as progress reports, and create an instruction module. The individual project themes all relate to material science and engineering. We have found that this program structure is effective in facilitating teacher understanding of a new and challenging topic and in providing immediate feedback on the teachers' understanding of their topics. If a teacher fully understands a concept, s/he will be able to talk clearly about it, create effective analogies, design content assessment, and plan related classroom and laboratory activities. In addition, as a result of the high number of presentations the teachers are required to give on their topics and the related educational module they need to develop, the teachers become very conversant on their specific research topic.

To spread the enthusiasm for and interest in MSE, the teachers are asked to design their instruction module in such a way as to foster interest and enthusiasm among school students and other teachers about the subject matter. It is also required that the module be constructed at minimum cost to accommodate common budget restrictions in public schools.

DETAILS OF SUMMER RESEARCH EXPERIENCE PROGRAM

A series of activities were important for establishing the Summer Research Experience program, including announcing and advertising the program; selecting the participants; creating a program calendar; choosing professional development activities (such as the development of basic knowledge, scientific knowledge, and the project itself); and managing the personnel involved.

A call for prospective teacher participants was distributed among Mayagüez-area high schools. The application required basic information, such as past experience and contact information. Due to time constraints, all teachers were personally invited for the summer of 2005, the initial phase of the project. A full selection process will be carried out when necessitated by a higher number of applicants. The proposed selection process is to choose each teacher through a selection committee that will evaluate and interview the candidates.

A full agenda of the first day and a schedule of the entire five-week program were given to the teachers. The first day,

an important one, was used for orientation and administrative details, such as parking arrangements, acquisition of keys, and any other necessary paperwork.

Before the summer program began, all UPRM investigators participating in the PREM program provided a project title and a draft of a possible research topic. This allowed the teachers to have a brief description of the available projects on the first day. The investigators also gave a short, informal presentation to the teachers. In the future, the teachers will receive the list prior to the first day to allow them to think about which project would be the best fit for their interests and background. The second day all teachers provided their first three choices. A project was assigned to each teacher according to preference, the investigators' recommendations, and the demand of the project. The investigator became the teacher's research advisor.

During the first week of the program, the teachers participated in several workshops on fundamental skills such as Word, Excel, Power Point, and the use of the library and Internet. This provided the teachers with the basic tools necessary for easily preparing a presentation every week and knowing how to present their data and communicate their progress. For this purpose, all teachers had an account in the Engineering Computer Laboratory where the necessary software and Internet access are available. There was a student in the computer lab ready to answer questions during regular operation hours, which meant that the teachers could go any time they wanted to process their data and start working on their modules, presentations, etc.

The teachers also participated in activities related to the scientific component of their program experience. They visited all PREM research laboratories, attended a weekly seminar, and had group meetings. The laboratory visits included a small presentation about what was done in those labs. The weekly seminar was a technical presentation by each PREM investigator. The teachers learned about most of the research on MSE conducted at UPRM through these two activities. During group meetings they presented their work and learned about the other teachers' work.

The teachers also had to create an instructional module to teach the main concept of their project to their own students. The design of the module or activity was supposed to comply with the mandatory standards of the Department of Education of Puerto Rico. The teachers chose the structure of the module according to their background and interest.

Each research advisor met with the teacher assigned to his or her research group at least once a week. The teacher was also invited to the research group meeting, where the advisor had the opportunity to make suggestions and openly discuss the teacher's progress with other research group members. In addition to the advisor, the teacher also had the assistance of an undergraduate or graduate student or both. All of them supported the teacher's project by providing any necessary technical training on research equipment and by helping with the construction of the instruction module.

The teachers gave a final presentation of their research and educational module on the last day of the Summer Research Experience. During this final presentation, the teachers specifically addressed school educational standards and any other pedagogical information that would help the audience to realize the requirements for integrating a new educational module into the schools.

In the following section the results of our first summer experience is presented. At this moment evaluation tools based upon that initial experience have been developed to assess the effectiveness of the training based on summary evaluations, as well as pertinent follow-up activities, including the creation of MSE students' clubs mentored by the participating science teachers. Those results will be presented in an subsequent article, detailing the assessment tools utilized and the impact on the students.

RESULTS

All of the teachers' projects were outstanding. The weekly presentations made clear how much the teachers' knowledge and confidence levels improved. It was also interesting to see the different approaches the teachers used according to their own backgrounds and interests in the research context.

For example, one teacher learned how to synthesize gold nanoparticles and studied the effect of synthesis parameters on particle size. For the educational component, the teacher developed a demonstrative teaching module, an approach she chose because of the impossibility of synthesizing gold particles at her school due to a lack of necessary lab equipment and materials. The module, therefore, consisted of an interactive animation of the procedure to produce gold nanoparticles. The goal of the project was to produce a series of instructive animations that were accompanied by text written at a level appropriate for her students. An undergraduate student proficient in Macromedia Flash™ assisted the teacher. The teacher designed the structure and format of the module, and the student wrote the program with input from the teacher. Figures 1a and 1b are two frames from the animation developed to explain the synthesis of gold nanoparticles.

Another teacher studied the deformation of metallic materials, the role of dislocations in plastic deformation, and the subsequent strengthening mechanisms. She designed and prepared a physical model to represent how a dislocation moves on sliding atomic planes and how it interacts with obstacles. Students could use the physical model to study the characteristics of dislocation movement. Figure 2 shows the physical model of the dislocation movement using high viscosity glycerin, aluminum pegs and a transparent acrylic box. The slow glycerin movement as the liquid moves over a smooth acrylic surface and oozes through a line-up of the pegs simulates dislocation slippage on a compact atomic plane and its interaction with obstacles. The resulting bowing of the liquid as it crosses the peg line-up is similar to dislocation bowing after crossing a precipitate line-up, which is an example of a strengthening mechanism in metallic systems (Weakley-Bollin, 2004).

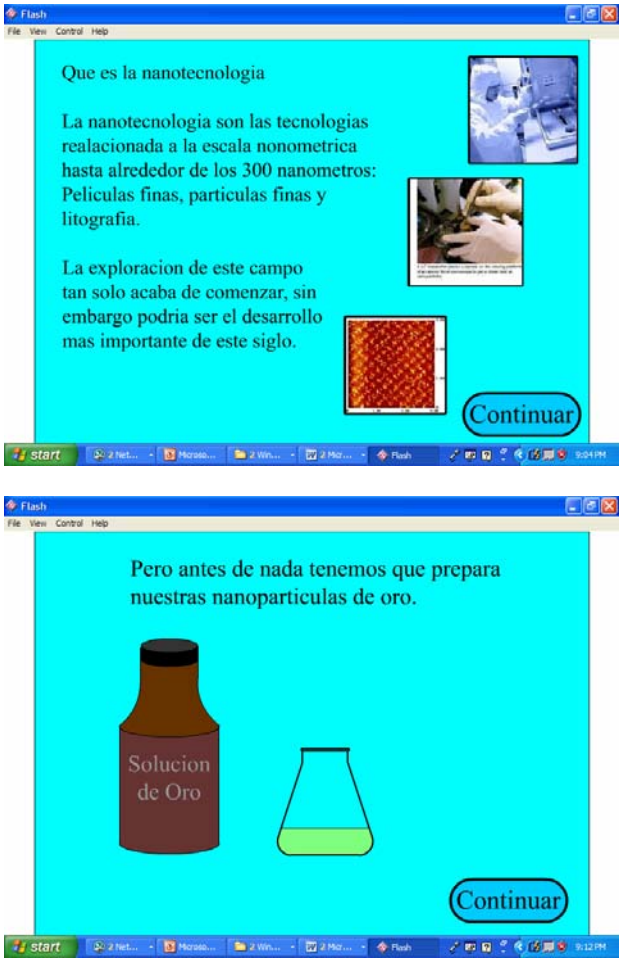

Figure 1: (a) First page of the Flash™ animation introducing nanotechnology; (b) Animation frame showing one step of gold nanoparticle synthesis.

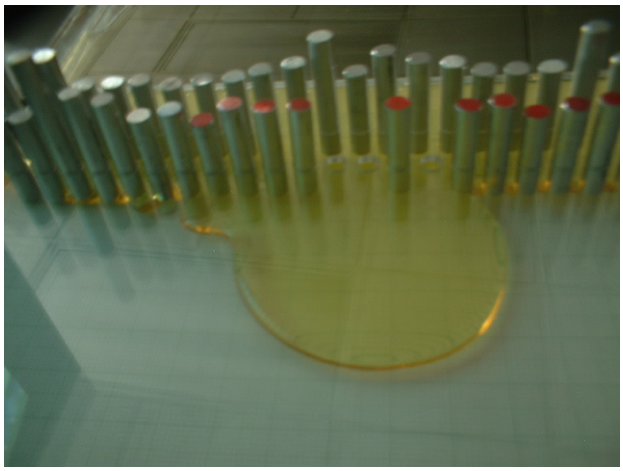

Figure 2: Physical model of a dislocation movement using an acrylic box, aluminum pegs, and glycerin.

ADDITIONAL QUALITATIVE OUTCOMES

An added value of this research experience was the increased familiarity the teachers gained with a materials research environment and the inherent complexity and increasingly interdisciplinary nature of engineering academia. The laboratory environment allowed interaction with scholars at all educational levels: from undergraduate students to professors (as the research group leaders). In addition, due to the inherent interdisciplinary nature of MSE, each research group consisted of students and faculty from a range of engineering and science departments. As a result, this exposure to a dynamic and synergistic setting broadened the teachers' view of the engineering profession. The teachers' professional development, therefore, included a component on the value of a diversified workforce. The Summer Research Experience also created a professional development opportunity for the students and faculty at UPRM as they learned to work with the teachers and learned about K-12 education. This development of communication and people skills is an important part of training the future engineering workforce (Yaşar, 2006).

Finally, in the following fall semester, the participating teachers encouraged their students to start their own Materials Science & Engineering Clubs. Under the guidance of their teacher mentor, student club members further explore the exciting field of MSE. PREM contributes to these clubs by having students lead demonstrative experiments during club meetings and PREM faculty visit the schools to talk about their own research work.

CONCLUSIONS

Subsequent interviews by the coordinator of the Office of Education and Outreach indicated that the participating teachers felt extremely satisfied with their contribution to research. Their presentations showed their proficiency in the research themes and overall comprehension of the underlying concepts. The teachers also noted that the experience demonstrated to them how demanding the projects were and how time consuming research is. Nevertheless, they enthusiastically accepted the challenge and were highly motivated to learn new concepts.

The particular institutional context at UPRM (Hispanic student body with a large percentage of female engineering) provides a fertile ground to expand the present initiative. In summary, PREM has helped create an interactive MSE community with constituents from all educational levels: from high school students and teachers, to undergraduate and graduate students, to researchers.

RECOMMENDATIONS

The developed modules have to be tested in the classroom, including assessment of their content and satisfaction of the target audience (students). The long-term results could be seen in several years if an engineer says that he/she chose the career because of the experience he/she had with an MSE activity prepared by his/her teacher (a PREM-trained one) in high school.

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