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The 'Lehigh Model' for Introduction of Engineering to High-School Students at ASM Materials Camp*

RYAN M. DEACON, CLIFFORD A. PRESCOTT and WOJCIECH Z. MISIOLEK
Department of Materials Science and Engineering, Lehigh University, Bethlehem, PA 18015, USA.
E-mail: wzm2@lehigh.edu

The Lehigh Valley ASM Materials Camp, held twice at Lehigh University, offered a new perspective on the way a materials camp for high-school students can be developed and presented. The distinguishing characteristic of the Lehigh Valley Chapter camp was that it was planned, developed, and presented by graduate student volunteers from Lehigh University. The focus of the camp was making materials science applicable to the high-school students by showing them how to recognize the role of materials science in applications they were already familiar with, such as sports, entertainment, and transportation.

Keywords: K-12; materials camp.

INTRODUCTION

SINCE 1952, the Materials Information Society (ASM) Materials Education Foundation has been charged with a difficult task: 'To excite young people worldwide in materials careers', according to the foundation mission statement. One of the ways the foundation accomplishes this goal is with its Materials Camp program. Targeting both high-school students and teachers, these hands-on camps introduce the field of materials science and engineering to individuals who may never have heard of it.

The foundation's Materials Camp efforts have been met with unbridled success, and the number of camps being held each year has doubled since the program first started in 2000 [1]. These camps are typically organized and run by personnel from the local ASM chapter, university faculty members, and members of local industry.

A new Materials Camp format was introduced and tested during the summers of 2004 and 2005 by the Lehigh Valley Chapter of ASM in Northeastern Pennsylvania. With major sponsorship from the ASM Materials Education Foundation, Carpenter Technology Corporation, Air Products and Chemicals, Brush Wellman Engineered Materials, EMV Technologies LLC, and Lehigh University, non-paid volunteer graduate students from the university's Materials Science and Engineering department organized and ran a Materials Camp for 16 local high-school students in an attempt to introduce them to the field of materials science and engineering.

The concept behind this new format is simple: ***the young teaching the young***. While this is an old concept in the education field, it was as yet untested in the history of the ASM Materials Camp program. This concept has been borrowed from the materials outreach program developed by the Department of Materials Science and Engineering at Lehigh University [2–4]. The goal of this program is to provide undergraduate seniors and graduate students an opportunity to work with local middle and high schools and to introduce the world of materials to younger students. One way this is accomplished is through a university course taught by one of the authors (WZM), for which students develop lessons relating engineering to high-school science classes. Due to the similarity in the tasks of both the Lehigh University outreach program and the Lehigh Valley ASM Materials Camp, several concepts were shared between the programs. The idea of utilizing graduate students as teachers was inspired by Arlan Benscoter, former chairman of the Lehigh Valley Chapter of ASM and renowned metallographer, who works closely with Lehigh University graduate students and felt they would bring a unique perspective to the camp.

THE LEHIGH MODEL

Solicitations for camp applicants were sent to area high schools targeting the best students. From these applicants, 16 junior- and senior-level students were selected based on their academic record, letters of recommendation and a personal statement. The camp was held from Monday through Friday, from 9 a.m. to 4.30 p.m. It was completely free of charge to the students, and

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included lunch and morning and afternoon snacks. Applications were sent to schools in both the Lehigh Valley and Reading, PA, areas. Carpenter Technologies Corporation, a major source of funding for the camp, provided transportation for the students enrolled from the Reading area.

Selection of camp participants was based on the individual student's grades, letter of recommendation and personal statement. While it was not expected, it was found that most of the students' grades and letters of recommendation were excellent and rather comparable; thus, the personal statement factored most significantly in the decision of accepting participants. On some occasions, the selection committee was faced with two applicants with equally strong applications. In these instances, preference was given to students who would become graduating seniors in the coming school year, as they would not have another chance to participate the following year. A photograph of the participating students and graduate student instructors from the 2004 camp can be seen in Fig. 1.

The academic program of the camp was developed by the graduate student volunteers. Initially, the entire group of graduate student volunteers met to brainstorm a general concept for the academic program. The results of this session was the themed-day model. Under this model, each day of the camp would have one theme, and the instruction would focus on products from that theme. Four themes were identified that were thought to be of interest for high-school students: sports, transportation, entertainment and failure analysis. The fifth day, Friday, was left open for several other activities, including a composite building competition, a tour of other engineering departments at Lehigh University, a family picnic and graduation ceremonies. Teams of graduate students were assigned to one particular day (theme), and the lesson plan for the entire day was developed by that individual team. Periodically, all of the instructors for the entire camp would meet together to discuss the ideas that had been raised individually and provide input on what proposed ideas they thought would work. This allowed the entire group to determine what needed refining, and add insight on possibilities for lesson plans that might not have been

Fig. 1. The instructors and attendees of the Lehigh Valley ASM Materials Camp., July 2004.
Front row: Andy Prescott*, Mike Minicozzi*, Tim Anderson*, Mario Epler*, Ryan Deacon*, Ken Adams*. Second row: Jen Guagler, Korrinn Strunk, Matt Zuwiala, Tom Carbone, Sean Magess, Brad Swavely, Kristina Snyder, Amanda Farace. Third row: Brian Newbury*, Dave Hartwich, Joseph Barron, Geoff Quinter, Tom Neill, Wes Vinson, Tyler Rabe, Steve Spehalski, Ashley Evanoski, Matt Perricone*. *Instructors

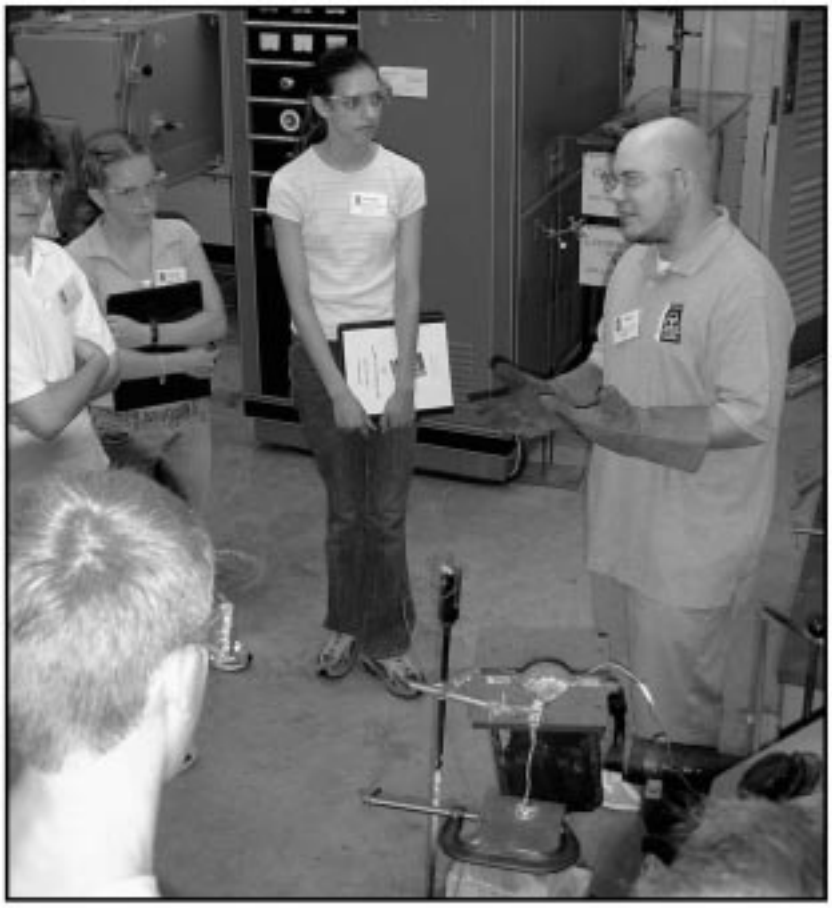

Fig. 2. During a laboratory on casting, instructor Mario Epler discusses cooling rates with students (from right to left, Ashley Evanoski, Amanda Farace and Thomas Carbone).

thought of by those responsible for designing the lesson plan of that theme.

Strong emphasis was placed on hands-on activities throughout all parts of the camp, with very short (less than 10 minutes) lectures to introduce the current topic and prepare the students for the lab activity. Lab activities were chosen based on their relevance to the day's particular theme and the overall materials lessons that could be learned during the activity. Various commonplace

Fig. 3. Instructor Matt Perricone holds an ice and newspaper composite, while student Joseph Barron prepares to take a swing with a hammer to demonstrate the composite strength.

products from each theme were used as examples in both the lectures and the labs. For example, on the transportation day, students were given a short lecture on how automobile wheels are manufactured (forging, casting, machining) and then spent time casting their own aluminum ingots and examining their microstructures and mechanical properties (Fig. 2). During part of the sports day, students had the opportunity to break different composites composed of ice and other everyday objects including newspaper, straw and wooden dowels as the reinforcement phase, in order to illustrate the strength of combining two relatively weak materials (Fig. 3).

At times, safety or feasibility prevented everyone from participating in an experiment; in these few cases, one single demonstration would be used to show the material concepts to the students. Demonstrations such as breaking a pane of tempered safety glass and smashing an automobile windshield were performed by selected students with instructor supervision while the others watched and discussed what they expected to happen, and how this compared to what actually happened. Demonstrations were also used for introducing equipment such as an electron microscope and welding instruments to the students.

When the instructors felt that a lecture on a subject would be more interesting or beneficial than a lab activity, an internationally known guest speaker from the professional community was selected to offer their expertise on the subject. These guest lecturers not only brought a wealth of knowledge and experience to the classroom, they also illustrated to the students the various fields which employ materials scientists. The guest speakers at the Lehigh Valley camp included Dr. Alan Pense, professor emeritus, who discussed the material design and deterioration of bridges, Dr. Richard Hertzberg, professor emeritus, who talked about some of the more interesting failure analysis projects he has worked on, and Eugene Albulescu, professor of practice, who spoke on the evolution of sound quality and tone in grand pianos due to improved understanding of the performance of various materials used for manufacturing piano, frames, wires, and felt hammers.

Toward the end of the week, students were given the opportunity to participate in a competition in which they each designed their own fiber/epoxy composites. This competition gave them a chance to apply the engineering ideas they had learned throughout the week, and the competitive nature of the activity excited many of the students.

On the final day of the camp, the students and their parents were invited for a closing ceremony with a certificate of attendance. This was designed to give the students a sense of completion and accomplishment for what they had experienced and offered them an opportunity to share with their parents what the week had been about. There were also invited speakers who discussed different career paths in the field of materials science and engineering. The general manager of EMV Technologies LLC, Lehigh spin-off technology development and technology transfer company, and a vice president of Carpenter Technology Corporation discussed their roles in the field of materials science and engineering. Additionally, an admissions specialist from Lehigh University discussed the college application and admissions process, a timely topic for the camp participants, most of whom would soon be applying to colleges. The event was well attended by the students' family members, and both the chairman of the Materials Science and Engineering Department, and the Dean of the Engineering College at Lehigh University.

DISCUSSION

In broad terms, the Materials Camp program has two general goals: first and foremost, to introduce the field of materials science and engineering to high-school students who might otherwise never become aware of the field, and, as a secondary goal, to teach the students some basic materials science and engineering concepts. The best measure for determining if these goals have been met is the results of the survey the students are given at the end of the camp [5, 6]. In addition to asking if the students enjoyed the overall experience, questions relating to the camp's impact are asked. In the survey from the 2005 Lehigh Valley Materials Camp, participants were asked to rate their agreement with several statements about the camp, with a value of 1 corresponding 'strongly disagree' and 6 corresponding to 'strongly agree'. The statements 'Through this camp experience, I learned how materials engineering is relevant to everyday events' and 'As a result of this camp experience, I have a better understanding of science/engineering and their applications' received scores of 5.33 and 5.13, respectively, indicating that the students did indeed learn about the field of materials science and how it plays an important role in their everyday lives.

In another section of the survey, students were asked to list the top three things they learned during the camp. Several students responded with specific materials science concepts, using terms learned in the camp, including the difference between ductile and brittle materials, different processing methods, and material responses to loading, including failure and fractography. In light of these survey results, it is evident that the students who participated in the camp acquired at least a small amount of new materials science knowledge. It is also interesting to note that, in this section, two of the students responded that they learned 'a lot about college and graduate school from the instructors' and 'a lot about colleges (activities, concepts and experiences) by talking to the graduate student [instructors]'. This kind of 'secondary learning' was a direct result of

the open and friendly atmosphere that was created by using instructors who are close in age to the students; this age-factor aspect of the camp will be discussed in further detail in this section.

In addition to the results of the survey, the Lehigh Valley Materials Camp was widely considered a success by outside observers [7]. It is felt among experts in professional societies [8], industry [9], and academia that the combination of utilizing teachers of similar age to the students and emphasizing hands-on activities is one of the best ways to introduce the field of materials science and engineering to young people. The Lehigh model has been looked to as an example around which other camps could be created and the organizers have been invited on several occasions to present the Lehigh model to other camp organizers [10]. There are four key elements of the Lehigh model that have largely attributed to its success that merit further discussion: the use of hands-on activities, the low student to instructor ratio, the selection of themes of interest to high-school students, and the age of the instructors.

Emphasis on hands-on activities has been a part of all Materials Camps since the original camp was started in 2000. The ASM Foundation, the organization responsible for the creation of the Materials Camp program, has long recognized that young people learn more when they actually do something, rather than watching someone else do it as part of a demonstration. As such, hands-on activities and very short lectures have been emphasized by the Foundation as crucial for the success of a Materials Camp.

In order to have as many hands-on activities as possible, a low student to instructor ratio is required. Many of the Materials Camp activities require direct supervision, either because the student has never performed the activity or to ensure the safety of the students. This is another key point that is emphasized during the creation of all Materials Camps, and is so important that the number of student participants is often dictated by the number of available instructors. For both the 2004 and 2005 Lehigh Valley Materials Camp, the student to instructor ratio was approximately 4 to 1.

The two aforementioned concepts (hands-on learning and a low student to instructor ratio) are common to all of the Materials Camps across the world and are a large factor in the success of the camps. What distinguishes the Lehigh model from other camps, however, are the use of themed days and the age of the instructors. By organizing the camp around themes that high-school students are interested in, and by focusing the activities on everyday items, the students can more readily understand the concepts they are learning. They were also more comfortable, in that most had some prior experience with some of the items they were examining. Several of the students made comments to this effect in the final survey, including the following: '[The camp] provided a look into materials engineering/sciences that I wouldn't have thought before. They made the labs fun and interesting with topics we like and can relate to.' Another student stated: 'I have learned a great deal of information from this camp. The examples used (i.e. the speakers lab, golf ball lab, etc.) were all ones we could relate to, which was neat.' These statements indicate that the use of these themes is an effective way of bringing the world of materials science and engineering to a level that high-school students can relate to and also enjoy.

The most distinguishing characteristic that separates the Lehigh model from other Materials Camps, and the factor most responsible for its success, is the age of the instructors. The major objective of the Lehigh model is to create an open, comfortable learning environment by utilizing instructors that are only 5–10 years older than the high-school students themselves. The feedback from the students indicates that this objective was met: 'The 'materials mentors' were a lot of fun, supportive, nice, easy to talk to and comprehend and interesting.' Another student stated: 'I felt comfortable working with my peers and also with the mentors.' 'I was pretty comfortable with everyone', another student responded. When asked what could have been done to make their relations with others more positive, one respondent said 'I believe the whole experience with the members and faculty was exceptional. We all got along, and eventually began to open up to each other and talk.' In one section of the survey that asked for any additional comments on any aspect of the camp, one student replied 'The mentors were very nice and easy to approach and ask for help. The other kids were cool because they like science as much as I do.' Another student found that instructors 'were friendly and qualified.' In a separate section of the survey, where students were asked to indicate their agreement with statements about the camp (a value of 1 corresponding to 'strongly disagree', a value of 10 meaning 'strongly agree'), the statements 'Staff made efforts to ensure I was comfortable' and 'Faculty and staff made me feel comfortable during the program' received scores of 9.8 and 9.7, respectively.

The effect of the age factor was evident not only in the classroom and laboratory, but also during the camp's lunches and breaks, where the instructors were able to communicate with the students about non-materials issues. Open discussions and conversations on everything, from the summer's movies and television shows to what college and graduate school are really like, were common during downtime throughout the camp. The friendly atmosphere undoubtedly had an impact in the classroom as well, as the students showed little if any hesitation to ask questions during the laboratory activities.

In addition to the four key factors that make the Lehigh model successful, there are two other minor aspects that were thought to contribute as well. A division of labor was clearly established early on in

the planning of the camp. Two Lehigh University graduate students were identified to co-chair the camp's efforts. The two co-chairs were responsible for all academic aspects of the camp, including recruiting graduate student volunteers and ensuring the academic integrity of the individual lessons. A volunteer from the local chapter handled all of the administrative tasks, including soliciting participants, arranging transportation for distant students and scheduling guest speakers. Finally, a professor from the Lehigh University Department of Materials Science volunteered to handle all of the funding issues, including solicitation from local industries. The balance of multiple leaders sharing the responsibilities of the camp allowed for proper attention to be given to each task. This division of labor was essential to the successful organization and execution of the camp. Communication among the camp organizers was also crucial to the camp's success. Several issues required the input of multiple persons, and open and frank discussions allowed important decisions to be made swiftly.

The other minor aspect of the camp that contributed to its success was the prior experience of the Lehigh University Materials Science and Engineering graduate students, who volunteered significant amounts of time and talent to developing the camp's academic program, and ensured the camp was delivered in a polished, professional manner. Most, if not all of the graduate students involved, had prior experience in giving both technical and non-technical presentations, either as teaching assistants at Lehigh University or at research conferences, and this experience aided them in their ability to connect with their audiences at the Materials Camp.

CONCLUSIONS

A new format to the traditional Materials Camp has been created at Lehigh University, where graduate student volunteers organized and executed a successful summer experience for local high-school students. Organizers made an effort to reach out to the students by discussing topics of interest to them. This methodology proved to be a useful way of exciting the students about what they were learning.

There are four main factors that constitute the 'Lehigh Model':

- an emphasis on hands-on activities;
- a low student to instructor ratio;
- selection of themes of interest to high-school students; and
- the utilization of instructors who are only 5–10 years older than the students.

The high-school students responded positively to the graduate student instructors, due to the closeness of their respective ages, and their ability to present the subject matter in a manner the students could easily understand. The students' responses to a post-camp survey indicate that the students not only enjoyed the camp experience, but also learned a great deal about the field of materials science and engineering.

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Ryan M. Deacon is a doctoral candidate in the Materials Science and Engineering Department at Lehigh University. A member of the Engineering Metallurgy Group, his

studies focus on high temperature corrosion, welding and physical metallurgy. He is a Vice Chair of the Lehigh Valley Chapter of ASM International and also serves on the executive board of the Graduate Student Senate of Lehigh University.

Clifford A. Prescott received a bachelor's degree from the Materials Science and Engineering Department and a master's degree from the Industrial Engineering Department while performing research at the Institute for Metal Forming at Lehigh University. He is currently employed by Exxon/Mobil in Houston, TX.

Wojciech Z. Misiolek is the Loewy Chair of Materials Forming and Processing, and Director of the Institute for Metal Forming (IMF) at Lehigh University in Bethlehem, PA. He is a faculty member of the Materials Science and Engineering Department and the Mechanical Engineering and Mechanics Departments. His research includes work in the area of materials deformation, powder metallurgy and metal machining. Dr. Misiolek has contributed to over 160 publications in the research literature. He holds a patent and is a Fellow of ASM International.