AC 2007-617: UNDERGRADUATE RESEARCH AS A MOTIVATION FOR ATTENDING GRADUATE SCHOOL

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Undergraduate Research as a Motivation for Attending Graduate School

Abstract

There is a clear problem at the university level in terms of directing students toward graduate schools. This problem is further complicated by the declining number of international graduate students' enrollment in U.S. universities, who usually account for a high percentage of all graduate engineering students. Due to the more-restrictive visa policies of the government put in place immediately after September 11, 2001, the perception among overseas students is that getting a U.S. visa is virtually impossible. As a result, the number of foreign students applying to American universities continues to decline dramatically. Such decline will certainly have long-term economic implications.

It is therefore critical to increase the enrollment of U.S. students in graduate schools through motivation. From the standpoint of the individual, motivation is an internal state that leads to the pursuit of certain objectives. Personal motivation affects the initiation, direction intensity and persistence of efforts.

Undergraduate engineering research has gained significant popularity in many engineering schools in the past few years. Engineering research includes the aspect of pursuing a scientific topic, a hypothesis or an idea in a systematic rigorous fashion. This requires critical thinking in order to answer questions and to produce new and original knowledge. Another aspect of research is describing the intellectual activity and communicating the new knowledge both orally and in writing.

This paper describes a research program that was conducted by fourteen undergraduate mechanical engineering students during the past three and a half years; and it also assesses the motivation of the students toward graduate studies using a survey was administered to the students. The students agreed that the research experience developed their scientific research skills and their data collection, documentation and dissemination abilities and taught them the logic of an engineering conference and journal articles. They also reported that the research experience in general served as an introduction/orientation for what to be expected at the graduate level research, and that it was an excellent motivation for directing them toward graduate school. They also felt that the research training and preparation were not encountered in other engineering courses.

1. Introduction

Recent trends point at the continued decline of the number of students attending graduate schools in the different engineering disciplines. There are two prime reasons for this. The first has to do with motivating and directing undergraduate engineering students to graduate programs. Grander [1] says: "There is a problem at the university level in terms of directing students into graduate school." The word motivation, according to [2] refers to two different but related ideas. From the standpoint of the individual, motivation is an internal state that leads to the pursuit of certain objectives. Personal motivation affects the initiation, direction intensity and persistence of efforts. From the standpoint of the teacher, motivation is the process of getting the students to pursue these objectives. Low motivation contributes to low-quality work, superficial effort and indifference toward the future.

The other reason for the declining number of students starting graduate studies in engineering is the very tedious visa regulations imposed on foreign students. These days, international students have hard time navigating the more-restrictive visa policies of the U.S. government put in place immediately after September 11, 2001. Selingo [3] states that the perception among overseas students is that getting a U.S. visa is virtually impossible. As a result, the number of foreign students applying to American universities continues to decline dramatically. Foreign applications to graduate engineering programs dropped an alarming 36 percent last year, according to the Council of Graduate Schools [4].

To cite some specific examples, the drop in the number of applications for the engineering graduate programs, between fall of 2003 and fall of 2004, at the University of Florida, the University of Southern California and Purdue University was 42, 39 and 54 percent, respectively. In general, the foreign students account for 55 percent of all Ph.D. engineering candidates in the U.S. [3]. It is pretty obvious that these trends have some very serious negative impact on engineering graduate schools. They may also have long-term economic implications for the U.S. [4].

Undergraduate research has gained significant popularity in many engineering schools in the past few years. Traditionally, engineering undergraduate students are provided with some design experiences in the cap stone design course, and as part of some other engineering courses, which include design-type small projects or open-ended problems, throughout the curriculum. While very valuable in many ways, this design experience does not constitute scientific research: It mainly aims at providing a design for a working or manufactureble part or system. To achieve this, the students usually apply their existing knowledge and technical skills that they acquire through their engineering courses.

Engineering research includes the aspect of pursuing a scientific topic, a hypothesis or an idea in a systematic rigorous fashion, and applying critical thinking in order to answer questions and to produce new and original knowledge. This aspect is not usually encountered in the typical undergraduate design projects. So an engineering student may graduate without getting exposed to a genuine engineering research experience. This becomes a weakness, especially if the student pursues a graduate study program or works in an industrial environment that requires some engineering research. Undergraduate research programs are very likely to overcome such shortcomings, and would provide the students with considerable training for seeking answers and independent scientific thinking.

An undergraduate research program is extremely beneficial in other ways. It creates new educational opportunities and serves as an active and cooperative learning environment that Shuman et al. [5] have alluded to. It includes instructions that promote student understanding and development. In addition, it allows for several levels of communications; and it upgrades professor/student communication by establishing modes and channels in a very interactive way. Such advantages may not be encountered in the typical undergraduate engineering curricula.

A student that participates in an undergraduate research program gets more exposure and training in areas such as writing reports, public speaking, research documentation and dissemination, structure discourse and strategies of creating articles for scientific conferences and journals (see Paretti [6]), and interpreting, discussing and using what is available in the scientific literature.

The above activities are very similar to what takes place at the graduate education level. In addition, undergraduate researchers usually interact with and consult with graduate students who are working in similar areas. All of this encourages undergraduate students to seek in-depth knowledge and directs them to graduate schools.

This paper briefly describes a research program that was conducted by several undergraduate mechanical engineering students during the past three and a half years. It also assesses the program's motivational effects on the students on directing the students to graduate schools, and it documents their comments and feedback.

2. Description of the research program

2.1 Topic and Tasks

The research program consisted of analytical modeling and experimental verification of the convective heat transfer of air flow in open-cell aluminum foam (Fig. 1). The analysis was one dimensional and followed that of a thin fin [7], with some modifications to account for the porous structure of the foam.

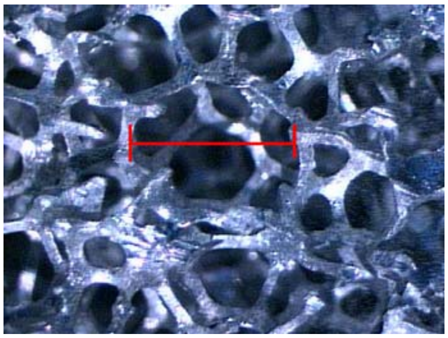

Fig. 1 Close-up Photo of the Open-Cell Structure of Aluminum Foam (Length of line 0.168 inches)

The analytical part was a little more difficult than what is usually encountered in a typical undergraduate course in heat transfer. It also required the solution of a second-order ordinary differential equation but not any higher-level mathematics [8].

The experimental part involved verification runs to validate the analytical model. The one-dimensional temperature profile was measured using thermocouples located strategically at different points inside a foam block heated from one side, and placed in an open-loop wind tunnel. The temperature measurements at different flow rate were collected and recorded using an automatic data acquisition system. The experimental results were compared to the analytical results [9-12].

Other areas of the research included simulation of the heat transfer problem in thermal management packages, and design and testing of new foam cooling devices for specific applications. The different tasks persuaded the students to make extensive use of computational, modeling and data treatment and presentation tools such as Matlab, Mathcad, Ansys, Excel and PowerPoint.

2.2 Participating Students

A total of fourteen undergraduate mechanical engineering students, included two female students, have participated in the research program. Most of the students were seniors. The students worked individually or in teams, based on their preference. There were three teams of two students each. Some of the students have graduated and are either attending graduate school or working for the industry.

2.3 Analytical Results

A brief description of the analytical results will be given here. Figure 2 is a schematic of the foam block with the nomenclature and the coordinate system. We assume that the airflow is one-dimensional in the positive x-direction and that the temperature filed is also one-

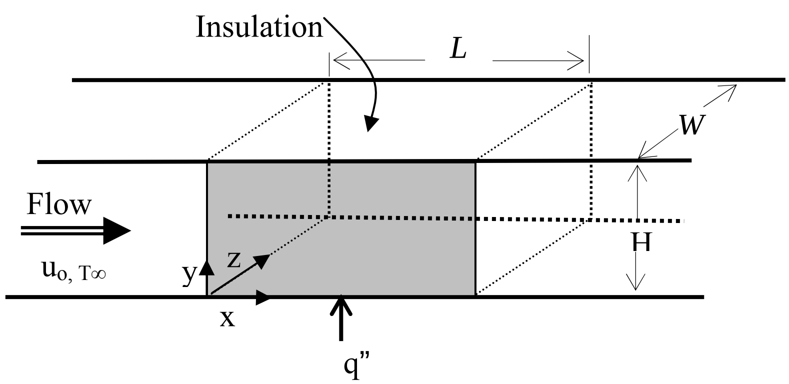

Fig. 2 Schematic of the Foam Sample and Flow Arrangement

dimensional and that it varies only with y. The dependence of the temperature on the flow direction is eliminated by assuming a small thickness of the foam in the flow direction. The heat transfer governing equation is

$$\frac{d^2\theta}{dy^2} - m_{fm}^2\,\theta = 0. \qquad (1)$$

where $\theta = (T - T_\infty)/(T_b - T_\infty)$, T is the average foam temperature, T_∞ is the ambient air temperature, T_b is the heated base temperature, and

$$m_{fm}^2 = \frac{h_{fm}\,\sigma}{k_s\,(1 - \varepsilon)} \quad . \qquad (2)$$

where m_{fm} is a new parameter, analogous to the well-known fin parameter, and was named the *foam parameter,* h_{fm} is the convective heat transfer coefficient inside the foam, k_s is the conductivity of aluminum, ε is the porosity and σ is the surface area per unit volume of the faom. The solution to (1) is given by

$$\theta = \frac{\cosh\ m_{fm}\ (H - y)}{\cosh\ m_{fm}\ H} . \qquad (3)$$

2.4 Experimental Results

The foam block tested had twenty pores per inch and had dimensions W = 4 inches, H = 9.875 inches and L = 2 inches. A sample of the experimental data is shown in Fig. 3 and is compared to the analytical solution given by Eq. (3).

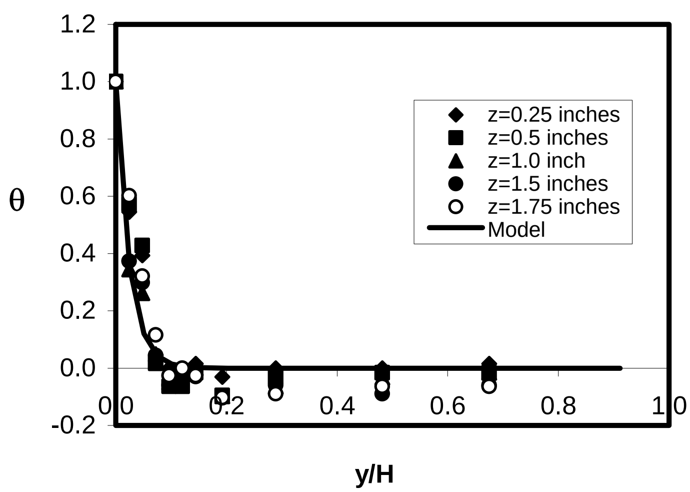

Fig. 3 Analytical and experimental results.

For other aspects of the research program, see [13] and [14].

3. Impact on Students' Direction Towards Gradute Studies

3.1 Students Survey

The impact of the research experience on the students' motivation and increased interest in attending graduate school was assessed by a questionnaire administered recently. A survey of twelve questions was given to the students to complete. The survey was designed to get information and feedback on the following themes:

- Whether students were attending graduate school, or would be attending graduate school.

- Whether the undergraduate research program served as an introduction/orientation, and would help students in their graduate studies.
- If the research program made the students want to attend graduate school and why.
- Whether they felt more comfortable conducting engineering research, and what skills they learned that they would use in their graduate studies.
- Contrasting the undergraduate research program with other courses including the cap stone course in terms of research skills learned and practiced.
- Any other comment the students wished to add.

3.2 Impact on Students

The responses of the eleven students who completed the survey were collected and analyzed to obtain general trends and attitudes towards graduate studies. Nine of the respondents have graduated. The following general statements could be safely made.

Four of the students were attending graduate school and four said they were planning on attending graduate school in the near future. One student said he was not planning on attending graduate school while the remaining student had no opinion.

Seven students indicated that the research experience would help them 'a lot' in their graduate studies, while two said it would provide 'some' help. The remaining two students had no opinion, since they were not interested in attending graduate school. The same exact response was recorded when students were asked if the research experience served as an introduction/orientation to graduate research.

Five students agreed that they were a lot more comfortable conducting engineering research, while the remaining six said they were somewhat comfortable, as a result of participating in the research program.

The above three areas were deemed important and directly related to the attitude of the students towards attending graduate schools. A total of eight questions of the survey addressed these areas. The results are plotted in Fig. 4. It is clear from the chart that the undergraduate research experience had a direct and strong impact on the participating students. The strongest impact was on increasing or establishing the level of comfort in conducting research. All students reported improvement in this area. This certainly improved their attitude towards graduate school.

Similar arguments can be made regarding another area of impact: the undergraduate research experience serving as training and would help in graduate work. Over eighty percent of the students agreed that the training would help. Again this was likely to improve the attitude of the students when they think about attending graduate school.

Over seventy percent of the students were either attending or were planning on attending graduate schools. The undergraduate research experience was certainly a factor, but not necessarily the only factor. The author believes that some of the students had prior intention of

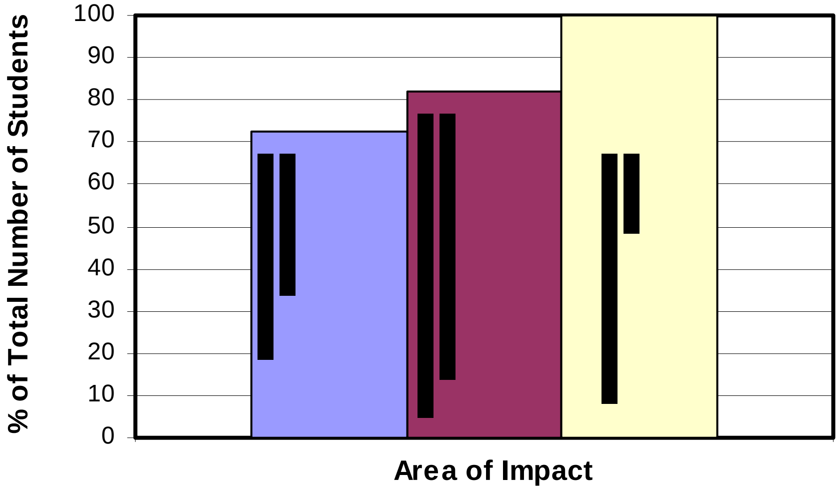

Fig. 4: Results for Three Impact Areas

continuing their studies. In such cases, the research experience reinforced their decisions. The students who were not interested in graduate studies participated in the undergraduate research for different reasons, such as making some extra money and writing the research experience as one item in their resumes.

Other areas of interest are discussed below. When asked about the skills learned during the undergraduate research experience, the students listed several skills such as: communication skills, experimental instrumentation and vocabulary, data analysis, analytical derivations, computer simulations, creativity, organizational skills, literature search, technical writing and leadership. One student said the research experience taught him patience, while another said it taught him "people skills."

Contrasting the undergraduate experience to other courses in the mechanical engineering undergraduate curriculum, including the cap stone course, seven out of the eleven students who completed the survey stated that the skills provided by the research experience were not provided by any of their other courses. Three agreed with the above statement regarding other courses, but has no opinion when comparing the research program to the cap stone course, probably because they had not taken that course. One student did not understand the question.

A few students provided their own comments. One student reflected: "The undergraduate research project provided me with motivation to continue a graduate degree and it served as a pre-view or short example of what I will actually do in a graduate program." Another student said: "I believe that undergraduate research must form part of any undergraduate engineering student's [education]." A third stated: "The research experience is basically the only motivation that I get in undergraduate studies to continue graduate ones." And one student said: "Group work and communications were excellent."

4. Conclusion

An undergraduate research program was described. The impact of the program on students' motivation and desire to attend graduate school was assessed using a survey. The research program trained the students in interpreting scientific and engineering literature and in presenting their results in conference and journal article format. As such, the program allowed the students to graduate with a more sophisticated research skills set, and served as training for what to be expected at the graduate level. Such training was not available in any other course in the undergraduate engineering curriculum. The undergraduate research program helped motivate and direct a considerable number of the participating students toward graduate schools.

5. Acknowledgement

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