

environment in undergraduate education through research, whereby students would get to know and appreciate the importance of research in chemical engineering.

The presentations and the vivid discussions by a very interested audience on some of the issues on undergraduate research led to some general conclusions. Several researchers who participated in the discussion were asked to submit their

written comments. Professor Krantz accepted and describes a different undergraduate research system offered at Colorado. Professor Koukios summarizes some of his impressions from educational systems with required undergraduate research and draws parallels between the American and European educational systems.

The main conclusions of this Symposium are summarized at the end of the eight contributions.

## WORCESTER POLYTECHNIC INSTITUTE

### UNDERGRADUATE RESEARCH: MYTH OR REALITY?

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"UNDERGRADUATE RESEARCH: Myth or Reality"; certainly an intriguing title and one that by its very nature has to be somewhat opinionated. One's opinions are shaped by their experiences. Thus, I would like to start by presenting a brief history of my experiences with undergraduate research.

I did my undergraduate work at Northeastern University in Boston, Massachusetts. At that time, Northeastern had an option available to those students with a specified Quality Point Average (I believe, 3.0 or greater out of 4.0). This option allowed these students to do a special project in lieu of design. Having heard of the rigors of the design course, I acted naturally, taking the path of least resistance by asking to do a special project. These special projects were generally small research efforts associated with the interest of the various faculty members and were one academic year in length.

After graduating from Northeastern, I went on to graduate school at Massachusetts Institute of Technology. While pursuing my doctoral degree there, I had the opportunity to become involved with several undergraduate research projects

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Albert Sacco, Jr. came to Worcester Polytechnic Institute in September 1977. He holds the rank of Assistant Professor in the Department of Chemical Engineering. His undergraduate work was at Northeastern University (B.S.) and his graduate studies (Ph.D.) at the Massachusetts Institute of Technology, all in chemical engineering. Dr. Sacco's research interests are in catalysis deactivation, solid-gas reactions, and phase equilibrium.

(B.S. theses). These projects were done by seniors at MIT, under the guidance of doctoral students, working on well developed, well financed research projects.

Finally, after obtaining my degree at MIT, I began teaching in the Department of Chemical Engineering at Worcester Polytechnic Institute. At WPI all students must complete two 21 week (usually, in practice, 28 week) projects. Both projects are generally of a research nature. One relates a technical topic to its social environment (IQP, Interactive Qualifying Project); the other is in essence a B.S. thesis (MQP, Major Qualifying Project).

Although my years as a teacher are few (3.5 years) I believe that my experience reflects a longer association with undergraduate research. In addition, the programs that I have been involved with reflect different attitudes on undergraduate research: Northeastern allowing only those

students with a strong interest and proven skill to undertake undergraduate research; MIT, working from a more select group, associates these projects very closely to on-going graduate research projects; and WPI where all students, individually or in groups, take part in a research experience.

As one can see, undergraduate research means different things to different people. In order to try and address whether undergraduate research is indeed a reality or a myth, I feel that we should have a working definition of research. Borrowing, in part, from Webster's New International Dictionary, Second Unabridged Edition, research is defined in the following manner:

*"RESEARCH—Studios inquiry or examination: specific and usually, critical and exhaustive investigation or experimentation having for its aim the discovery of new facts and their correct interpretation; the revision of accepted conclusion, theories, or laws, in the light of newly developed facts, or the practical application of such new or revised conclusion, etc. . . ."*

The words I consider to be key words are italicized.

Any project that adheres to this definition is certainly publishable. I further restrict our definition to include the statement that if the undergraduate project is of a research nature it has been, or shortly will be, published in a refereed publication. With these definitions and restrictions in mind, the following questions were asked informally of 20 faculty members at WPI and approximately five faculty at five other universities.

- How many undergraduate research projects done by a single undergraduate result in a publication in a refereed journal?
- How many undergraduate research projects done by a group of undergraduates result in a publication in a refereed journal?
- If the project is done as a part of an on-going research effort, how often does this project result in a publication? Part of a publication?

## UNIVERSITY OF MAINE

### UNDERGRADUATE RESEARCH: A Necessary Education Option And Its Costs And Benefits

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CHEMICAL ENGINEERING IS A practice rather than a science. Even though the principles of science are applied to solve engineering problems,

- If an undergraduate project is continued from year to year, how often does this lead to publication?
- How valuable is undergraduate research?

The answers I received can be summarized as follows: Typically, whether done individually or in groups, undergraduate research projects result in fewer than 15% being published in refereed journals. If the project is associated with an existing research program, the number published increases to approximately 30-40%. However, this increase does not reflect an increase in publications for individual projects. It does reflect the fact that parts of the undergraduate project will be included in publications associated with this research. The number of publications was perceived to increase for projects that were continued or on-going. However, this increase was thought to be minimal. Finally, all faculty felt the undergraduate involvement in research was an excellent learning experience.

Obviously, the sample of faculty informally polled is too small for definitive conclusions to be drawn. I do believe, however, that the answers received reflect general trends. The answers reflect my own experience, which is that undergraduate research projects are seriously constrained by time and, unless attached to an on-going graduate research project, money. The need for well defined manageable undergraduate projects is, in my opinion, reflected in the increased publication rate for projects being part of a larger, well defined effort. The results of my informal survey suggest that based on the stated criteria, undergraduate research is more myth than reality. Admittedly, the criteria were restrictive and the sample small; but, perhaps the real value in undergraduate research lies not in the research itself, but in the knowledge and experience gained in the search for understanding. □

it is seldom that the final solution can be predicted from first principles with sufficient confidence to eliminate all need for demonstration. More often, the problem requires at least demonstration and frequently experimental study of elements of the process or experimental determination of needed physical data. Ideally, chemical engineering students should not only be required to take experimental as well as theoretical courses, but should also be given the opportunity to exercise judgment in deciding when experimental work