Educational Priorities of Graduate Education in MSE Must Undergo Reforms

To the Editor:

Your Public Affairs Forum by Julia Phillips ["NSF Workshop on Graduate Education Examines Needs for the 21st Century," August 1995, p. 13] raised a number of important issues concerning graduate education in materials science and engineering (MSE).

Since World War II the field of MSE has matured into a discipline in its own right. The conceptual foundations of the subject, experimental techniques, and theoretical/modeling tools span the dominant materials classes of metals, ceramics, semiconductors, and polymers. Of course, the discipline of MSE is very broad and physicists, chemists, and engineers continue to contribute to its development. But broadly applicable experimental techniques now exist to synthesize and process an enormous range of materials. Well-established techniques of characterization and modeling may also be applied to analyze their structures and properties over a wide range of length scales. At the same time materials-based industries are demanding trained personnel with increased flexibility and breadth to cope with the increasing diversity and complexity of the design and manufacture of functional and structural materials systems for engineering applications. The field of MSE is now sufficiently developed that this demand can be met. Julia Phillips has raised the question of whether it is met by the current structure of the PhD program, with its focus on a narrowly defined research project.

The most significant aspect of the current PhD program is that it provides training in research and independent study. However, it has serious deficiencies.

Since MSE has always been a highly interdisciplinary field, a significant fraction of students starting PhD work have first degrees in physics, chemistry, engineering, or some discipline other than MSE. It is quite normal to find that many of these students, through no fault of theirs, have little or no conception of basic concepts in materials science such as a stress-strain relation, a dislocation, a temperature-composition phase diagram, a point group, or how a transistor works. And yet many of these students complete their PhD programs and are turned out into the market place without much exposure to many of these basic concepts. Clearly, it is desirable that all PhD candidates in MSE acquire a minimum level of knowledge in MSE before they compete for jobs. This could be achieved by requiring that all such students pass a set of core courses covering the fundamentals and engineering applications of materials. For example, these core courses could be: (i) structure of materials (equilibrium and nonequilibrium aspects); (ii) mechanical properties; (iii) electrical, optical, and magnetic properties; and (iv) applications of engineering materials. Of course, this core course content could be packaged in alternative ways.

There is also a case to be made for a program of more advanced graduate courses which would broaden each student's knowledge of his/her chosen specialty. For example, advanced courses on materials modeling (covering the atomic, microstructural and macroscopic length scales) would be of use to many students, as would advanced courses on the synthesis and processing of metallic, polymeric, ceramic, and semiconductor materials. There are many other possible advanced courses. These advanced courses could be taken at the same time as the student is engaged in research. The core courses could serve as a base for the advanced courses, thereby increasing the efficiency of the teaching.

Other industrially relevant broadening elements include presentation skills (written and oral), project management, quality assurance in research, record keeping, and traceability of records. The PhD project itself could be used as a vehicle through which the student is introduced to project management, quality assurance, and record keeping. Industrial speakers could be invited to deliver lectures on these topics. At Oxford University the Part II project, which is a nine-month research project undertaken as part of the first degree in MSE, has incorporated these broadening elements as requirements. They have met with approval from students and industry.

Several universities in the United States are already providing an excellent range of graduate courses for PhD students in MSE. But many university departments have insufficient staff to take on this additional teaching load. There is also the important point raised by Gregory Moore ["Breadth and Flexibility Prepares Researchers for 21st Century," *MRS Bulletin*, November 1995, p. 8] that many faculty members are apparently not in favor of broadening elements in graduate education. Perhaps more significantly there is the distinct possibility that such a graduate program would increase the time required for the PhD degree. In the United States there is already widespread concern about the existing length of time required to complete a PhD program. In the United Kingdom there is a strict three-year upper limit on funding provided as a student grant from research councils. If broadening elements are to be introduced these questions of resources will have to be addressed. One possibility might be to seek increased industrial sponsorship for PhD degrees. Another, more radical solution, is to reappraise our priorities for the PhD program and give greater weight to these broadening elements. That would inevitably result in less time for the PhD research project if the existing completion times are not to be increased.

Clearly, difficult decisions about educational priorities and the allocation of resources will have to be made if graduate education in MSE is to undergo the reforms we believe are urgently needed.

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