

# Is Current Engineering Education Relevant to the Fundamental Problems Now Facing Society?

David G. Luenberger  
Department of Engineering-Economic Systems  
Stanford University

Many of today's most pressing societal problems, and tomorrow's problems which will be even more urgent, require an approach identical in philosophy to that which has been characteristic of engineering for the past several decades. These complex social problems demand a mode of analysis founded in the logic of science but tempered by experience and good judgment, they demand the teamwork characteristic of a good large organization, and they demand a sincere commitment to obtain workable solutions. This is the philosophy of engineering, yet there is a danger that engineering will not meet the challenge of these new problems unless some significant changes are introduced into engineering education.

The engineering tradition, that of combining fundamental scientific understanding with the willingness and ability to cross over the boundaries of complete knowledge through innovation, intuition, and experience to new situations, is certainly the most important ingredient taught in an engineering school. This tradition is not conveyed directly but instead it is built up in stages by foundation courses in science and mathematics, by specific design and application courses emphasizing modeling and problem solving, and by laboratories. The specific application courses vary among departments, among institutions, and with time. In any one instance they tend, quite naturally, to focus on the aspects of engineering relating to the current problems in the particular field. The laboratories have proved to be an essential component of the engineering curriculum since it is through these that the student learns what it means to formulate

and verify an hypothesis and obtains a feeling for data. This gradually evolved but now nearly universal formula for the education of engineers has convincingly proved its merit in a variety of fields and through periods of changing technology. There is every reason to believe that if directed toward our societal problems it will continue to be as effective.

The changes now required of the curriculum, however, are of a more fundamental nature than we have witnessed previously. Problems faced by engineers have been in constant agitation and change, and our institutions have managed to keep up--indeed, often to keep ahead--of these changes. The difference now is that whereas essentially all fields of engineering in the past relied on the physical sciences for their foundations (there are some exceptions such as industrial engineering), the fundamental problems now facing society have major components outside the domain of these sciences. Thus, these problems even when lying in a physical setting require more than a physical answer. Problems of pollution may be greatly alleviated by the development of new technology, but important dimensions of a total solution are sure to include tax legislation and public awareness. The transportation jams, although eased by the development of new vehicles, will be unsnarled mainly through long-range planning and coordination. Housing programs will be significantly influenced by new construction methods, but the questions of financing and careful social design will determine their real effectiveness. We can expect major innovations in health care through the development of micro-electronic devices that can be implanted in the human body, but in a large undeveloped region the evolution of a comprehensive system composed of a central hospital and several satellite health centers buttressed with good

information and education systems will provide health care where it has not been found before. There is no doubt that students of the future will interact with various computer and television terminals to learn certain basics, but, as education thereby becomes more centralized, the associated planning problems will far outweigh the technical problems of developing the terminals. All of these problems and the others that are being continuously uncovered demand major analysis of nonphysical facets. This is the fundamental difference in today's problems over those conventionally attacked by engineers.

The implication of this to engineering curricula is clear. The foundation base in science must be broadened from the physical sciences to include the social sciences as well. Thus, in addition to the close relationships that we have with mathematics, physics, and chemistry we must develop similar relationships with sociology, psychology, political science, and economics. It will require a major commitment to design meaningful and yet manageable course programs that include these disciplines. Social science departments, quite naturally, are not presently organized in a manner that would make such course structuring straightforward, and there is significant overlap among them. The initiative for this restructuring and for the development of long-term relationships with these disciplines must come, as it did with other sciences, from the engineering school. Social scientists will in many cases be reluctant to develop these relationships--not because of a desire to keep their science to themselves, but because they may feel that they have very little to offer. They, like, many physicists of four decades ago, may feel that the problems we wish to attack are too complex and that their science is too infantile.

In addition to this major change, the purposeful inclusion of social science in the curriculum, there must be corresponding changes in the application and design courses. Emphasis would again be modeling, problem solving, and techniques of analysis. There should be courses in broadly applicable techniques such as optimization, decision analysis, data analysis, and control, and specialty courses in perhaps medical systems, aerospace systems, computers, or urban design. This aspect of the engineering curriculum, although in many respects the most changeable, is the part that is easiest to change. It is this part which has been in constant flux throughout the history of engineering education.

The final indispensable component of an engineering program designed to train engineers for a career in societal problem analysis is an experience akin to that traditionally provided by the laboratory. To some extent experience of this type relevant to fundamental societal problems can be provided through computer projects designed to develop a feeling for handling vast quantities of data and through class solution of pre-packaged problems. But something more is needed. A large societal problem is quite unlike even the most advanced electronic device in that it cannot be displayed in the laboratory for students to study and experiment with semester after semester. Real innovation and creativity will be required to supply this essential component of an engineering education.

The most effective, although somewhat costly, scheme for doing this is the internship program where, rather than bringing problems to the students, students are sent out to the problems. This program has operated successfully in graduate engineering at Stanford with students going to industry, government, or consulting companies for periods ranging from three to twelve months. Through this mechanism they have the opportunity,

after being armed with skills of analysis and being backed up by concerned faculty, to face the responsibility and challenge of a real problem. They later return to the university to build on their experience, redirect and focus their interests, and, incidentally, greatly stimulate their university associates. An alternate approach, that is of lower cost, is to offer project courses where responsibility for a specific job is taken and a student-faculty team work on it together for a semester or two. Another approach is for a practitioner to relate (after-the-fact) the detailed experience of a specific project in a series of seminars. There is real opportunity and real need for creative development of other meaningful laboratory-like experiences relevant to societal problems that can be administered in large quantity.

Some might feel that this broadening of the conventional base of engineering to include social science is too great a step and that the nonphysical elements of important social problems should be addressed by social scientists already expert in these areas. It is true that much of the applied work of this type is already being done by social scientists. Currently, most of the "engineering" of economic systems as, for example, development of national economic policy, is being done by "applied" economists. The same is true, although it is of lesser magnitude, of the social "engineering" being done. This phenomenon parallels that of early applied physical science where, for example, most of the "engineering" of electrical systems was done by physicists. The fundamental question that must be considered, however, is not what specific individuals will enter this new field but rather what specific educational programs will be most relevant to their training. The required philosophy is that of the engineering tradition and hence on this score engineering provides a natural

long-term base. Moreover, engineering has already begun to establish itself, and quite convincingly so in many instances, in the substantive areas of social problems. Engineers are moving from their background in the physical aspects of problems to the broader social considerations of these same areas. For example, in the area of telecommunications where engineers uniquely have command of the associated technological aspects they are beginning to attack the fundamental policy issues that arise in conjunction with the rapid growth of that field. The same is true in transportation, housing, information systems, and a variety of other fields. In the long run, however, this transition to the broader questions of planning and policy must be accompanied by a fundamental broadening of engineering education. If this change is not introduced, it is indeed likely that the need will be satisfied by expansion of the applied social sciences, and engineering then, in the long run, may become isolated from these problems. It seems more likely, however, in view of the overwhelming trend in engineering to seek solutions to societal problems, that the required associated innovation in education will be made.

The change in engineering education will be accompanied by the emergence of a new image of engineering and a new breed of engineer. In the past, engineers have typically dealt with ideas and with things. The engineer of the future, attacking societal problems, will deal with ideas and with people. His training will emphasize mathematics, physical science, and social science and he will understand the engineering tradition. His training in mathematics will be somewhat different than is now typical since it will emphasize structuring of problems involving hundreds or thousands of variables. More emphasis will be given to probability and

more emphasis will be given to discrete rather than continuous mathematics. Physical intuition will give way or be supplemented by mathematical, social and economic intuition. His understanding of people will be enhanced by training in some of the personal-contact skills taught now in business schools, long-established as useful to engineers, but more fundamentally by the inclusion of a strong program in social science.

As the new image of engineering emerges a new kind of individual will be attracted to it. Young students committed to the solution of the fundamental problems facing society, who now often do not see an engineering career as a means to achieve their objectives, will in many cases associate with the new image. Engineering as a whole will achieve a new and greater balance both in substance and in the character of its individuals. Engineering will come to be synonymous more with "applied" and "effective" than with "building" and "invention." Education of these new engineers, aiming toward the important problems of society of today and tomorrow, assuredly will be both rewarding and challenging.