Jimmy Wei

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TOWARD THE DEFINITION OF A NEW ENGINEERING EDUCATION

Sanjoy K. Mitter

The definition of what an ideal Undergraduate Education in Engineering at MIT should be cannot be undertaken without a serious reexamination of the role and function of an engineer in a modern industrial society. This means that the education of an engineer has to be given a much broader definition than is currently done in most engineering schools and also at MIT. In spite of all assertions to the contrary, our definition of excellence in engineering is extremely narrow and we are reluctant to strive for an education which is excellent in the larger arena of competition with the sciences, the arts, humanities and the professional fields (law, medicine, etc.). During the last twenty years (highly accentuated in the last ten years), our attitudes have become increasingly "blue collar" (in the most regressive sense of the term). We wish to produce skilled workers[1] armed with a lot of "know how" and little "knowledge." There is an essential contradiction here since we believe that U.S. industry will be increasingly "knowledge-based," if it is to survive in the international market where it will have to compete.

Coupled with this is the pervasive inferiority complex which the engineering professional suffers from vis-à-vis the sciences and the arts. We take pride in the fact that engineering is essentially derivative and not fundamental. This is reflected in the low esteem that engineers seem to have in the society at large. The New York Times does not devote a front page article to an engineering achievement even though it may do so for some half-baked, ill-conceived theory in physics. The influence of the National Academy of Engineering is miniscule compared to that of the

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[1] This terminology will be increasingly justified as the industrial structure of the United States changes.

National Academy of Sciences. There is no Nobel Prize for any branch of Engineering (significantly, Japan has established something like a Nobel Prize in Engineering -- the first awards went to Shannon and Kalman). The same symptoms are clearly visible in the local scene (although there has been some improvement in recent years). The influence that the School of Science exerts on the general governance of MIT (including education and research, the resources that are devoted to the School of Science) is in my view totally out of proportion to its contributions (even in an absolute sense) and certainly size (say, measured by the number of students). Incidentally, the current state of affairs within MIT is mostly due to the values we choose to emphasize.

It is obvious that the status of engineering and engineers in our society cannot be changed on a time scale which is other than long-term. I believe, however, that MIT can lead in the definition of a new type of engineer by initiating a new program of engineering education, which is truly excellent in the larger sense I have alluded to before and truly "elitist." I outline below some of the elements of such an engineering education.

(i) What distinguishes engineering from the pure sciences (read physics) is that engineering is concerned with synthesis of new systems (invention, synthesis of new laws) and not discovering the fundamental laws of nature which exist and have always existed. This aspect of synthesis, which is captured in a deep way, by the "black box" approach, requires the understanding of synthesis of "elements of a "system" to follow a prescribed behaviour. Problems of approximation of models, dealing with uncertainty in models and in interaction with the environment, understanding complexity are all fundamental aspects of this synthesis question. It requires looking at systems both in terms of its "parts" and as a "whole."

This synthesis viewpoint is deep and should be taught to all students at MIT.

(iii) There are synthesis problems which can be solved by analysis as is customarily done in physics. This is often what is meant by the scientific method. In some sense, the undergraduate curriculum revision of the EECS department under Gordon Brown accomplished this. I believe even this part of the EECS curriculum needs reexamination from a synthesis point of view.

At the other extreme is the synthesis of large software systems. Here even a qualitative conceptual understanding of what constitutes good synthesis is currently lacking. Perhaps these synthesis problems have something in common with global viewpoints present in great art and great literature.

(iv) If this is correct, then the preoccupation of MIT for the last twenty years with the "two cultures" thesis of that mediocre novelist C.P. Snow is totally misguided. What is needed is a humanities education which is not fragmentary, but emphasizes intellectual unity and synthesis. The Renaissance cannot be understood without studying its historical context, its art, its literature and seeing the intellectual threads which bind all this together. The conclusion is that humanities education must have some depth to it and students need to take a coherent set of courses in order to appreciate this depth. Moreover, the new type of engineers we are trying to educate need to have this in-depth humanities education for the obvious reasons and also to obtain, at least implicitly, the global creative view of the humanities.

(v) Of the pure sciences, Biology is the one science which has to be concerned with understanding synthesis--the synthesis of the physiological and cognitive functions. Biology and Cognitive Science therefore become a "kingpin" in engineering education. Therefore a new alliance between Engineering and Biology and the Cognitive Sciences is needed. Moreover, this is very much a two-way communication.

All students need an education in Biology and the Cognitive Sciences.

(vi) Social Science and Economics is currently not at its pinnacle of glory. The reasons for this are undoubtedly complex. To build a foundation of economics and social science which imitates physics must however be questioned. An inward looking, critical but in the <u>negative</u> sense Science, Technology and Society program which is an appendage to the rest of the institute is also not the answer. Our students need to understand the autonomous social and economics forces which shape technology (and of course society), but also need to understand how to redirect and change these processes. Is automation and robotics the answer to all of America's industrial problems? How does one create technology which harnesses the creative abilities of human beings? Surprisingly, this last question was asked to me several times during my recent trip to Japan.

How can one do all this in four years? I see two possibilities:

(i) Not to do it in four years and institute a five-year program in which the first two years will be liberal education in science, engineering and the humanities. In addition to the current freshman year, which needs to be made more rigorous, the second year will be devoted to more Mathematics, Biology (and Cognitive Science), a course or two representing the synthesis viewpoint of engineering (with different departments presenting it in different ways), and humanities. The five-year program allows one to accommodate the depth and breadth that we currently associate with our departmental degree programs. The education of the first two years will allow one to teach the later subjects in a more integrated, sophisticated and deep way (this has nothing to do with the depth/breadth issue).

(ii) A four-year program, with the first two years as outlined, followed by a degree program with an options structure.

There will be some sacrifice in the acquisition of facts on the part of students, but not necessarily the ability to acquire knowledge.

Coupled with this we need to do a number of things:

(a) A significant change in style and attitude on the way we teach is needed. We have to recognize that the ability to solve well-structured homework problems is not an end itself but only a means to formulate and solve complex, unstructured problems. More time is needed for students to reflect and assimilate.

(b) Students should have the opportunity to work with a research group and participate in a design/research project. This should be an ongoing activity for two/three years. It is an essential component of the education and not an overload.

(c) A signal needs to come from all levels of the administration that scholarship, intellectual depth, originality and creativity are the elements which make an institution great. The rewarding of excellence in undergraduate teaching is a derivative issue and not fundamental and only arises because scholarship is not given the recognition it deserves. We have to emphasize that writing proposals and raising funds are not the most important criteria in the reward structure of the institution.