Reforming the Master of Science in Engineering

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Introduction

To place in context the current discussion to "re-invent" engineering education we go back fifty years. World War II disclosed that American engineering education was inadequate to meet the new realities produced by the war. Prior to the war the typical engineering graduate had only a bachelor's degree with very little science beyond the sophomore year. To create the needed advanced technology to wage the war, Ph.D's in science were enlisted to work on undersea warfare technology, radar and nuclear weapons. Then there was Sputnik. Both World War II and Sputnik served as wake-up-calls to the universities to do something about engineering education, that is, a shift in the education of the engineering student to emphasize the science underlying engineering. Not only courses, but research as well, reflected this change.

Beginning in the 1970s through to the present, there was the realization or perception that America was falling behind Japan and other nations in manufacturing and in general, in relating science and technology advances to the market and economic growth. Fault has been placed at the doorstep of engineering education, both graduate and undergraduate.

To deal with present concerns there have been any number of studies as well as articles written on the general theme of new ways of thinking about graduate education. Two important reports on this subject are the report by the National Research Council, Committee on Science, Engineering, and Public Policy, "Reshaping the Graduate Education of Scientists and Engineers, " and the National Academy of Engineering, "Academic Engineering Research in a Changing World: Issues, Problems and Solutions. " Another important report that focuses primarily on undergraduate education but has implications for graduate education is the NSF report, "Restructuring Engineering Education: A Focus on Change." A consistent theme which arises throughout these studies as well as other studies is the recommendation to make the traditional graduate and undergraduate education of engineers more relevant and versatile.

What we wish to focus on in this paper is the Master's level of education of engineers. Alternatives to the Master of Science degree are being discussed. We find discussions of the master's degree as the first professional degree, sometimes referred to as the Master of Engineering or Practice Oriented Masters's degree as an alternative to the Master of Science. There are a number of factors or circumstances dictating the need for reform of the Master's degree, some of which reside with the issue of international competitiveness as well as those identified previously. The arguments go something like this: international competitiveness has created a need for engineers who understand design methodology and concurrent engineering. To prepare engineers for careers in design requires not only learning about these topics, but an understanding of the practice of

engineering and experience in solving problems with realistic industrial constraints. Without linking directly to international competitiveness, there is the feeling that to better meet industrial needs a more practice oriented Master's is needed. Others link the Master of Engineering with the argument that within a 4 year undergraduate curriculum we can no longer properly educate our students to meet current industrial needs. What all of these arguments have in common is the need for education to be more relevant and versatile for industrial practice as has been identified in the national studies.

The arguments tied to design are not the only arguments to be made for the Master of Engineering, In increasing numbers our graduates are being employed in non-traditional engineering jobs, i.e., not doing traditional product/process design, and not being employed in engineering firms. Because society's most important problems, needs and opportunities are being dealt with by non-engineering entities (industries), government and professional services and are forced to be interdisciplinary in nature, the engineer is being called upon to deal with these issues by virtue of his problem solving skills. This does not detract, though, from the view that the Master's student understand the practice of engineering and develop experience in solving problems with realistic industrial constraints, in other words his education to be more relevant and versatile for industrial practice. In addition, the implication or implicit in the new Master of Engineering is that a level of professionalism be brought to the education of our students that may not have been there before.

What then do we make of the Master of Science degree in this new round of discussion going on in graduate education? Where does it fit, and can it undergo changes to fit what appears to be the new realities of the market place? The point of view adopted in this paper is that the Master of Science can and should reform itself to meet the new realities by listening to the arguments for the Master of Engineering.

Current Scene

Let's review the current scene in the education of the Master of Science student. By and large the Master's graduate programs are driven by research. Faculty research contracts, and the institution's focus on the creation of new knowledge are all the ingredients which go into making up the present setting for graduate education at the Master's level (and the Ph. D., as well). By and large the current scene is one in which the education of the graduate student is focused on research, be it for the student who, upon receiving the Master's, continues on for the Ph.D. or who goes into industry.

The fact is that not all of our students who receive the Master of Science degree go into research and development in industry nor are they all going on for the Ph.D. In light of this, and the need to meet industrial needs, I think that it is safe to say that a case can be made for the Master of Engineering degree and that a research degree is not for all students who choose to pursue a Master's degree. There are students, though, who are going onto graduate school with interests in research and hopes to pursue a career in research and possibly academia which would require education for the Ph.D. Surely this will continue into the future, and with this in mine, this paper is written for the Master of Science as its focus.

Reviewing for a minute those arguments being made for the Master of Engineering, and what they share in common, namely, a more relevant and versatile education for industrial practice, or looked at another way, a heightened sense of professionalism, we might ask ourselves if this should be reserved solely for the Master of Engineering degree? Or, can and should the attributes listed above be brought to the Master of Science. The view adopted here is that they can be, and there is a case to be made for it. This does not mean we abandon the research focus of the Master of Science.

Professionalism

If we focus on making the education of the engineering student more relevant and versatile, we need to ask ourselves what this actually means and how do we translate this into the Master of Science. There are two factors which are required: 1) faculty understanding; and 2) program change. Before we talk about program change a key factor in all of this discussion is the faculty and their understanding of the changing market place and what it will take to make the education of their students more relevant and versatile. This is a separate issue and one that is not fully addressed in this paper.

What might program changes be to bring about the needed change? Four areas are explored: 1) communication skills; 2) technical literacy; 3) industrial research; and 4) industrial exposure.

1) *Communication Skills.* This is an issue that has been identified to be addressed in the undergraduate education of engineering students. The practicing engineer is called upon to make verbal presentations, using overheads or their equivalents using the laptop computer, and to communicate through the written word. This is independent of the level of education, be it bachelors, masters, or Ph.D. In the context of education we find our students making verbal presentation in classes. There has been an increased awareness and attention being paid to technical writing, e.g., lab reports, project reports and so on.

At what level, though, are we dealing with communication skills? We still hear complaints about the engineering students' abilities to communicate. How often have we been present at a formal student presentation where the overheads were poorly prepared - small, hard-to-read type, hand-drawn figures and unlabeled axes on graphs. By communicating to the graduate student how to prepare a veiwgraph for a technical presentation, the faculty advisor can go a long way in developing a sense of professionalism in his or her student. It does not require a great deal of time - simply the awareness on the part of the faculty of the importance of the issue and technical presentations. This is but one example in communication skills. Another one in which the faculty advisor could play an important role would be to listen to his or her student before the student made a technical presentation so as to provide proper feedback to the student. I'm sure that this is being done by faculty, so that what I'm saying is not new or revolutionary, but how wide-spread is it? And is it seen as something important in developing the professionalism that is required for the new market place.

2) *Technical Literacy.* For the most part once a student starts to work on a research project, he or she becomes focused and proficient, learning a great deal about the project and subject. After a number of years in teaching, my observation has been that the usual research project/student connection leads to tunnel vision. While the student becomes knowledgeable in the research project and that portion he is working on, it usually is in a limited, narrow area of engineering. Unless the student has the breadth of experience or the faculty advisor makes the effort to place the work in a broader context for the student, the student knows only his project and it is what I refer to as tunnel vision. The consequence of this is that technical literacy is usually limited. In what sense can we enhance the technical literacy of the student so as to provide broader versatility in the student's education.

As an example of what I'm referring to and what can be done, I refer to what we have done at Binghamton. The Integrated Electronics Engineering Center (IEEC) provides a number of core research opportunities for students in electronics packaging. Non-core research projects, outside of the Center, are likewise available to students. Students from various engineering disciplines such as mechanical engineering, electrical engineering, and industrial engineering are engaged in projects leading to the Master of Science. Typically, the research projects are not any different from what we would encounter at any other research

university, that is, the focus on an electronics packaging technology problem. To broaden our students knowledge and vocabulary in electronics packaging, we've introduced a one-credit seminar course. The objective of the course is to broaden the student's vocabulary in electronics packaging. The idea for this came from discussions with industry researchers. A mix of university faculty and industry lecturers present talks on packaging topics that do this. Of course it's not just vocabulary that is offered but a broader perspective on electronics packaging. The student is now in a position to see where his or her work fits in a broader context. The success of this approach can be measured by student response to the course, their ability to "speak" the language of electronics packaging and the interest shown by industry in our students.

3) Industrial Research. There has been a large gap between university research and industrial research. The opportunities, though, for graduate students to be involved in industry driven research is increasing. Witness the increased opportunities through university/industry consortia and engineering centers that link universities with industry, opportunities to work on industrially relevant projects at the National Institute of Standards and Technology, and federally funded programs such as the NSF Grant Opportunities for Academic Liaison with Industry (GOALI). The GOALI program provides faculty members and students with short-term research experiences in industry as well as collaborative research projects between academe and industry. The latter allows engineers from academe to conduct fundamental, long-term research in conjunction with the more applied research work done by industrial partners.

The case to be made for industrially driven research is the context in which the work is usually placed. While the GOALI program would actually place the student in an industrial setting and all the benefits that would accrue from this experience, the range of research experiences identified above are likewise enriching experiences for the student. Through industrially driven research on the Binghamton campus, our experience indicates that the student's appreciation for industry has been enhanced, and the student, in general, behaves in a more professional manner. Over each of the past several years between 25-30 Binghamton students have pursued their MS or Ph.D. thesis research at Universal Instruments Surface Mount Laboratory. A word of caution is necessary when we talk about industrial research applied towards thesis work. It must satisfy the criteria set forth for a Master of Science thesis, and not simply be a project that does not forward the basic knowledge or understanding of a discipline.

4) *Industrial Exposure.* While industry research opportunities are improving for graduate students (as well as for faculty) and their access to them, the opportunity for the student to work in industry during his or her graduate program is also becoming available. The GOALI program is again an example of a program that offers students this opportunity. Through the faculty and students in industry program, faculty members as well as graduate students work full time in industry, anywhere from two months to two years. The latter would probably be more applicable to the Ph.D. candidate, with the shorter period for the Master's candidate. The GOALI grant covers a portion of the participant's salary, with the industry partner picking up the rest. Participants also have the option of working on an industrially relevant project at the National Institute of Standards and Technology. In either case, faculty members have the opportunity to learn about new areas of research and current industrial problems-information that could be passed on to students. Graduate student participants benefit by receiving hands-on research training in industrial work.

The GOALI program is not the only way for a student to obtain industrial exposure. The 30 or so Binghamton students who have completed their thesis research at Universal's Surface Mount Laboratory received finding on research grants supported by Universal. By having the students do their thesis work at the industrial site relieves the University of the burden of maintaining a laboratory at the financial level that an industry could support. Moreover, the industry has the financial resources to not only maintain but also to

upgrade the lab facilities that would be a challenging effort for the university. Consequently, it is a winning proposition for all parties - the students, who gain industrial exposure, and work on industrially sponsored research, as well as work with state-of-the-art equipment; the faculty advisors who likewise have the opportunity to learn about new areas of research and current industrial problems; the industry who has access to young, fresh, motivated talent (the students); and lastly, the university.

Summary

While the arguments are compelling for a Master of Engineering or Practice Oriented Master of Engineering degree, it is not clear that it will supplant or replace the Master of Science for all students who wish to pursue an advanced degree. This, of course, would change if the proponents of the view that the Master of Engineering be the first professional degree prevail. Then, in my opinion, the role of the Master of Science degree is re-opened for discussion.

The view adopted is that the Master of Science can and should be reformed in light of new market realities, and that attributes of the Master of Engineering can be brought to the Master of Science. This does not mean that there isn't a place for the Master of Engineering degree as well. Four areas of reform are discussed: 1) communication skills; 2) technical literacy; 3) industrial research; and 4) industrial exposure. In all four areas examples are given to demonstrate what can be brought to the Master of Science program.

Would there bean added cost to the program? Not really. Depending on what would be adopted for industrial exposure, there could be an increased length of time of study, but here again it would be specific to the approach used, and it might not increase the course of study.

A key element to the whole discussion is the faculty and their recognition of the need for change.

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