AC 2007-1388: AN ICONOCLASTIC VIEW OF GRADUATE EDUCATION: THE 4+1 PROGRAM, AN ACCELERATED ROUTE TO THE MS DEGREE

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An Iconoclastic View of Graduate Education
The 4+1 Program: An Accelerated Route to the MS Degree

Abstract

Graduate engineering education is a key to the maintenance of U.S. competitiveness in the world market. The world has been an extremely dynamic engine during the last fifty years, and we have witnessed a dramatic change in the world order. The change has been evolutionary in many cases, but events in Eastern Europe, Asia, the Middle East and the erstwhile Soviet Union are only slightly less cataclysmic than the events associated with the Second World War. In a world where strength is measured in terms of the financial resource, the technological ability and the intellectual capability of a populace, Japan, China, India and the EEC are poised to make further strides, while the U.S. is slipping when measured by a number of economic and educational indicators

The U.S. and the world face serious challenges - challenges of social, technological, and economic nature. A poorly-kept secret is that engineering capability is crucial to the resolution of these problems! Engineering pervades our environment, it is our personal companion from a few days after we are conceived until we die - it is a life prolonging, life enhancing endeavor. Engineering is certainly the solution to the technical problems civilization faces, it is also the solution to many of the social challenges confronting society on local and global scales.

This paper describes the development and implementation of the 4+1 blended, dual-degree program offered in the College of Engineering. This program destroyed many of the myths which surround graduate education, and provided it as an immediate option to a greater public. This program was designed to fill the needs of students, the needs of society and the needs of industry. Five-year undergraduate degrees, often touted as means to the same end, financially penalize the student and place the school at a competitive disadvantage. The 4+1 provides a win-win situation for all participants, and has been strongly supported by students, faculty and industry. The program has dramatically increased the number of students pursuing advanced degrees at our primarily undergraduate institution.

Introduction

Graduate engineering education is a key to the maintenance of U.S. competitiveness in the world market. The world has been an extremely dynamic engine during the last fifty years, and we have witnessed a dramatic change in the world order. The change has been evolutionary in many cases, but recent events in Eastern Europe, the Middle East, China, India, Japan and the erstwhile Soviet Union are only slightly less cataclysmic than the Second World War. That war set the economic order for the 1940's, 1950's and 1960's. After 1945, the Soviet Union was a nation in ruins, a nation that had lost over 20% of its' population in a conflict fought largely on its' soil. It faced the challenge of an arms race with a United States that had, comparatively, escaped the ravages of war, had emerged as the leader of the free world and had discovered a way to make defense spending spur the economy. Arguably, the collapse of the Union was the result of Soviet participation in an arms race they were destined to loose. Eastern Europe was ravaged by war,

conquered and controlled by an oppressive foreign power. Western Europe was in disarray, most countries had been occupied, all had been severely drained by effort during the war. Germany and Japan were occupied nations, totally controlled by outside forces. China, devastated by years of Japanese control, was racked by civil war. On this stage, America developed into an unrivaled economic power, producing nearly 40% of the "world GNP" with less than 10% of its' population.

The stage has changed! Part of this change is an inevitable realignment as countries recovered after the devastation that characterized the years 1937-1945. However, part of the change is also caused by policies followed by governments, by multinational companies and by individuals. Today the Pacific Rim is dominant, the European Economic Community is a viable force, and China and India are becoming our chief economic rivals, and not coincidentally our chief technical rivals as well. In a world where strength is measured in terms of the financial resource, the technological ability and the intellectual capability of a populace India, China, Japan and the EEC are poised to make further strides. It is ironic and telling that while writing this paper I can look at the underside of various components of my computer to check the spelling of Asian and European country names.

The U.S. and the world face serious challenges - challenges of social, technological, and economic nature. A well kept secret is that engineering capability is crucial to the resolution of these problems! Engineering pervades our environment, it is our personal companion from a few days after we are conceived until we die - it is a life prolonging, life enhancing endeavor. Engineering is certainly the solution to the technical problems we face, it is also the solution to the social challenges confronting us on local and global scales.

BS Engineers - Birds in Gilded Cages

The plight of engineers with BS degrees is viewed as enviable by most other college graduates. As engineers we know it is an earned situation. BS engineers command high salaries *vis-a-vis* their counterparts in other majors. The engineering curriculum is usually more extensive and more intensive than other curricula, and the BS engineer provides an immediate and valuable service to their employer. Graduates in most other disciplines are aware that furthering their careers, to their own and their employers benefits, will require that they go on to a professional or graduate school of some sort. Only engineers are thrust into the professional spotlight after exposure to a BS degree. The rigorous program, coupled with the siren song of financial well being and the surprising lack of awareness many students have of their options, creates a situation where few students go into graduate programs. It is a sad commentary that the best recruiter of American engineering graduate students is an economic recession.

Today, American graduate schools are often heavily populated by bright, hardworking foreign-born students. In the past, these students stayed in the U.S. after graduation, became citizens, and have greatly advanced the engineering infrastructure in this country. Now, many of the students choose to return to their native countries, taking their expertise with them, the incipient "brain-drain" is flowing against us. It is critical that we increase the number of engineering graduate students who will stay in the U.S.

Myth and Truth

The first thing engineering educators must do is make students aware of their options. Educators must examine the root causes of the poor matriculation rates for American graduate students. There appears to be six main reasons that students actively avoid graduate school in engineering. These reasons are underpinned by a pervasive and enduring mythology that diminishes the lives of some of our students. The first is that there is a financial penalty for those who attend graduate school. The second, they are not sure that their academic performance as undergraduates places them in competitive positions for graduate school. Third, they believe it will cost them thousands of dollars to continue their education, in tuition and living expense. Fourth, they believe it limits their future career options. Fifth, they believe it is much better to go to work, and then return to grad school. And finally, students are afraid of academic "burnt-out" after their undergraduate degrees, and need a change in environment.

To address these in turn. First, no investment one makes in themselves has a better return than graduate education. Examining the data for average salaries of degreed engineers over the course of their lifetime available in NSF technology indicators publications one finds that an MS degree is worth an additional $250,000 over the course of a lifetime, a Ph.D. five times that. Furthermore, this graduate salary differential is increasing as a function of time. Engineering students must be made aware of their options and of the value unique to their engineering degree. Second, there are many roads to the graduate degree, graduate schools weigh many factors in selecting students and GPA is but one of them. By virtue of their interests and initiative, the content of their senior projects or the experiences they have in summer jobs, students can make personal connections with faculty who seek graduate students. Faculty members can forgive a fraction of a grade point if the student is genuinely interested and informed about that faculty's program and prior publications. Students with variegated academic records can survive, even prosper in graduate school. Professor's undergraduate academic records are like fine wine, they seem to improve with age. Third, the refrain "I can't go deeper into debt, graduate school is too costly", flies in the face of what we have discovered about salaries. Furthermore, students typically get paid (albeit modestly) to go to graduate school and the tuition is usually waived. Students cannot afford not to go to graduate school. Fourth, graduate school enhances job opportunity, in terms of financial reward, work challenges and advancement opportunity. It provides a vertical and horizontal mobility undreamed of by those with BS degrees. The image of the narrow, self-absorbed, absent-minded Ph.D., trapped in a research crucible is a cultural bromide that has little basis in fact. A Ph.D. in particular is a springboard to other careers. Engineers can become doctors, politicians, journalists, entrepreneurs, the advanced degree is an enabling background. Fifth, in a perfect world, working before graduate school would under-gird an excellent graduate experience. However, to paraphrase a famous quote, *grad school delayed is often grad school denied*. As engineers work, they become accustomed to cash flow, and they form entanglements that often prevent them from returning to school to further their education. Finally, graduate school is a totally different environment from that encountered previously by the undergraduate. The freedom associated with the experience, and the personal responsibility it implies is an unmatched growth experience for many students. For the first time they have the opportunity to "do it right". They are able to dive into a topic deeply, and pander to their own intellectual curiosity. They begin to segue from student to a professional intellectual colleague.

Filling a Need

Cal Poly, San Luis Obispo is a member of the California State University System. The campus is involved in joint Ph.D. programs, but does not offer a Ph.D of its' own. The School of Engineering offers comprehensive masters degrees, and has a total population of about 320 graduate students (the undergraduate population is about 4800). Cal Poly is renown for its' laboratory intensive, hands-on approach to education. Faculty teaching loads are high, and the commitment to the student is legendary. The senior project is still the capstone to the undergraduate experience, the school is unique in its' heavy commitment to the liberal arts component of a college engineering education. Unlike most other CSU campuses, which are located in areas of high population density, Cal Poly is rural. Thus, the majority of CENG graduate students are full-time, only a small pool of part-time students is available. For this reason, Cal Poly is focused on filling the needs of full-time MS candidates.

The Council of Graduate Schools in the United States presents the following statement: *"Master's programs are intended to answer the personal needs of the student and the special needs of society that are not satisfied by* the *Baccalaureate program - needs that can only be met by more advanced and specialized study in a particular field. Candidates need such programs to prepare for scholarly or professional careers or perhaps merely to slake a thirst for further knowledge. Society, in turn, has a need for scholars, scientists, teachers, and professionals in a multitude of fields, and for generally well-educated men and women whatever their walk of life*." This is an excellent definition, it implies a matching of needs and a win-win situation for the degree candidate and the society that will place value on their education. As academics we must recognize these needs and strive to find suitable candidates for our graduate programs and to match them to societal demand.

Does the need exist? Employers occasionally lament the "lack of preparation" that characterizes a newly graduated B.S. engineer. Some employers see this lack in terms of well defined professional skills, others in terms of writing and communication skills, still others in terms of a lack of "interdisciplinarity". What can we ask of a four year program? One response is to keep adding material to a curriculum, to create a *de facto* five year degree. Another response is to retreat into specialization at an early academic stage. In the former case graduates leave school knowing less about more than nascent graduates have ever known. In the latter case, students careers, in the long term, are crippled.

Engineering curricula are expected to provide for a greater depth of specialization, increased design and manufacturing skills, more extensive "hands-on" capabilities, a better background in the liberal arts and a solid grounding in managerial skills for their graduates. It is clear that society does not want trained engineers, who can only cope with well defined technical problems. Society demands engineers who are educated, who can cope not only with technical problems, but with less defined interdisciplinary problems in a social context. Industry is firmly grounded in its ability to draw upon technical innovation. The National Science and Technology Council has reported that science and technology have generated about half the productivity growth the United States has enjoyed over the last fifty years and created millions of high-skill, high-wage jobs. The Department of Commerce estimates that information technology industries have contributed more than one-third of the growth in real output for the economy over the last

four years. The future depends on our ability to sustain scientific and technical progress. To do this we must meet the growing demand for the highly trained science and engineering workers whose knowledge and inspired work make continued progress possible.

The Cal Poly Baccalaureate degree is a perfect segue not only to employment, but to advanced study as well. The same factors that make graduates so attractive to industry, make them attractive in graduate or professional schools as well. Many students could benefit from an applied masters degree, a masters of professional practice if you will. This is one goal of our 4+1 program, which will be described in detail below. The undergraduate curricula includes a vigorous hands-on and extensive liberal arts education. In place of the senior project, the student substitutes a thesis, in many cases based on a project growing out of an internship with industry. Currently students take 192 to 202 units (quarter) and receive a BS, for 235 to 240 units, with a restructured undergraduate curriculum, students receive a masters degree. This program is cost effective for industry, for the student and for the university.

In addition, the Council also states "A college or *university should initiate a Master's degree program only when a demonstrable need exists and when the institution's resources and special traditions insure it can* provide a *program of merit."* This statement reinforces the emphasis on matching needs - an implied contract. In addition it also introduces the concept of quality. How should quality be measured? Unfortunately, many institutions develop a reputation for quality based on admissions, defining quality in terms of who is turned away! Others choose to define quality in terms of professional surveys of dubious statistical validity. Some accreditation is done at the graduate level, but the consensus opinion of engineers is that this procedure, critical at the undergraduate level, is not appropriate for Master's programs. The major difficulty arises in developing criteria for judgement, people can develop a consensus on what is not appropriate - a consensus on what is proper is more elusive. A pragmatic definition would indicate that a good Master's program is one that prepares its' students for their next career step, whatever that may be. If a student decides to enter a Ph.D. program, the Master's degree should speed them on this path, if the student chooses to enter industry, they should go in with an added value that is recognized by employers (salary). The Masters program should enhance the technical capability of its' participants (curricula content), must involve participants in practice related experience (providing an apprenticeship, a gentile transition from academia to industry) and should provide an infrastructure for a rewarding, lifelong participation in society (educational animus). The first precept is central to content, the second for participation and the final the animus of graduate education.

A Mechanism, the 4+1 Program

The 4+1 program in Engineering actually had humble beginnings. It grew out of the observation that many good engineering students lingered several quarters before they graduated, taking few units and either finishing their senior project or finishing several general education and breadth classes to satisfy their graduation requirements. We surveyed these students, and asked if they would be interested in earning credits toward a master's degree while working on these other tasks. We also surveyed our industrial partners, asking if they would value students with MS degrees over those with BS degrees. Both groups answered yes, and the 4+1 was born. *A priori*, the program had three objectives:

- Provide an accelerated route to an empowering terminal professional degree for students who intend to become practicing engineers. A degree which not only retains the strong laboratory emphasis and industrial interaction found in the BS curriculum, but which also provides an attractive, efficient educational option to undergraduate students.
- Provide an accelerated route to job-entry education for the more complex and evolving interdisciplinary areas of engineering, such as research and development, innovative design, systems analysis and design, bioengineering, manufacturing, mechatronics and engineering management.
- Provide an accelerated route to preparation for further study in engineering, leading to the Doctor of Engineering or Ph.D. degree.

Definition of the 4 + 1 Program

The 4 + 1 Program is an accelerated route to the professional degree. In many evolving technical areas, four years is not enough time for the formal education of an engineer about to enter a lifelong career of professional practice, even when the individual is committed to life long learning. The 4 + 1 program started in the General Engineering program in 1998 and now allows General Engineering, Aeronautical Engineering, Mechanical Engineering, Electrical Engineering, Industrial Engineering, Manufacturing Engineering, Computer Science, Computer Engineering, Civil and Environmental Engineering, and Materials Engineering students to progress toward the terminal applied MS in Engineering degree appropriate to their interests, or in existing specializations in Biochemical Engineering, Bioengineering, Biomedical Engineering, Integrated Technology Management, while still undergraduates. In addition to the program delivered through the MS Engineering, the Aeronautical Engineering Department, the Mechanical Engineering Department, the Computer Science Department , the Electrical Engineering Department, and the Industrial and Manufacturing Engineering Department offer 4+1 programs leading to MS Degrees in their respective programs. Each of these programs enables students to earn both a BS and an MS degree in five calendar years. Many students are able to create hybryd programs, which allow them to earn a BS and an MS degree in different disciplines.

The 4+1 program allows students to double count units for both the BS and the MS degree, and in some cases, to eliminate the senior project requirement. The purpose of the senior project is accomplished through the MS thesis requirement. The 4 + 1 student is allowed to earn graduate credit for several of their senior electives, effectively decreasing the summed unit requirement for the two degrees. The scheduling flexibility provided by the 4 + 1 program enables students to complete their degrees in the most efficient manner. Students may double count four to eight units, depending on the undergraduate program and their committee requirements, subject to a discrete unit total of 231 units (186 unit BS and a 45 unit MS). The forty-five units applicable to the MS degree must be at the 400 or 500 level. Thus a student in General Engineering could count one four-unit 400 level course and one four-unit 500 level course (or two four-unit 400 level courses, or two four-unit 500 level courses) toward requirements for both degrees. Again, there must be a minimum total of 231 discrete units in any 4+1 students program, requirements for particular programs, and thus the number of double counted units allowed, will vary. There

must be a minimum of twenty-three 500 level units in the graduate formal study plan. Students may begin double-counting in the quarter they were accepted into the 4+1 program.

Joining the 4+1 Program

Participation in the program is based on prior academic performance and other measures of professional promise. Students are admitted by a faculty committee, chosen on the basis of the student's area of interest. Participating students must maintain a minimum grade point average (GPA) of 2.5 in their undergraduate work, and a 3.0 GPA in courses applied to their graduate program. Students are not required to go through the normal graduate admissions process.

Prospective 4 + 1 students should develop a tentative study plan, in conjunction with their advisor, as early as the end of the second quarter of their junior year. All 4+1 students must complete a thesis. The thesis serves as the capstone experience for the program and obviates the need for the student to complete a senior project. In addition the thesis fulfills the requirement for the MS degree, and is part of the total unit requirements. The program allows the student to complete a more meaningful capstone experience, linking the classroom experience to thesis work. Furthermore, this arrangement increases a student's possibilities for industrial interaction in their professional program.

Application Procedures

Students apply for the program as early as their junior year and as late as one quarter prior to earning their BS degree. A 2.5 minimum GPA is required of all applicants – this requirement can be satisfied by the grade point average earned over the last sixty units students have taken prior to application to the program, or by the students overall grade point average. Before formally applying to the 4+1 program, students should contact the graduate coordinator for their program of interest. To apply for the 4+1 program, students complete a CSU Graduate Application, a Change of Objective Form and a Graduate Formal Study Plan. They then submit these, with a brief statement of purpose, to the graduate coordinator in their program of choice. These documents are reviewed by the Graduate Coordinator and the program's Graduate Admissions Committee. The necessary forms are available in the pertinent program /department office. The study plan should clearly identify those units the student intends to apply to both the BS and MS degrees.

After acceptance to the program, the student will develop a thesis proposal with the student's graduate advisor. The graduate advisor is a faculty member the student chooses, and who agrees to be the students advisor. This person also serves as the chair of the student's thesis committee. Students accepted into the program receive an acceptance letter from the graduate coordinator with copies sent to the department head and to the university records office.

Gaining Graduate Status

Graduate status is attained when the student has completed the number of units required to earn the BS degree in their undergraduate major, or 180 units at the students discretion. For example, a General Engineering student attains graduate status when they have completed 180 to 190 units which appear on their undergraduate study plan and/or their graduate study plan. Note that this

does not imply that they have completed the requirements for the BS degree, just that they have completed an equivalent number of units on-program.

The students graduate coordinator and advisor will track the students progress, and notify the Records Office when the student has passed this milestone. At this time the student officially becomes a graduate student, and their registration and financial aid status are changed. Graduate students gain priority for registration, but loose eligibility for some financial aid programs which are limited to undergraduate students. Students with graduate status who are participating in the 4+1 program must maintain a 3.0 GPA. They are subject to all other requirements for graduate students listed in the catalog.

Graduation

The 4+1 student, on completing their approved program of study, will petition for both the undergraduate and graduate degrees, and receive both at the same graduation ceremony.

Parachutes

The student may elect to terminate their participation in the 4+1 program at any time. Students must then complete all catalog requirements for the BS degree, including the senior project. Programs may allow students to apply effort completed on the thesis requirement to count toward the senior project requirement. The student who terminates the 4+1 program and then decides to return for a graduate degree must reapply for the graduate program and complete all requirements for the graduate program listed in the catalog.

Summary and Key Features

- Students are admitted based on catalog requirements for GPA. It is not an honors program. It does not prohibit a department from having an honors program, but the 4+1 program is itself not an honors program.

- Students are not necessarily required to do a senior project in this program. The purposes of a senior project are fulfilled by the thesis requirement. All 4+1 students are required to complete either a senior project or a thesis. If a student terminates participation in the program before attaining both degrees, thesis units can be used toward the senior project requirement necessary to complete the BS degree.

- The 4+1 program is only available to students enrolled as undergraduates at the University.

- Students receive both degrees at the same ceremony and at the same time. Degrees are earned in parallel, not serially.

- Students achieve graduate status when they have earned the **number** of units required for a BS degree in their major on their program. Note that it is the number that triggers this status, it does not imply that all requirements for a BS degree have been met. Graduate

status has several implications – for example it affects capture status, it affects library status and it affects financial aid status.

- Students are allowed to "double count" units. Students are required to earn a minimum of 231 (186+45) discrete units to earn both degrees. Other units may be double counted to fulfill requirements for both degrees. A minimum of four units must be allowed for double counting, the maximum double counting allowed is at the discretion of the department / program subject to the 231 unit requirement.

Conclusion

The 4+1 blended dual-degree program offered in the College of Engineering fills the needs of students, the needs of society and the needs of industry. Five-year undergraduate degrees, often touted as means to the same end, financially penalize the student and place the school at a competitive disadvantage. The 4+1 provides a win-win situation for all participants, and is supported by students, faculty and industry. Data to this point demonstrates an increase in the number of students attending graduate school and a marked increase in the salaries received by MS graduates. Furthermore, surveys indicate not only a high student satisfaction with the program, but a high employer satisfaction with the program as well.

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