AC 2008-1567: A REVIEW OF THE 4+1 ACCELERATED MASTERS DEGREE PROGRAM:STUDENT AWARENESS PRESAGES STUDENT OPPORTUNITIES

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A Review of the 4+1 Accelerated Masters Degree Program: Student Awareness Presages Student Opportunities

Abstract

The 4 + 1 Program is an accelerated route to the professional masters (MS) 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 1996 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.

This paper describes the implementation of the 4+1 blended dual-degree program offered in the College of Engineering, and the outcomes it has produced for students. This program was designed to fill the needs of students, the needs of society and the needs of industry. Ten years after its formal implementation, results indicate that the program is achieving many of its goals. Data indicates that 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. Data presented in the paper also show that the program has met its original objectives, to provide an accelerated route to an empowering terminal professional degree for students who intend to become practicing engineers, to provide an accelerated route to job-entry education for the more complex and evolving interdisciplinary areas of engineering, and to provide an accelerated route to preparation for further study in engineering, leading to the Doctor of Engineering or Ph.D. degree.

Introduction

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.

Currently a detachment exists between engineering graduate education and engineering practice. This is neither a chance occurrence, nor one that happened recently or rapidly. Rather, in the U.S. it developed over five decades of emphasis on the development of an academic research base, focused in science. Investing in science was a wise and critical action to take, and that investment should be maintained. However, a glaring economic challenge exists because the nation did not place a symmetric emphasis on engineering graduate education. There has been strong emphasis on discovery, but innovation has been a poor stepchild. Again, this is not a new phenomenon, scholars of technological history have told us that there has been an asymmetric investment in and reliance on discovery, with an implicit assumption that innovation will follow immediately and naturally. In fact, many assume that the words are synonymous. "*From Bacon's time to the present, more than 350 years, promoters of the sciences have convinced their patrons that science is the way to truth and that it is also the chief source of the progressive inventions that have changed the material world. The myth that the knowledge incorporated in any invention must originate in science is now accepted in Western culture as an article of faith, and the science policies of nations rest on that faith.*[1]"

The nation's requirements for technology development, and the need to educate engineers who will enable this technological growth require universities to rethink the educational paradigms which have shaped engineering education for the last half century. The position of the U.S. in the 21st century will rely on a continuous supply of well-educated, professionally-oriented engineers in addition to those educated in the traditional research-based graduate programs leading to the Ph.D. degree. Graduate engineering education in the United States nucleated epitaxially upon the template employed by colleges of science. These templates were developed in reaction to a report prepared in 1945 in reaction to experiences during World War II[2]. Engineering graduate programs grew mimicking these structures and developed policies typical of the colleges of science. This cookie-cutter approach neglects a basic difference in the philosophies of science and of engineering. Admittedly, the distinction between science and engineering is often blurred, and some of the very best of engineers and scientists are tantamount to indistinguishable. However, science is typically driven by discovery, and its main output is information, whereas engineering is driven by creation and its main output is innovation.

A key word for science is discover, and the result of a scientist's work is a "fact". Scientists might ask how, what or why about something they observed. The engineer is attempting to innovate - to use these "facts" to benefit society in some way, and that society recognizes the value of the innovation by purchasing the tangible product that the engineer develops. The engineer would probably ask what challenge does society face that I can use a fact, typically in consort with other facts, to address. They would also be concerned about the practicality of the approach. The public generally feels that engineering is a process characterized by certainty rather than its true, deeply subjunctive nature. Engineers are seen as a commodity, a tool to be used to implement an imposed solution rather than a partner in identifying the solution. Engineers are often brought to a situation to do things right, when their real value lies in the determination of doing the right thing. Engineering is a intensely creative process, where the identification of a problem is a crucial as its resolution. It is a process where the optimal solution is identified from a large set of possible solutions by taking constraints into consideration. Engineers are a key to innovation, their exposures and inclinations prepare them to recognize opportunity, and to understand what agencies must be assembled to seize the opportunity.

Engineers are becoming a scarce and valuable resource. Engineers are professionals who are rewarded for performance more than seniority. As such, life-long-learning is critical to engineers because of the dynamic nature of their profession. Any activity that improves an engineer's ability to adapt to a changing technological landscape is valuable. Some of these activities include participating in training courses, or continuing education experiences from universities or professional organizations and on-the-job experience. Engineers typically enter the workforce with a BS degree. One way to enable their life-long-learning skills is to expose them to graduate engineering education directly after their bachelors degree. There is a need for a professionally oriented MS program graduates who are focused on innovation and implementation. The 4+1 program was developed with just this in mind. It is a program which benefits the student, benefits the faculty who are implementing the program and benefits the society which the graduates serve. The graduate degree provides students with unprecedented vertical mobility and horizontal flexibility in their careers and underpins the success of existing corporations and the development of new industries. Some evidence exists that the MS degree is becoming the preferred degree for entry into the engineering profession. Indeed, the American Society of Civil Engineers has legislated that an MS degree will be a prerequisite for professional licensure beginning in 2009[3] and the National Academy of Engineering (NAE) has also suggested that the MS degree should be considered the entry level degree for professional practice of engineering[4].

The 4+1 Program

Promoting the graduate school option at our institution has been particularly daunting, as we have a long culture of educating baccalaureate engineers who enter industry immediately after graduation. In fact, until a decade ago, the graduate student population at the college was less than two percent (2%) of the total student population, and this was the largest graduate group at the university! Currently, the graduate population is about 8%, but the population is not evenly distributed among departments. Some programs have populations nearing 25%, some of these with intents to go to greater numbers.

Graduate numbers have been increased in these departments because the departments have made a concerted effort to inform students and to raise the level of their student's aspirations. There has been a campaign to enlighten students by destroying some pervasive myths that discourage our talented student pool from matriculating to graduate programs at our university or other universities. These myths are that graduate education is an altruistic effort that diminishes your lifetime earnings, that only students with *magna cum laude* grade point averages should apply or would be considered, that tuition and living costs will force students further into debt, that graduate education limits your career choices and opportunities, that working before going to grad school is the best option, and that the graduate experience is simply an extension of the undergraduate experience. We make sure the students are aware that:

1. Few investments one makes in themselves have 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.[5]

2. 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.

3. Students typically get paid (albeit modestly) to go to graduate school and the tuition is usually waived.

4. Graduate school enhances job opportunity, in terms of financial reward, work challenges and advancement opportunity. It provides a vertical mobility and a horizontal flexibility undreamed of by those with BS degrees.

5. 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.*

6. 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 can be intoxicating.

Mechanism

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. In these cases, 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. Note that the entry level requirement is purposefully held to a lower level than is usually associated with graduate programs. This is in recognition of two facts, first, grade inflation has not yet stricken all departments at our institution. Second, the MS degree is becoming the entry level degree for those entering professional practice and must be made more accessible. Students are not required to go through the normal graduate admissions process. 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 student's 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.

Assessment of the 4+1 Program

The College recently completed an external review of the masters programs in the college. The reviewers found that the MS programs are supported by both faculty and students. They found that students particularly appreciated the 4+1 program. The reviewers had a number of concerns, some particular to the 4+1 program. These concerns were:

a. *The 4+1 program is popular among the students and the faculty. It provides a relatively easy way to attract students into the graduate programs. Students choose it because it allows them to remain at Cal Poly, they are familiar with the system, the faculty, and already have housing and a social support system in place. On the down side, the 4+1 program blurs the lines between being an undergraduate and graduate student. Students and faculty are unclear when the transition is made. They are treated more as super seniors.*

b. *Students felt that the number of undergraduate students (many 4+1 students) taking 500 level courses during their senior year influence the classes negatively, making them more like senior level classes rather than graduate level classes. Missing were the rigor and graduate level discussion appropriate for 500-level courses.*

c. *There appear to be differences between MS program requirements and policies among departments, and even within a department. Clearly, some differences between departments are expected, but others may lead to confusion. For example, the number of units which are "double-counted" (for BS and MS in a 4+1 program) does not seem to be consistent among departments. Requirements of culminating experiences also vary from department to department. These differences make it difficult to compare program quality across departments.*

d. *Many of the students complete a project in place of doing a thesis. Many of these projects are industry sponsored. Especially for 4+1 students, the project is more like a super senior project as opposed to true graduate level research. There is little originality in thought in many of the projects. While most of these students will work in industry and this will be a terminal degree for them, the lack of a thesis reduces the quality of the graduate student experience. Furthermore, for the small fraction of students who choose to go on to a doctoral program, a true thesis will indeed be required.*

Most of these concerns can be traced to the vision of appropriate graduate education derived from the report referenced earlier. The model this vision produced is suitable for first-tier theoretical science education, and the paradigm for graduate programs developed on that basis. A subtle elitism and a cookie-cutter mentality is evidenced in some of the criticisms of the 4+1 program at this institution. To address these in turn, it is the intention of the 4+1 program to blur the lines between graduate and undergraduate programs, and thus make them more penetrable, particularly by non-traditional but well qualified students. Unless the real concern is the size of the class, rigor in the classroom is an artifact of the activities of the professor and of the participating students, thus, this criticism may be a self indictment. Differences in policy between departments should be encouraged, it is an artifact of the differences in outcomes desired by the faculty. The final criticism is again underpinned by the vision of graduate education which grew from the Bush report[2]. It recognizes originality in developing facts, but not in implementing facts to solve a pertinent problem, innovation.

Student Enrollment

The graduate enrollment has increased greatly over the life of the program, with a disproportionate, but appropriate share of this enrollment in those departments which have embraced the 4+1 program. Figure 1 shows the growth in graduate enrollment during the last decade. Clearly, the 4+1 is meeting the goal of increasing the graduate enrollment in the college. The total enrollment is still a small fraction of the total, but it is focused in the three departments that aggressively offer the degree.

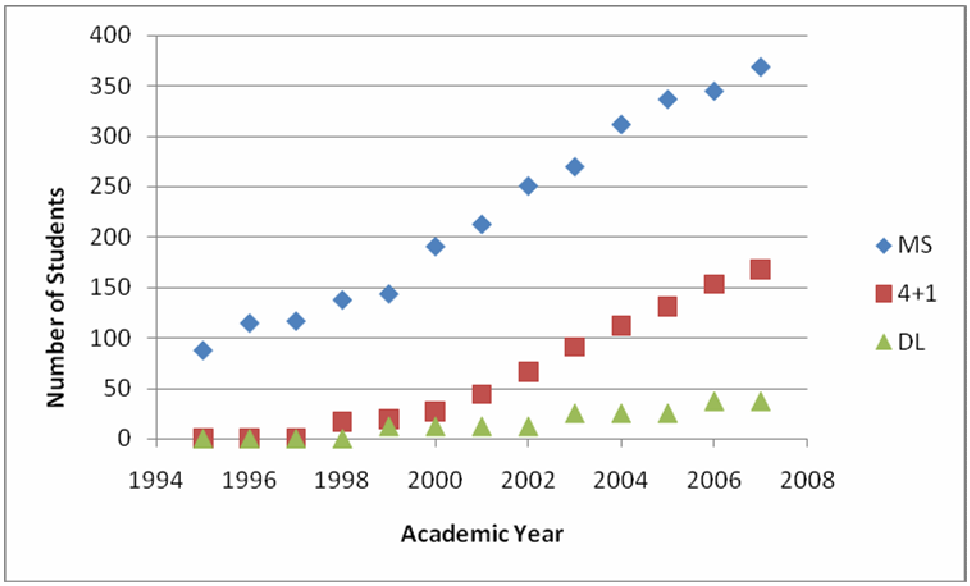

Figure 1. Graduate Enrollment 1994 through 2007

Student Employment

Student salaries are an excellent indication of demand. There is a wide scatter in starting salaries, and a wide scatter in current salaries of 4+1 graduates. Much of the scatter can be attributed to the variance between the disciplines involved, starting salaries for a particular

department often are significantly and systematically different from starting salaries in another department. But in all cases the MS salary significantly exceeds the BS salary for the particular discipline. The data show that starting salaries for 4+1 graduates is increasing over time, and that their salaries do increase with time in service. The data are presented in Figure 2 as a scatter plot, no detailed statistical analysis is attempted at this time.

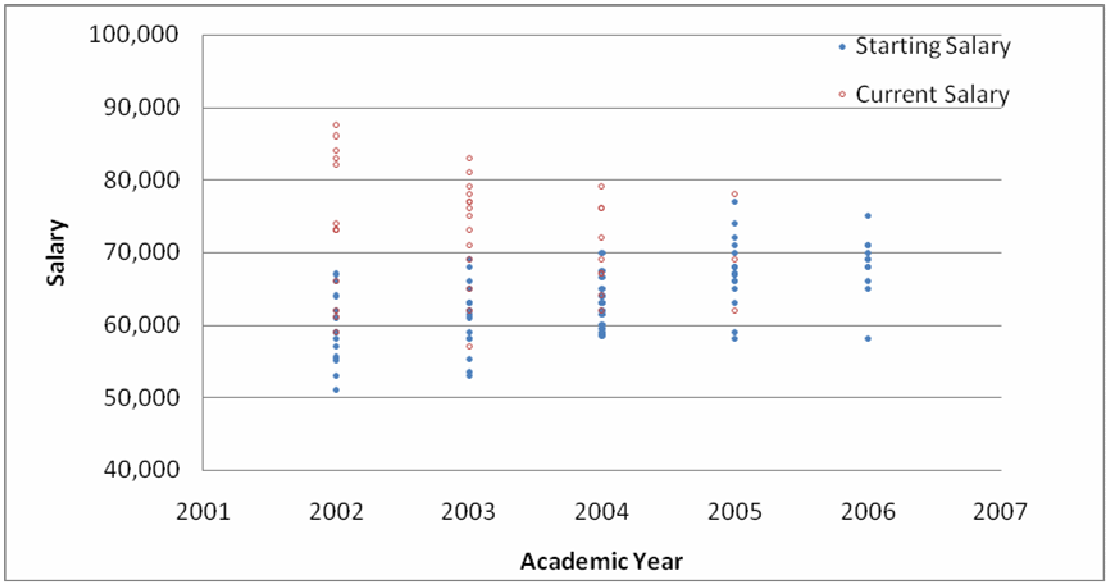

Figure 2. Salaries Reported by Graduates of the 4+1 Program

Conclusion

The 4+1 program is achieving its stated goals. It is providing an accelerated route to an empowering terminal professional degree for an ever increasing number of students who intend to become practicing engineers. It is being well accepted by industry as measured by starting salaries and by the advancement of graduates in their places of employment. It is also providing a vehicle for faculty professional development, though that is not treated in this paper. It is satisfying graduates, who are pleased with their educational outcomes and their professional attainment.

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