
AC 2011-1850: THE 4+1 PROGRAM AND DISTANCE LEARNING MEETING OBJECTIVES AND OUTCOMES

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The 4+1 Program Meeting Objectives and Outcomes

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, the Middle East and the erstwhile Soviet Union are only slightly less cataclysmic than 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 4 + 1 Program is an accelerated route to the professional 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 1998 and now allows General Engineering, Aeronautical Engineering, Biomedical 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 summarizes the results of an early assessment of the attainment of several educational objectives by the MS graduates of the Biomedical and General Engineering Department. The assessment is evolving and is focused on a determination of the professional progress of these graduates. Data indicates that the program has provided benefit for its participants, and remains strongly supported by students, faculty and industry.

Introduction

The Masters of Science (MS) in Biomedical Engineering, established in 2006, is the only MS in Biomedical Engineering in the California State University system. It has evolved from a long-standing specialization within the MS in Engineering Program, administered by the College. The MS program is properly housed in the Biomedical and General Engineering Department, which was established in 2005. There was a one-year hiatus between the establishment of the department, with its attendant bachelors degree and this MS degree because of arcane (and occasionally byzantine) rules for the establishment of new programs. The department was operating, *de facto*, through the General Engineering program administered by the college for over a decade prior to its formal establishment. The formal establishment of the department was triggered by input from two major constituencies; overwhelming student demand, underpinned by industrial pressure and support. The Biomedical Engineering and General Engineering Department is the only degree granting program in the CSU system. It has consistently drawn a large number of well-qualified applicants. In fact, the department has attracted the highest

quality and most gender-diverse applicants in the College of Engineering each year since its formation. The program has grown at rate in excess of that planned, and faculty hiring has not kept pace; the student to faculty ratio is higher than that of other programs in the college and at the university. The programs heritage, its strong link to off-campus constituents, and the resource-poor, reactionary campus environment in which it is steeped, has led to non-traditional approaches, educational philosophies and needs for efficiencies not visited on other programs at the college or university. These challenges have created a vibrant engine that provides benefit to students, industry, California and the nation. The program is a rich source for biomedical engineering professional masters graduates at a time when those graduates are sorely needed.

The 4+1 Program

The 4 + 1 Program is an accelerated route to the professional 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 1998 and now allows General Engineering, Biomedical 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 program is designed to fill the needs of students, the needs of society and the needs of industry.

The 4 + 1 described in this paper is not unique in its basic concept, many engineering programs have dual BS MS degree programs, joint BS MS Programs, blended BS MS programs or other similarly named programs. In fact, a majority of engineering colleges have some sort joint degree program, typically available to most of their majors, occasionally available to only selected majors in these colleges. All of these programs are meant to reduce the ardor of the application process, and to provide a means for students to efficiently earn two degrees in a timely manner. However, the program in the Biomedical Engineering Department is unique in its philosophy and in its implementation. In contrast to programs at other institutions, and some other programs in our own college, which target only students with grade point averages(GPA) in excess of 3.25, 3.4 and in some cases 3.5 on a 4.0 scale, the program described targets students with GPA of 2.5 or better. Furthermore, the program encourages students with GPA in excess of 3.4 to seek higher level advanced degrees (the Ph.D., not available at our institution) elsewhere. The program is also unique in that it actively seeks students from mother majors to participate in the graduate portion of its 4+1 program, many other such programs, even those at our own institution, are specific to undergraduates in their own engineering discipline. The department has desired, and has seen an increase in the absolute numbers and in the percentage of senior students selecting the 4+1 program. This is an explicit recognition of the need for most engineers to earn advanced degrees to be able to function and advance in the complex technical environment our graduates face.

Philosophy Underpinnig the MS Engineering Program

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 definition has been embraced by faculty in the Biomedical Engineering (BME) MS program, 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. The faculty are aware, based on their interactions with industry, that 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 2009¹ 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 engineering². The Biomedical and General Engineering Department has adopted this philosophy in projecting the department demography in its strategic plan. Since 2005 the department has grown from two hundred to over eight hundred students, over half are in the biomedical programs. Table 1 shows the projected and actual growth of the department.

	2006	2007	2008	2009	2010	2015
BS actual	143	338	367	463	497	
MS actual	58	77	86	96	117	
BS Target	150	250	350	400	450	450
MS Target	50	65	80	90	100	150

Table 1. Actual and Targeted Student Populations in the Biomedical Engineering Department

The MS students are drawn from four pools, each of which enriches the educational environment of the department and college in their own way. The largest group of MS students are 4+1 matriculates from the Biomedical and General Engineering program itself, making up roughly fifty percent of the MS population, another ten percent are 4+1 students from other disciplines at the university. Thirty percent of the population is comprised of students who are distance learners, these students are employees of several of our industrial partners. Twenty percent of the students are traditional MS candidates, coming with BS degrees from other institutions.

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 of the total student population, and this was the largest graduate group at the university! Currently, the graduate population is about, but the population is not evenly distributed among departments. In fact, over half of the graduate student population at the college resides in two departments, Biomedical & General Engineering and Civil & Environmental Engineering. These programs are attempting to use non-traditional methods to meet the needs of growing numbers of students. Many other programs have chosen to deemphasize their MS programs as well as reduce their BS admissions as the CSU population shrinks due to budget constraints.

Graduate numbers have increased in BME because the department has made a resolute effort to inform students and to raise the level of their student's academic ambitions. There has been a crusade to enlighten students by attacking some pervasive myths that discourage our talented student pool from attending graduate programs at our university or other universities. These myths are that graduate education is an fool's errand that diminishes your lifetime earnings, that only students with *summa 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.

Starting in the freshman year, our students are made aware that few investments one makes in themselves have a better return than graduate education. An MS degree is worth an additional \$250,000 over the course of a lifetime, a Ph.D. five times that.⁵ They also know that GPA is just one of many factors in admission. Their work experience and senior project efforts, are just two ways students can make personal connections with faculty who seek graduate students. Students have found that graduate education enhances job opportunity, in terms of financial reward, work challenges and advancement opportunity. It provides vertical mobility and a horizontal flexibility not experienced by BS graduates. They know that even though working before going to grad school can provide for a greater learning experience, the risk is that *grad school delayed is often grad school denied*. They come to fully understand that the graduate environment is unlike their undergraduate experience, many are intoxicated by the freedom associated with the experience, and the personal responsibility it affords.

Figure 1 shows the graduate population at the college of engineering as a function of time. The discontinuous jump in the population in 2009 was caused by a policy change that required all graduate students to register each quarter. This was an effort to encourage students to complete their thesis in a timely manner – judging from the reduction in population in the following year, the effort had some success. The figure clearly shows that the growth in graduate population after 1999 is attributable to the popularity of the 4+1 program, augmented by the distance learning program in BME. The current MSE-BME program is by far the most popular option for both formal Masters and Blended (4+1) degrees within the college of engineering. It has a vibrant distance learning program at three corporate sites, and will expand to others in the future. The distance learning cadre will increase to sixty five in 2011, as an additional cohort of students will be added.

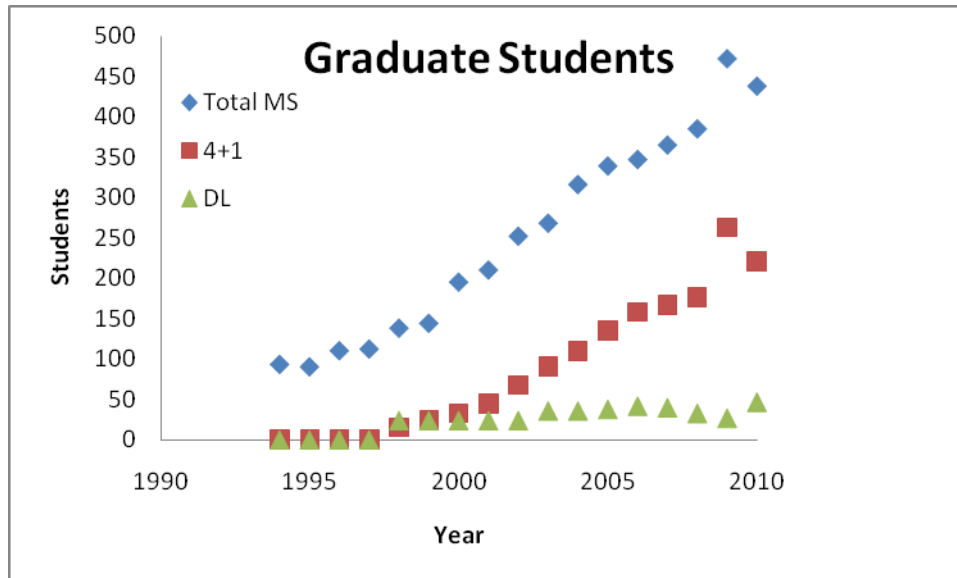


Figure 1. Graduate Population in the College of Engineering.

Program Goals

A priori, one goal for the MS in Biomedical Engineering is to provide its graduates with a rigorous, broad-based advanced engineering education coupled with a depth of requisite applied biology. This will serve to launch graduates into the many diverse career opportunities of Biomedical Engineering. In addition, the program also provides preparation for further study in engineering or professional schools, leading to the MD, Doctor of Engineering or Ph.D. degree. Clearly, the key goal for the program is to provide an empowering terminal professional degree for students who intend to become practicing engineers, a degree that 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. The degree must provide job-entry education for the more complex and evolving interdisciplinary area of biomedical engineering. With the explosion of biotech and biomed industries throughout California, it is apparent to students throughout the College of Engineering that their more traditional BS, such as EE, ME, or MATE, might be marketable in biomedical industry, but having a Masters in Biomedical Engineering coupled in addition to their BS will give them a tremendous competitive edge over other professionals seeking employment. The demand for a Masters in Biomedical Engineering is overwhelming and acute. The degree must provide a basis that allows graduates to maintain currency in their fields, but cannot simply fill the pail, it must flame the attitudinal fire for life-long-learning.

To further these goals we expect each graduate to possess advanced practical knowledge of biomedical engineering to meet their needs to design, optimize, and reengineer processes and methods to produce competitive biomedical systems and devices, to possess sufficient knowledge to develop innovative solutions to clinically relevant biomedical problems, and to be able to lead and manage in the biomedical engineering arena.

The explicit educational objectives for the graduate program, rooted in the educational outcomes we expect students to accomplish prior to graduation are the following. Graduates of our MS

program are expected: 1) to become successful practitioners of biomedical engineering or other professions, 2) to continue improving and expanding their technical and professional skills through formal and/or informal means and 3) to contribute to community and professional groups using the unique competencies provided by their biomedical engineering educational experiences.

Assessment Methods

The program is using a number of devices to assess the attainment of program objectives – achievements we expect of our graduates after they have been in the work force for 5 to 10 years and program outcomes – things we expect our graduates to be able to do upon graduation. A variety of quantitative assessment tools are used to assess course and program outcomes: Performance on selected written exams, on oral examinations, on selected homework problems, in laboratory assignments, and in key projects. Qualitative assessment tools such as surveys and focus groups are also being used for assessment purposes.

The program uses direct and indirect measures to determine the attainment of program educational objectives. The key methods used are: a) periodic alumni surveys, rating their preparation and the importance of program emphasis, their salaries, and their level of professional and personal development activities. b) Employer Data: Surveys and focus groups, as well as advisory board panels provide feedback on employer satisfaction. c) Graduate School and professional school performance – including placement and graduation rates, as well as subsequent employment. This paper is focused on the results of alumni surveys, and in particular on the career progression of our graduates. Pertinent portions of the alumni survey employed for 4+1 graduates are shown below:

Name: **Class:**
Address: **Phone:** **E-mail:**
Employer: **Job Title:**
Graduate School/Program:
Highest Degree Earned: PhD MS Other:
Field of Highest Degree:

We would like you to assess how well the Department has prepared you in light of these desired attributes for its graduates. On a scale of 1-5, with **1 representing little or no preparation** and **5 representing excellent preparation**, please give your assessment of the Department's success in imparting you with:

- a) An ability to apply knowledge of mathematics, science and engineering;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- b) An ability to design and conduct experiments, as well as analyze and interpret data;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- d) An ability to function on multi-disciplinary teams;

- (Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- e) An ability to identify, formulate and solve engineering problems;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- f) An understanding of professional and ethical responsibilities;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- g) An ability to communicate effectively;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- i) A recognition of the need for, and an ability to engage in life-long learning;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- j) A knowledge of contemporary issues;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- k) An ability to use techniques, skills, and modern engineering tools necessary for engineering practice;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- l) An understanding of biology and physiology;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- m) The ability to apply advanced mathematics (including differential equations and statistics), science, and engineering to solve the problems at the interface of engineering and biology;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)
- n) The ability to make measurements on and interpret data from living systems, addressing the problems associated with the interaction between living and non-living materials and systems;
(Little Preparation) 1 2 3 4 5 (Excellent Preparation)

We would also like your answers to the following questions:

2. Are you a practicing biomedical engineer?
If you are not a practicing biomedical engineer, what path has your career taken?
3. Are you doing what you want to do professionally?
If contacted would you be willing to provide data for a salary history?
If you are not, what steps are you taking to change this situation?
4. Are you a member of a Professional Society?
5. Have you participated in a workshop or course since graduating?
6. Have you held any leadership positions (related to your work or otherwise) since graduating?
7. Would you care to participate in an Alumni Panel?
8. Are you in a position to hire a Intern or support a graduate student?
9. Would you like to be a BME class agent?
10. Do you feel that your experience at our institution benefited you professionally?
11. Are you happy with the education that you received?
If yes, what did you like?
If no, what was lacking?

Outcomes:

The most pertinent data gathered thus far is associated with student salaries. Student salaries are an excellent indication of initial demand, and the growth in salary an indication of career progression. There is a wide scatter in starting salaries, and a wide scatter in current salaries of MS graduates, furthermore, less than fifty percent of graduates responded to the survey, and a fraction of respondents provided salary data. Much of the scatter can be attributed to the variance in geography, starting salaries for a particular location often are significantly and systematically different from starting salaries in another location. The MS salary significantly exceeds the BS salary, by between twelve and fifteen percent depending on the year. The data show that starting salaries for MS graduates is increasing over time, and that their salaries do increase with time in service. The data are presented in Figure 2. The x-axis in this plot reflects the student year of graduation, the open circles reflect starting salaries reported by students who graduated with their 4+1 degrees during that year. The open squares reflect the reported current salaries – salaries reported during the last survey - for students who graduated during the year indicated on the x axis . There is not necessarily a one to one correspondence between those students reporting in the current survey and those students who originally reported their starting salary, and the number of students who graduated during a given year who respond to the survey changes, but there are a number of graduates who understand the value of the survey for the program, and who regularly participate.



Figure 2. Self-reported Starting Salaries and Current Salaries for MS Graduates.

Conclusion

Preliminary results indicate that the program is achieving its key goal, students are desired by industry and are financially rewarded for their additional educational attainments. Early indications are that the MS degree also accelerates salary growth vis-à-vis the BS degree, and that it provides for more rapid advancement within a company, and easier movement to other companies or to other divisions within a given company when that is desired by the graduate. Data indicates that the MS program does provide 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, and seems to have improved the prospects of those students.

Bibliography

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