AC 2011-1062: THE DISMANTLING OF THE ENGINEERING EDUCATION PIPELINE

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The Dismantling of the Engineering Education Pipeline

Abstract

Community colleges play a critical role in helping to produce engineers that are urgently needed in order to maintain America's global technological competitiveness. Community colleges serve as an important pipeline for large numbers of ethnically diverse transfer students who pursue engineering degrees in four-year institutions. A few states, such as Maryland and California, have launched broad efforts to make the transfer process easier for community college students in general. Recent developments, however, have threatened the viability of engineering programs in California Community Colleges, endangering this very important pipeline in the engineering educational system. The increasing divergence of the lower-division requirements among different four-year institutions and among the different fields of engineering has led to the erosion of what used to be a standard set of core engineering courses (graphics, statics, properties of materials, circuits, programming) that were required by all engineering programs. This has in turn made it more difficult for community college students to identify and access required lower-division engineering courses, thereby creating barriers to transfer, increasing costs and time to transfer, and discouraging students from pursuing engineering degrees. Additionally, the recent budget crisis has forced many community colleges to cancel low-enrollment classes and high-cost programs including those in engineering. This paper addresses the factors that have led to the gradual erosion of the lower-division core curriculum and the effects that these curriculum changes have had on community college engineering programs. It also explores the implications on the future of the engineering education system, and discusses ongoing attempts to address this growing educational crisis.

Introduction

The California Community College system has grown to be the largest system of higher education in the world, with 112 colleges serving close to 3 million students every year,[1] by providing affordable and accessible education. The community college system feeds two large public university systems, the 23-campus comprehensive California State University (CSU) system, and the 10-campus research-oriented University of California (UC) system, as well as numerous private and out-of-state universities. Ideally, students should be able to complete all of their lower-division coursework at a community college and then transfer to a four-year institution to complete the last two years, thus earning a bachelor's degree in approximately four years.

In the 2006-2007 academic year, for instance, 55% of California State University (CSU) graduates and 28% of University of California (UC) graduates began their college years at a community college—and, upon transferring to either four-year institution, obtained GPAs equal to, or better than, "native" CSU or UC students.[1] The success of California community college transfer students is consistent with a recent national study based on a database tracking of students from 21 flagship universities showing that students who transferred from community

colleges graduate at the same rate as those who enrolled as first-time freshmen, despite being more likely to be from low-income families and more likely to have not had great pre-college academic credentials.[2]

For years, this 2+2 concept worked well for community college students majoring in engineering because there was consistency in the lower-division engineering curriculum among four-year institutions. This common set of lower-division courses, commonly referred to as "the core", was replicated at community colleges, and students were then able to start their engineering coursework at a local community college with the option of transferring to one of the many four-year schools across the state.

Recently, the diversification of transfer requirements among university engineering programs across the state, perhaps catalyzed in part by the continuous improvement process required by ABET 2000 criteria,[3] has led to the erosion of the lower-division engineering core. This paper explores the factors that have led to the gradual erosion of the lower-division core curriculum, the effects that these curriculum changes have on community college engineering programs, and their implications on the future of the state's engineering education system.

The Engineering Lower-Division Core

For many years, a common lower-division core curriculum allowed students to complete the first two years of their engineering education at a California Community College (CCC), and then transfer to almost any four-year engineering program in the state to complete their bachelor's degree, often with two additional years of study. The original core curriculum had been developed by mutual agreement among representatives from CCC, UC, and CSU engineering programs, primarily under the auspices of the California Engineering Liaison Council (CA ELC), a statewide organization that has met regularly since 1947 to help steer the state's engineering education in a manner that will facilitate transfer from two-year to four-year programs.[4] The courses that constituted the lower-division core included not only calculus, physics and chemistry sequences, but also a set of foundation engineering courses – graphics, statics, properties of materials, circuits, and programming. These courses were required of all engineering students in all four-year engineering programs regardless of major and hence an equivalent set of courses was offered by community college engineering programs, thereby often supporting one or two full-time engineering faculty.

In recent decades, however, in response to a variety of pressures (e.g., to decrease time to graduation, to replace dated courses with new courses, to increase breadth requirements, to respond to changes in accreditation criteria, etc.), well-intentioned but autonomous university engineering faculty have made independent changes to their lower-division curricula. These changes have resulted in a gradual diversification in transfer requirements for community college students. The diversification includes variability of requirements for students in the same major transferring to different institutions, as well as for students in different majors transferring to the same university.

Table 1 illustrates the variability of lower-division requirements among different engineering majors for the same institution (UC Berkeley). Although there is a high degree of uniformity in

Table 1. Transfer Requirements for Various Engineering Majors at UC Berkeley*

	Calculus I, II, III	Differential Eqns & Linear Alg	Physics I, II	Physics III	General Chemistry I	General Chemistry II	Intro to Design & Analysis	Graphics	Materials Science	Solid Mechanics	Thermodynamics	Microelectronic Circuits	Intro Computer Programming	Advanced Comp. Programming	Data Structures
Bioengineering	X	X	X		X		R		R[1]			R[1]	R		
Bio/Materials	X	X	X		X		R		R			R	R		
Chemical	X	R	X		X	X			R			R	R		
Civil	X	X	X	X[1]	X	X[1]	R		R[4]	R			R		
Computational	X	X	X	X[3]	X	X[3]	R		X[3]				R		
Electrical/Comp	X	X	X	X	X				R			R	R	R	R
Environmental	X	X	X	X[3]	X	X[3]	X[3]						R		
Industrial	X	X	X		X		R	R[2]	R[2]	R[2]	R[2]	R[2]	R	R	
Manufacturing	X	X	X		X		R	R		R	R		R		
Materials	X	X	X	X	X	X	R		R	R			R		
Mechanical	X	X	X		X		R	R		R	R		R		
Nuclear	X	X	X	X	X		R		R			R	R		

R = Recommended X = Required [1] choose one [2] choose two [3] choose three
[4] specialized Civil Materials course only

*Data obtained from ASSIST (Articulation System Stimulating Interinstitutional Student Transfer) website assist.org. [5]

required courses in mathematics and physics, only one course (computer programming) of the core is recommended for all majors, and even that single course requirement varies slightly in content among the majors (refer to first row of Table 3). Statics is no longer required for any of the majors. Graphics and thermodynamics are both recommended for only three out of the twelve majors.

The variability of the lower-division requirements among universities for the same major is illustrated in Table 2. For Civil Engineering, although there is again a high degree of uniformity

Table 2. Transfer Requirements for Civil Engineering Majors

	Calculus I, II, III	Differential Eqns	Linear Algebra	Physics I, II	Physics III	Gen Chemistry I	Gen Chemistry II	Intro to Engineering	Graphics	Materials Science	Strength of Materials	Statics	Dynamics	Circuits	Comp/Programming	Surveying	Geology
UC Berkeley	X	X[2]	X[2]	X	X[1]	X	X[1]	R[4]		R[6]	R[2]	R[2]		R[7]	R		R
UC Davis	X	X	X	X	X	X	X			X		X		X	X	R	
UC Irvine	X	R	R	X	R	X	R	R[5]				R	R		R		
UCLA	X	X	X	X	X	X	X			R	R	R[2]	R[2]		X		
Cal Poly SLO	X	X[2]	X[2]	X	X	X	R	R[5]	R	X	R	X	R		X	R	R
CSU Chico	X	X		X	X[1]	X	X[1]	X[4]	X	X		X		X	X	X	X[1]
CSU Fresno	X	X		X	X	X		X[5]	X			X		X	X	X	X
CSU Fullerton	X	X[2]	X[2]	X	X							X		X		X	
CSU LA	X	X	X	X	X	X			X	X	X	X		X	X	X	
CSU LB	X	X		X	X	X		X[3]	X	X[6]		X			X	X	
CSUS	X	X		X	X	X	X[1]		X	X		X		X[1]		X	
SDSU	X	X		X		X		X[5]				X	X			X	
SF State	X	X[2]	X[2]	X	X	X		X[3]	X	X		X	X	X	X	X	
San Jose State	X	X	X[1]	X	X	X	X[1]	X	X[2]	X		X		X	X[2]	X	

R = Recommended X = Required [1] choose one [2] combined course
[3] Careers/soft skills [4] Design [5] specialized Intro to Civil only
[6] specialized Civil Materials course only [7] microelectronic circuits

*Data obtained from ASSIST (Articulation System Stimulating Interinstitutional Student Transfer) website assist.org.[5]

in the required courses in mathematics and physics for both CSU and UC schools, the same cannot be said regarding engineering courses. Graphics and Surveying tend to be required by CSUs but not the UCs. There is not a single engineering course that is required or recommended by all the institutions. Even the requirement for Statics, which is fundamental in the study of Civil Engineering, has deviations in two of the institutions: UC Berkeley combines it with Strength of Materials while Cal Poly SLO combines it with Dynamics.

Another level of variability in the required lower-division curriculum is introduced when corresponding courses at different institutions are not equivalent. For instance, although computer programming is a required or recommended course for most of the majors at most of the institutions, there is a high degree of variability in the course content among the different institutions and majors. Table 3 is a summary of the Introductory Engineering Computation/Programming transfer requirements for different majors and different institutions.

Table 3. Introductory Computation/Programming Requirement for Transfer Students

	Aerospace	Biochemical	Biomedical	Chemical	Civil	Computer	Electrical	Environmental	Industrial	Manufacturing	Materials	Mechanical	Nuclear	Structural
UC Berkeley	-	9	9	Any	9	10	10	9	9	9	9	9	9	-
UC Davis	-	10	8	10	8	1,2	2,8	-	-	-	10	8	-	-
UC Irvine	3	-	5	2	2	5	1	2	-	-	3	3	-	-
UC Los Angeles	2	-	2	2	2	2	2	-	-	-	2	2	-	-
UC Riverside	-	-	2	2	-	2	2	2	-	-	2	7,8	-	-
UC San Diego	2	2	2	2	-	4	1	2	-	-	-	2	-	9
UC Santa Barbara	-	-	-	6	-	4	1	-	-	-	-	6	-	-
UC Santa Cruz	-	-	-	-	-	1	1	-	-	-	-	-	-	-
Cal Poly SLO	0	-	7	-	7	2	2	6,7	7	7	6,7	6,7	-	-
CSU Chico	-	-	-	-	0	2	2	-	-	-	0	-	-	-
CSU Fresno	-	-	-	-	2	2	2	-	-	-	-	2	-	-
CSU Fullerton	-	-	-	-	0	2	2	-	-	-	-	1	-	-
CSU LA	-	-	-	-	3	-	1	-	-	-	-	3	-	-
CSU LB	2	-	-	2	2	2	2	-	-	-	-	2	-	-
CSU Sacramento	-	-	-	-	0	1	1	-	-	-	-	10	-	-
San Diego State	0	-	-	-	7	2	2	7	-	-	-	7	-	-
SF State	-	-	-	-	2	2	2	-	-	-	-	2	-	-
San Jose State	2	-	-	0	2	4	2	2	2,4	-	0	2	-	-

- Major not offered 0. No required course 1. C 2. C++
3. Fortran 4. Java 5. Python 6. C/MATLAB
7. Excel/MATLAB 8. MATLAB problem-solving focus 9. MATLAB programming
10. Other

*Data obtained from ASSIST (Articulation System Stimulating Interinstitutional Student Transfer) website assist.org.[5]

As the table illustrates, the required programming language and the course content vary widely. As a result, a community college that can only offer one course of computer programming will have difficulty developing a class that can support a group of students with different majors and transfer institutions.

A similar situation exists with regard to the Freshman Introduction to Engineering course, some form of which is recommended or required for a majority of engineering majors. This course ranges from a 1-unit survey of career options to a 3-unit project-based introduction to design, which is in many cases discipline specific. Other engineering courses have more subtle differences in their content, still making articulation difficult or impossible. For example, several universities offer a combined Differential Equations and Linear Algebra course, while others require two separate courses (see Table 2). Many institutions recommend or require a circuit analysis course for a number of majors, but some require a lab while others do not. UC Berkeley requires a microelectronic circuits course, which does not articulate with the analog circuits course offered by most community colleges (and most other UC and CSU programs).

Effects of the Eroding Core on Community College Engineering Programs

The diversification of transfer requirements that has led to a "maze of standards" can be attributed to California universities' "strong tradition of faculty at each university having control of their institutions' academic programs."[6] For engineering, the diversification of the lower-

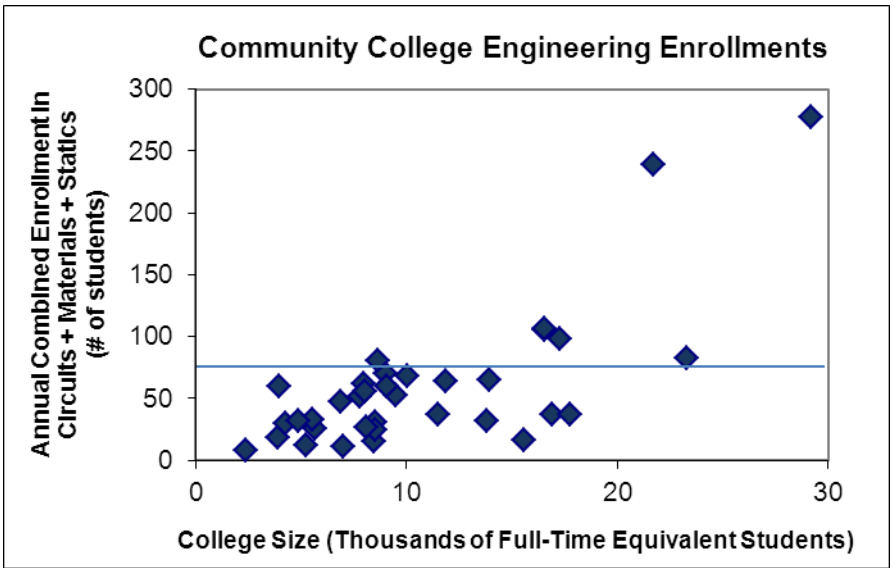

Figure 1. Combined annual enrollments in sophomore-level 'core' engineering courses (Circuits + Materials + Statics) versus overall college size for California Community Colleges (each diamond represents one college). The horizontal line indicates 75 students, equal to an average of 25 students per course if each offered once per year. Engineering enrollment data are from CA ELC Enrollment Survey, F06-S07 or most recent complete year reported. College FTES were obtained from CCCCO Data Mart for the appropriate year.[7]

division requirements has increased the number of courses that community colleges must offer, in order to maintain transfer options to different engineering majors and different universities. As detailed below, this has led to decreased enrollments and increased program costs in engineering, often leading to cancellation of courses and sometimes entire programs, a threat which has been exacerbated by the ongoing state budget crisis.

Figure 1 shows the yearly combined enrollment in the three sophomore-level "core" engineering courses (Circuits, Materials, and Statics) versus college size (FTES), for 35 community colleges that responded to a 2007 CA ELC enrollment survey. Of these 35 community colleges, only six (or 17.1%) have average enrollments of over 25 students per course, a threshold often required to prevent course cancellation.

To further illustrate the effect of the erosion of the lower-division engineering core curriculum on the viability of community college engineering programs, an analysis of a hypothetical scenario is done for a typical community college in the San Francisco Bay Area that transfers an average of 25 engineering students every year. Table 4 shows the transfer requirements for four of the most popular engineering majors for four of the biggest engineering universities in the

Table 4. Transfer requirements for the most common engineering majors in Bay Area universities and projected community college enrollment.

	Civil				Computer				Electrical				Mechanical				Enrollment*
	UCB	UCD	SFSU	SJSU	UCB	UCD	SFSU	SJSU	UCB	UCD	SFSU	SJSU	UCB	UCD	SFSU	SJSU	
Intro Engr	X		X	X				X			X	X	X		X	X	16
Graphics			X	X			X	X					X	X	X	X	14
Materials		X	X	X										X	X	X	11
Statics		X	X	X										X	X	X	11
Solid Mech	X												X				3
Dynamics			X								X				X		4
Circuits Lec		X	X	X		X	X	X		X	X	X		X	X	X	19
Circuits Lab							X	X			X	X			X		8
Microelec					X				X								2
MATLAB	X	X		X						X			X	X		X	12
C++/Java						X	X	X		X	X	X			X		10
Other Progr			X		X	X		X	X	X							7
Data Struct					X	X	X		X								4
Thermodyn													X				2
Surveying		X	X	X													5

*Projected enrollment for 25 transfer students with the following assumed distribution: 20% Civil, 15% Computer, 20% Electrical, and 30% Mechanical; 20% UCB, 20% UCD, 20% SFSU, and 40% SJSU.

area: UC Berkeley, UC Davis, San Francisco State University, and San Jose State University. To compute the projected enrollment (last column of the table) for 25 transfer students, the following student distribution is assumed—distribution by major: 20% Civil, 15% Computer, 20% Electrical, and 30% Mechanical; distribution by transfer institution 20% UCB, 20% UCD, 20% SFSU, and 40% SJSU.

Out of the fifteen lower-division engineering courses that are listed as required for at least one of the transfer institutions, only one course has a projected enrollment even close to what most community college administrators would consider as financially viable to offer: Circuits Lecture with 19. Unfortunately, due to the "premature transfer" issue discussed in the next section below, it is unlikely that even this course could sustain an enrollment of greater than 15 students on a regular basis, making it difficult to sustain a viable engineering program.

Figure 2 demonstrates that having 25 engineering transfers per year, used in the hypothetical scenario above, is in fact better than average for California Community Colleges. Of the 101

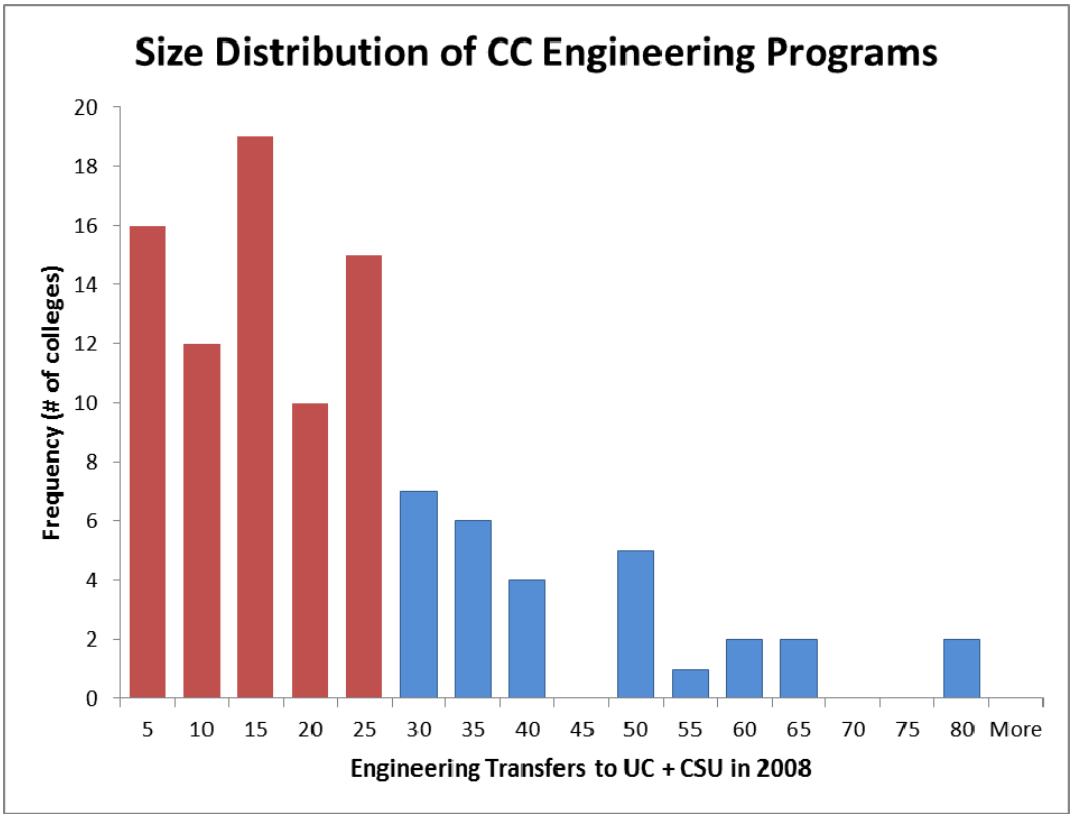

Figure 2. Distribution among individual California Community Colleges of engineering transfers to UC and CSU in Fall Term 2008. Of the 101 colleges with engineering transfers, 71 colleges transferred less than 25 students each, accounting for 42% of the 2,148 total transfers. Median number of transfers per college = 17.0 students; Mean number of transfers per college = 21.3 students. Data are from California Postsecondary Education Commission.[8]

colleges with engineering transfers to UC and CSU in 2008, the average number of transfers from a college was 21.3 students (median of 17.0 students). In fact, 71 of the 101 colleges transferred less than 25 students. Based upon the course enrollment analysis above, and given current trends in transfer requirements, it is conceivable that many of these small to medium-sized engineering programs (which accounted for 42% of the total 2,148 transfers) will cease to exist in the foreseeable future. Most sobering is that 44 colleges had fewer than 15 transfers each. In light of the current budget crisis in California, it seems likely that a significant number of these small engineering programs (which accounted for 17% of total transfers) will be cancelled just in the next few years.

Effects of the Eroding Core on Community College Engineering Students

The diversification of lower-division engineering requirements has negatively impacted transfer students in a number of ways, as evidenced in the results of recent studies by the RP Group (The Research and Planning Group for California Community Colleges). This group is currently engaged in a large-scale research project studying factors that affect transfer in Career and Technical Education (CTE) disciplines, which include Engineering.[9] Phase I of the research project included both forward-mapping and backward-mapping quantitative analyses of CTE student cohorts over multiple years, as well as qualitative surveys of pre- and post-transfer students, and of CTE faculty, counselors, and administrators. Some of the impacts on engineering transfer students that are apparent in these results are enumerated below.

1. Increased complexity of academic planning: Because most students are not guaranteed transfer acceptance into a particular institution or major program, they must construct an academic plan that keeps open multiple options, a daunting challenge when the requirements differ radically (and change frequently). Not surprisingly, survey respondents identified the variation in major transfer requirements among four-year institutions as one of the top challenges to CTE transfer, with the RP Group noting that "inconsistent lower-division major requirements represent a significant barrier to transfer for Engineering students."[10] Post-transfer engineering students emphasized that establishing and updating a comprehensive educational plan was critical to their transfer success.

2. Increased number of courses and time to transfer: In an effort to prepare for multiple transfer targets in this complex academic landscape, students often accumulate more community college courses than are ultimately needed to satisfy the transfer and graduation requirements of their eventual degree program. In an analysis of 4,200 "Engineering completers" (transfer students who successfully earned engineering Bachelor degrees) between 1996 and 2009, the RP Group found that 45% of students completed 70 or more semester units prior to transfer, with 24% of students completing in excess of 86 units. This in turn contributed to increased times to transfer, with 38% of students requiring 4 or more years of community college attendance prior to transfer.

3. Swirl: As noted earlier, individual community colleges have become increasingly unable to sustain the full range of lower-division courses required by the various UC and CSU engineering programs. Consequently, students are increasingly compelled to "swirl" (i.e., attend multiple community colleges) in order to satisfy transfer requirements. The RP Group found that more than half (52%) of Engineering completers attended multiple community colleges, with roughly

one-quarter (23%) of the students attending 3 or more. (Note that the comparative numbers in Accounting were only 35% and 11%, respectively.)

4. Premature transfer: As transfer students have experienced greater uncertainty and decreased availability of required lower-division courses, many have been tempted to apply for transfer into the receiving institutions without these requirements. In the face of increasing numbers of these underprepared applicants, it appears that university programs have in turn felt pressured to lower their requirements for entering transfer students. For instance, UC Berkeley's lower-division engineering courses are now recommended rather than required for transfer. In evidence of this, the RP Group found that even among Engineering degree completers, "40% of students who transferred to the UC and 50% who transitioned to the CSU had to take three or more lower-division major preparation courses post-transfer—clearly delaying their time to degree completion."[11] In fact, fully 35% of students had completed only one semester of calculus or less prior to transfer, in essence making these students university juniors, but engineering freshmen.

It is this last fact that is most concerning, especially given that 61% of the Engineering completers required 6 or more years in total to obtain their degree. With the increasing costs of a university education, fewer and fewer students, especially from underrepresented groups, will be able to shoulder this burden. Unfortunately, neither the RP Group's research to date nor other statewide databases provide any indication of how many students dropped out of the engineering pipeline in the face of these substantial obstacles. The backward-mapping analysis includes only those students who succeeded in navigating the maze ("completers"), while the forward-mapping analysis includes only those students who took at least 12 units of engineering courses at the community college ("concentrators"). One notable finding is that "the transfer rate for Engineering concentrators tops all other disciplines at 80%. However, the number of students in this category is very small—just over 200 per year statewide."[11] (For relative comparison, there were 2,148 engineering transfers to UC and CSU in 2008.) It seems likely that substantial numbers of prospective engineering transfers fell outside both the concentrator and completer classifications, and may simply have thrown up their hands and changed career paths before ever reaching either mark.

The Business-As-Usual Scenario

If left unaddressed, the diversification of transfer requirements, coupled with the tendency for students to transfer prematurely or avoid engineering altogether, creates a feedback loop that further erodes community college engineering programs. Given the precarious nature of engineering course enrollments discussed earlier, further erosion will likely lead to cancellation of courses and elimination of full-time engineering faculty positions at many small to medium-sized community colleges. In addition to the decreased access and increased costs this would entail for students, another unfortunate consequence of this is the loss of career and academic guidance that is currently provided by community college engineering faculty. Respondents in the RP Group surveys indicated that the top factor in supporting CTE transfer was: "Two-year college instructors who help create transfer paths and promote CTE transfer."[10]

Another less obvious consequence is the impact upon other science and math disciplines. According to class surveys performed in multiple years by one of the authors,[12] and corroborated

by anecdotal reports from other instructors of their own informal surveys, engineering majors represent the majority (often greater than 75%) of students in calculus-based physics courses, advanced mathematics courses (Calculus I, II, III, Differential Equations, Linear Algebra), and some computer programming courses offered in community colleges. At many small community colleges, most of these courses are themselves barely viable from an enrollment standpoint. If cancellation of engineering programs leads to even a slight loss in students from these courses, they too would become at risk of cancellation. The end result may be the eventual elimination of all STEM transfer programs from smaller community colleges.

Redefining the Core

As a response to the state legislature's increasing pressure to streamline the transfer process for millions of California community college students, both the CSU and the UC systems have attempted to make the lower-division requirements more consistent. Although CSU's Lower Division Transfer Pattern (LDTP) project,[13] and UC's Intersegmental Major Preparation Articulated Curriculum (IMPAC) project[14] have had moderate success in creating common lower-division curricula for many majors, streamlining the curriculum for engineering majors has been a challenge. The recent SB 1440 legislation in California,[15] aimed at using an Associate Degree approach to standardize lower-division requirements for transfer to CSU, seems similarly unlikely to improve the situation for engineering majors.

For the LDTP statewide engineering pattern, there is again a high degree of uniformity in the General Education classes, as well as the required courses in mathematics and physics, but a high variability in the required engineering courses. Table 5 summarizes the required engineering courses for the statewide pattern of the LDTP curriculum for Civil, Electrical and Mechanical engineers. Out of the 45 units of courses, not a single engineering course is common to all three majors. The rest of the major-specific lower-division curriculum that is needed to complete the 60-70 units needed to transfer is campus specific, which again results in variability in the curriculum, making it difficult for community colleges to develop curriculum that is widely articulated and to maintain programs that have healthy enrollments.

Table 5. CSU Statewide Lower-Division Transfer Pattern[13] of engineering courses for the three biggest engineering majors.

	Civil	Electrical	Mechanical
Graphics	X		
Materials			X
Statics	X		X
Circuits Lecture		X	X
Computer Programming		X	
Surveying	X		

The results of the IMPAC project are even less promising. The project recommends an Engineering Transfer Curriculum (ETC) base that includes the following courses:[14]

- 2 courses in Composition: English Composition, Critical Thinking/English Composition.
- 1 course in Arts or Humanities
- 1 course in Social and Behavioral Sciences (recommend US History and Government, if needed)
- 5-6 courses in Mathematics: precalculus (if needed), calculus (2 courses), multivariable calculus (1 course), differential equations (1 course), linear algebra (1 course).
- 2-3 courses in Physics: one year sequence of calculus-based physics and laboratories.
- 1 course Chemistry: college chemistry and laboratory.
- 1 course Programming: introductory programming for engineering and CS majors.
- 1 course Introduction to Engineering or Skills for Engineering Success: freshman course or choice of courses specified by the community college engineering faculty designed to expose students to engineering methodology and the excitement of engineering.
- 1 course oral communications (required for CSU, recommended for UC)

Note that the only engineering courses included in ETC Base are *Introduction to Engineering* and *Programming*. The ETC Advanced curriculum that is yet to be developed will include additional major-specific courses, and will undoubtedly result in a transfer engineering curriculum that is as diversified and as confusing as it has ever been. In fact, the IMPAC 2005-2006 Annual Report recommends that the ASSIST web site be used as the best source of guidance for community college students who have decided on a specific engineering major and university campus.

A recent development in California higher education is the passing of SB 1440 bill, which establishes the Student Transfer Achievement Reform Act.[15] SB 1440 would require that a student who receives an "associate degree for transfer" be deemed eligible for transfer into a California State University. The associate degree for transfer would include a set of general education requirements and a defined set of courses in their major area, to be determined by the community colleges. This bill is intended to streamline the transfer process for community college students.

Although well intentioned, this bill includes provisions that may lead to further erosion of the core engineering curriculum. The bill requires that the associate degree for transfer consist of 60 semester units (or 90 quarter units) with General Education courses and a major or area of emphasis of at least 18 units. For engineering, these 60 semester units would include courses in GE Breadth, mathematics and physics, leaving no room for any engineering courses that have math and/or physics prerequisites. As a result, students would be able to transfer as engineering majors without having to take any engineering courses in a community college. The bill also requires that "the CSU shall grant a student priority admission to his or her local CSU campus and to a program or major that is similar to his or her CC major or area of emphasis, as determined by the CSU campus to which the student is admitted." Under this provision, a student who completes an associate degree for transfer in a major (e.g., physics) that is similar to engineering (as determined by the CSU campus) will be given priority admission as an engineering major.

The Academic Senate for California Community Colleges has taken the lead in developing Transfer Model Curricula[16] for several majors. At the time of writing this paper, work in developing curriculum for engineering has not begun.

Given that the recent attempts described above have failed to provide any noticeable improvement in the engineering transfer situation, what are our options?

1) Develop a new and improved standardized core, based on both content and student learning outcomes using the highest possible standards reasonable. This approach has proven successful in California for other disciplines such as Nursing and Child Development, which are touted as models of effective practice in CTE transfer by the RP Group,[10] and could lead to system-wide articulation, along the lines of recent suggestions by Dr. Jack Scott, Chancellor of the California Community Colleges.[17]
2) Concentrate on regional articulation to make collaboration between four-year and community college faculty easier. Engineering faculty from a number of community colleges in the San Francisco Bay Area (including the authors) have been meeting recently with regional university engineering representatives to discuss the prospects for such a collaboration.
3) Develop collaborations among community college engineering programs to expand access for students via cooperative scheduling, cross-enrollment, educational technologies (e.g., distance education), and support structures. A new Joint Engineering Partnership, created as part of an NSF-IEECI (Innovations in Engineering Education and Curriculum Improvement) grant, has just started to explore this avenue.[18]
4) Articulate programs rather than courses. In many ways, this would allow the greatest opportunity for innovation and local flexibility, especially at the community college level. However, it would require a dramatic change from the status quo that is not only unlikely to be acceptable, but also may lead to additional problems for students arising from an increasing diversification among institutions.
5) Increase partnership between four-year and two-year institutions. Consider:
    a. Promoting concurrent enrollment arrangements.
    b. Developing one-to-one mutual agreements between an individual community college engineering program and a single university, which result in alignment of lower division curriculum for all majors.

Whatever the next step might be, engineering faculty at four-year schools will have to be actively involved to remedy this situation. Innovation is good but we still need consistency between approaches. At the very least, four-year schools need to work with other four-year schools (particularly those within a region) as well as with the community colleges to ensure reasonable consistency. When changes are proposed to the lower-division, the impacts to community colleges need to be evaluated and assessed before changes are finalized. To facilitate this type of collaboration, a process needs to be created to assist all institutions involved.

For decades California has provided an impressive and effective community college pathway to engineering. As shown in Figure 3, approximately 33% of all UC and CSU engineering graduates in 2008 started their Bachelor's degrees at a community college (individually, 23% of UC and 41% of CSU graduates). The community college pathway therefore represents a sizeable portion of the engineering pipeline in California. For many students, particularly those from underrepresented groups, this pathway to engineering may be the only practical way for them to access an engineering education.

Although this percentage is impressive, it is even higher in other disciplines. Figure 4 shows that among all non-engineering bachelor's degree recipients in 2008, 47% of all UC and CSU

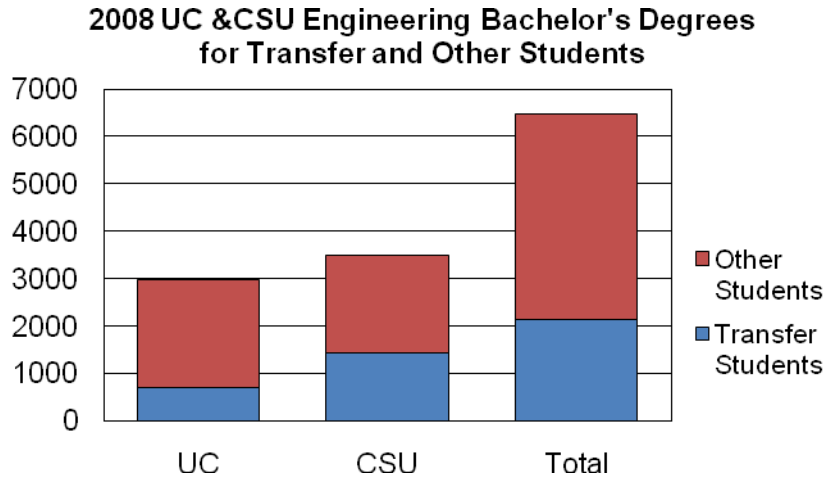

Figure 3. UC and CSU engineering graduates for 2008 showing engineering transfer students from community colleges compared to students who did not transfer from a community college. Data are from California Postsecondary Education Commission.[8]

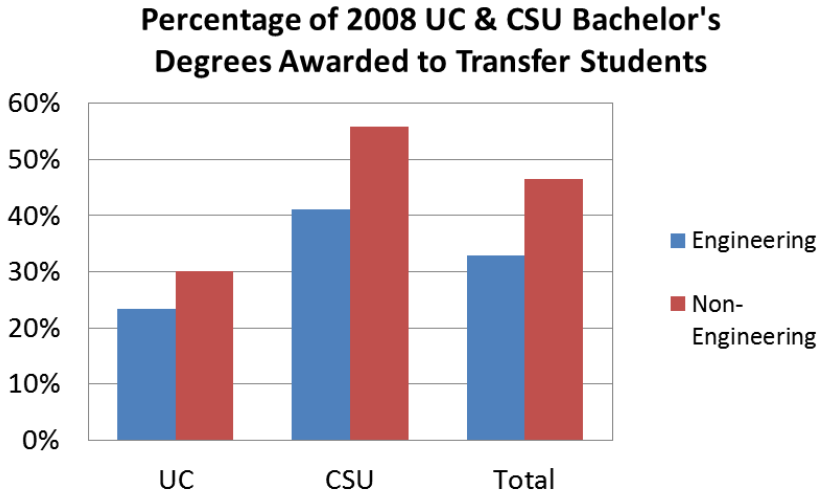

Figure 4. Percentage of 2008 UC and CSU Bachelor's Degrees that were awarded to community college transfer students, for Engineering and non-Engineering majors. Data are from California Postsecondary Education Commission.[8]

graduates were transfer students (individually, 30% of UC and 56% of CSU graduates). In other words, there is a relatively smaller representation of community college transfers among engineering graduates when compared to other majors. It is worth noting that this is not because engineering transfer students are less successful at UC and CSU. On the contrary, a 2002 UC study found that engineering transfers were actually more successful, in terms of both GPA and completion rates, than all other types of transfer students.[19] Although there may exist a number of other possible explanations for why transfer students are relatively less common among UC and CSU engineering majors, certainly among the contributing factors are the increasing complexity of engineering transfer requirements, and the decreasing availability of articulated lower-division courses at the community colleges.

Education has been "the great equalizer". There have been countless positive and profound effects that an affordable higher education has had on California's economy and culture. Californians have recognized this by generously supporting the community colleges with their tax dollars, building over decades a substantial investment in the community college system. It is important therefore that the role of the community colleges be strengthened and not undermined by the work done at the four-year schools.

Most importantly, a significant number of the engineers graduating today would never have entered, much less completed, the engineering pipeline without the community college option. Although the community colleges are distributed widely across the state, they collectively play a vital role in educating engineers. The community colleges are the "open door" to higher education, providing students opportunities they never thought possible, and helping them achieve goals they never could have imagined. If the community college pathway is no longer viable for engineering students, then we have allowed our education system to become more exclusive, more expensive, and less efficient. We have dismantled a large portion of the engineering education pipeline, and have barred access to those students least likely to find a detour around the barriers we have inadvertently created.

The question we all must consider is this: How many future students (many from underrepresented groups) will drop out of the engineering pipeline as the transfer system deteriorates? Can we afford the loss when the country already struggles to graduate enough engineers to sustain our global competitive advantage? The stakes are high. It is time to do the essential work that is so desperately needed to preserve a higher education of open doors.

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