AC 2012-5295: NOW MORE THAN EVER: THE NEED FOR A COMMON ENGINEERING CORE CURRICULUM

Dr. Michael G. Jenkins P.E., California State University, Fresno

Michael G. Jenkins is a professor in mechanical engineering and Former Dean of Engineering at California State University, Fresno. He is an advocate of the active learning and teaching philosophy per ABET EC2000. Jenkins is a registered professional engineer in Washington and is actively involved through leadership roles in national/international committees such as ASTM, ASME and ISO. He is also an experienced ABET Program Evaluator (PEV) for general engineering and mechanical engineering. Jenkins received his B.S.M.E. from Marquette University, his M.S.M.E. from Purdue University, and his Ph.D. from the University of Washington. He worked at PACCAR Technical Center as an R&D engineer and at Oak Ridge National Laboratory as a development staff member. He was also faculty and associate chair at University of Washington, Seattle, and professor and chair at University of Detroit Mercy before starting his position as faculty and dean at CSU, Fresno. His research and teaching interests include characterization of advanced materials (e.g., ceramics), experimental mechanics, data base development, cumulative damage mechanics, and probabilistic design and reliability.

Dr. Walter V. Loscutoff, California State University, Fresno

Walter V. Loscutoff is a professor and Former Chair of mechanical engineering as well as Former Associate Dean of Engineering at California State University, Fresno. Loscutoff received his B.S.M.E., M.S.A.E., and Ph.D. from the University of California, Berkley. He worked at Flow Industries, Inc., as Executive Vice President & COO of Flow Research, Inc.; Vice President and General Manager of FlowDril Corporation; Manager of Research and Technology Division, at Pacific Northwest National Laboratory through Battelle Memorial Institute; Associate; Project Manager; Program Manager, and Section Manager and Rocketdyne: and Research Engineer. He was also Assistant Professor at University of California, Davis, and Adjunct Associate Professor at Washington State University before starting his position as faculty at CSU, Fresno. His research and teaching interests include advanced materials, alternate energy, systems analysis, and project management.

Dr. Thomas Nguyen

Now More Than Ever:
The Need for a Common Engineering Core Curriculum

Michael G. Jenkins[1], PhD, PE; Walter V. Loscutoff[1], PhD; Thomas L. Nguyen[2], PhD

[1]California State University, Fresno, CA; [2]Levitas Consultants, Merced, CA

Abstract

For decades, the hallmark of engineering educational programs was a "common core curriculum" that provided all engineering students, regardless of engineering discipline, with a foundation of standard, lower-division courses in mathematics, science and engineering topics. These core courses (e.g., calculus, differential equations, physics, chemistry, drafting, freshman design, statics, dynamics, strength of materials, thermodynamics, programming, circuits, etc.) were common to all disciplines. Over the past decade or so, increasing divergence of lower-division requirements among different four-year institutions and among the different fields of engineering, has led to fading of the common engineering core. 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 on students, faculty, and pre-engineering programs. In addition, the paper explores the implications on the future of the engineering educational system, the cost to taxpayers, and the system's effectiveness at producing the engineers that are needed to ensure the viability of the engineering profession.

Introduction

Engineering is defined as the profession "that applies knowledge of the mathematical and natural sciences gained by study, experience, and practice to develop ways to economically utilize the materials and forces of nature for the benefit of humankind." [1]

The National Society of Professional Engineers (NSPE) asserts that engineering educational programs must prepare graduates for the practice of engineering at a professional level.[1] Programs should include certain elements that distinguish the engineering function, namely, the analysis, design, and synthesis of engineering systems. Basic and advanced programs of study should be designed to provide engineering graduates with competent technical and managerial skills as well as broad, cultural education in the humanities and social sciences. This approach enables engineers to provide the technical and managerial leadership in industry, government, and society needed to fulfill the engineering profession's public purpose.

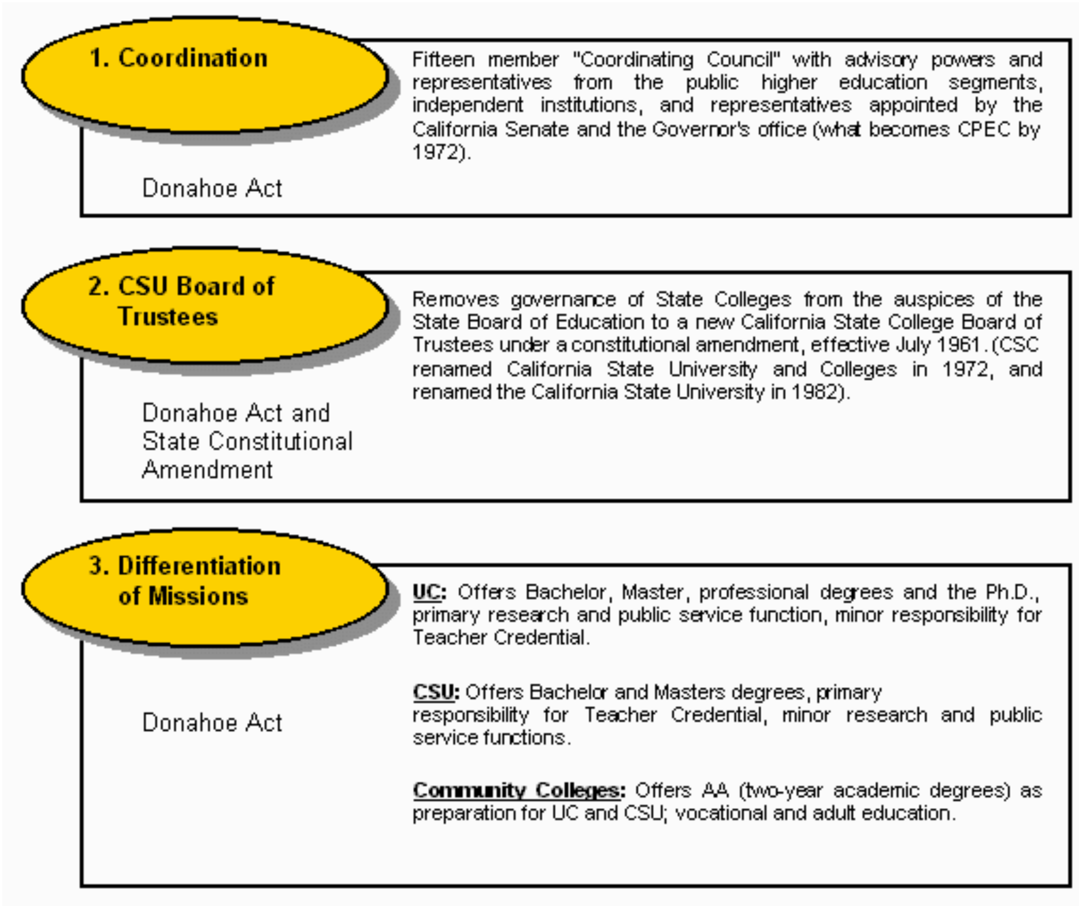

Figure 1 – California Master Plan for Higher Education[4] (adopted in 1960)

However, pressures from multiple sources are pointing to the need to change the way higher education approaches engineering degrees. For example:

- Stagnant numbers of new degreed engineers annually despite increasing demand (e.g., about 75,000 to 80,000 BS degrees per year in the United States since 2000)[2]
- Mandates for greater degree efficiency (e.g., minimum 120 semester-unit graduation requirements) in public institutions such as those in California[3]
- Increased costs of four-year undergraduate engineering programs at single institutions make attractive a cost-effective option that involves a two-year, lower-division pre-engineering program at one institution combined with a two-year upper division engineering program at another institution.

A common engineering core for all disciplines lends itself to addressing the preceding three points. This common core provides the basis of pre-engineering (i.e., lower division) programs that can be taught at two-year institutions, thereby "freeing up" four-year institutions to concentrate on upper division and graduate programs in engineering. Capacity is increased for engineering degrees, costs of engineering degrees are reduced and programs can increase efficiency by concentrating on graduating students from professional programs. Finally, the common core helps increase viability of pre-engineering programs at community colleges by concentrating enrollment in common core courses rather than having to cancel other core course due to low enrollments.

Background

The California Master Plan for Higher Education[4] was implemented in 1960 to provide access and efficiencies in creating an educated workforce by differentiating the mission of the three major entities of the higher education system (see Figure 1). The University of California (UC) system offers bachelors, masters, doctoral and professional degrees as well as providing primary research and public service function with minor teacher credentialing. The California State University (CSU) system offers bachelors and masters degrees with primary responsibility for teacher credentials with minor research and public service functions. The Community College system offers two-year, associate degree programs as preparation for the UC and CSU.

Professional programs such as those for engineering degrees, have posed, and are posing challenges to the Master Plan because of:

- Higher cost of delivery: faculty, facilities, class size.
- Funding that is often not based on cost of doing business.
- Accreditation requirements.
- Space needs for specialized laboratories.
- Acquisition, maintenance and replacement costs of specialized equipment.
- Limitations on type and number of lower division transfer courses.

It is interesting to note that common lower-division core courses in engineering programs used to be the norm across disciplines. However over the past decade or so the common engineering core has eroded or disappeared at many institutions. In the opinion of the authors, some possible reasons for this include:

- As disciplines became more specialized, programs suffered from curricula bloat (i.e., more and more courses were added without regard to streamlining or maximum credits to degree completion).
- Accreditation requirement changes[6] (e.g., EC2000 from Engineering Accreditation Commission [EAC] of Accreditation Board for Engineering and Technology [ABET]), especially for those imposed by discipline-specific professional organizations often required inclusion of focused topics in the upper division courses at the expense of breadth at the lower division.
- When forced to reduce minimum units to degree completion (e.g., 180 quarter units or 120 semester units) and coupled with increasing number of required general education units, programs reduced required common courses in order to concentrate on discipline-specific courses.

Proposed Common Core

With devolution of engineering higher education away from a common core over the past decade, it is time to revisit the reasons for and against the common core.

Some **advantages** of lower-division common core:

- Simplifies academic roadmaps for engineering students who transfer out of or into engineering programs.
- Provides a common "body of knowledge" for engineers regardless of discipline.
- Provides a basis for accepting lower division transfers into upper division-only programs (quality, preparedness, etc.).

- Can speed time to graduation, hence, is more cost effective for the students.
- Provides economies of scale of lower-division curricula (i.e., more students per offered sections).
- Provides a more effective course management and teaching assignment due to the centralized nature of the common core.
- Concentrates enrollment in common core courses, thereby enabling the offering of courses that might have been cancelled due to low enrollment.

Some, tongue-in-cheek, **"disadvantages"** of lower-division common core:

- "Cramps the style" of faculty in specialized disciplines.
- Allows highly-educated (e.g., doctorate-holding) engineering faculty to focus on upper-division and graduate course offerings.
- Allows students to complete their lower-division requirements at less expensive pre-engineering programs often offered in community colleges.
- Gives students more flexibility in taking lower division courses at times and locations that fit their schedules.

In California and the twenty-three-campus California State University system, in particular, some common problems for the sixteen campuses that offer engineering programs include:

- Access-driven admissions normally allow students to "check-a-box" when choosing engineering disciplines without regard to their quality or preparedness.
- CSU admissions process advocates students to transfer with 60 semester units of coursework regardless of applicability of the courses to their major (i.e., general education courses are encouraged). In fact, students with at least 60 semester units of transfer credit are automatically eligible for admission to any CSU campus for which they apply, regardless of major, as an upper-division transferee.
- These upper-division transfer students are many-times disillusioned because they often lack the necessary engineering cores course they enter as university juniors but as engineering freshman.
- Poor or non-CSU system-based articulation of courses confuses, misleads and/or misinforms community college counselors and students alike.

Table 1 "Traditional" Common Core Courses (fundamentals and engineering)

Traditional Common Core (Fundamentals)	**Traditional Common Core (Engineering)**
Calculus 1 (4 semester units)	Freshman Design (3 semester units)
Calculus 2 (4 semester units)	Introduction to Graphics (3 semester units)
Calculus 3 (4 semester units)	Intro to Materials (3 semester units)
Differential Equation (3 semester units)	Statics (3 semester units)
Physics 1 Lecture (3 semester units)	Dynamics (3 semester units)
Physics 1 Laboratory (1 semester units)	Mechanics of Materials Lecture (3 semester units)
Physics 2 Lecture (3 semester units)	Mechanics of Materials Laboratory (1 semester units)
Physics 2 Laboratory (1 semester units)	Circuits Lecture (3 semester units)
Chemistry 1 Lecture (3 semester units)	Circuits Laboratory (1 semester units)
Chemistry 1 Laboratory (1 semester units)	Computer Programming (3 semester units)
Chemistry 2 Lecture (3 semester units)	Thermodynamics (3 semester units)
Chemistry 2 Laboratory (1 semester units)	
Total (31 semester units)	Total (29 semester units)

Grand Total=60 semester units

The common core for engineering disciplines can be separated into two major components: fundamental and engineering. From a degree standpoint, all engineering students, regardless of discipline, complete the two components of the common core as lower division students before completing degree requirements as upper division in a third component of discipline-specific courses. A representative listing of a "traditional" common core is shown in Table 1.

The evolution of accreditation requirements such as EC2000 from EAC for ABET[6] has encouraged more interaction with constituents of engineering programs. This has resulted in shifts in focus and emphasis to both technical and non-technical (i.e., "soft-skills") coursework in engineering degree programs. Therefore, a proposed common core is shown in Table 2.

Note that although this common appears to increase the number of semester units, attention is qualitatively focused on the topics, not quantitatively on units. The essential focus of the common core should be on answering the question "What is the critical foundation (both fundamentals and engineering) all lower-division engineering students will bring with them into their upper division studies regardless of engineering discipline?"

Table 2 Proposed Common Core Courses (fundamentals and engineering)

Traditional Common Core (Fundamentals)	**Traditional Common Core (Engineering)**
Calculus 1 (4 semester units)	Freshman Design (3 semester units)
Calculus 2 (4 semester units)	Introduction to Graphics (3 semester units)
Calculus 3 (4 semester units)	Intro to Materials (3 semester units)
Differential Equation (3 semester units)	Technical Communication (3 semester units)
Probability & Statistics (3 semester units)	Statics (3 semester units)
Physics 1 Lecture (3 semester units)	Dynamics (3 semester units)
Physics 1 Laboratory (1 semester units)	Mechanics of Materials Lecture (3 semester units)
Physics 2 Lecture (3 semester units)	Mechanics of Materials Laboratory (1 semester units)
Physics 2 Laboratory (1 semester units)	Circuits Lecture (3 semester units)
Chemistry 1 Lecture (3 semester units)	Circuits Laboratory (1 semester units)
Chemistry 1 Laboratory (1 semester units)	Computer Programming (3 semester units)
Life Science 2 Lecture (3 semester units)	Thermodynamics (3 semester units)
Life Science 2 Laboratory (1 semester units)	Engineering Economics (3 semester units)
Total (34 semester units)	Total (35 semester units)

Grand Total=69 semester credits

Note: Highlighted courses are those that can additional satisfy general education requirements.

A flow chart showing the relation of the proposed lower-division common core is shown in Figure 2.

It should be noted that some of the additional courses highlighted in Table 2, (as well as other courses such as Calculus 1 and Chemistry 1) can also be used to satisfy general education (GE) requirements. For example in the CSU, Calculus 1 satisfies GE B4 Quantitative Reasoning, Chemistry 1 satisfies GE B1 Physical Science, Technical Communication satisfies GE A3 Critical Thinking, and Engineering Economics satisfies GE D3 Social Sciences.

It is also noteworthy that the proposed common core satisfies the minimum EAC accreditation requirements from ABET for engineering programs for topics in mathematics and basic science (32 minimum semester units) and goes a long way to satisfying the minimum engineering topics (48 minimum semester units).

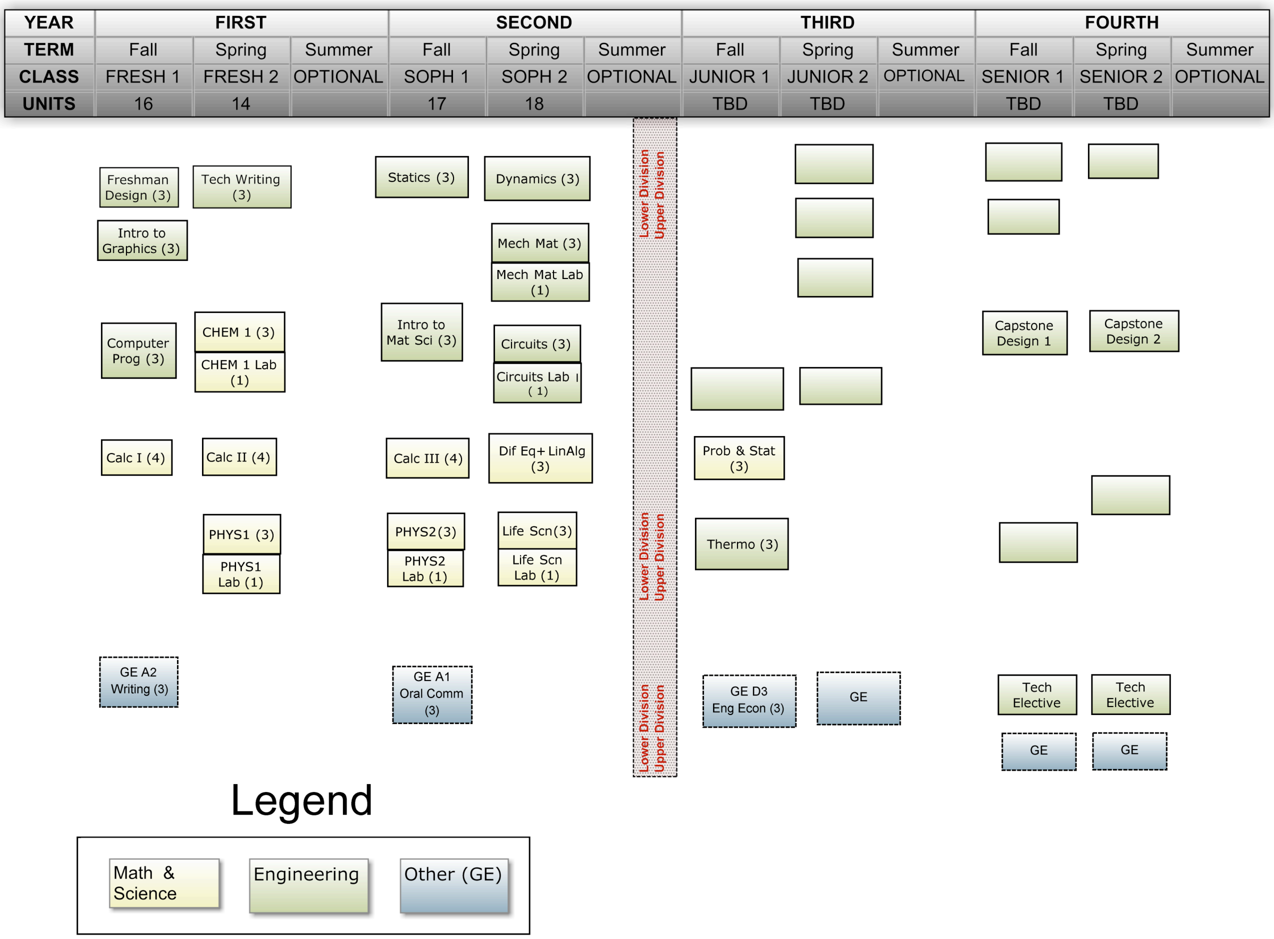

Figure 2 Example of academic flowchart showing common core in lower division engineering curriculum in relation to upper division curriculum

Implementation

Accepting the need for a common core for engineering education, suitably modified to address accreditation requirements and needs of the profession, including those that are discipline specific, some suggested steps to implement a common core are as follows.

- Create local coalitions of 4-year and 2-year engineering schools (e.g., the proposed Central California Engineering Education Coordination Council that involves the Lyles College of Engineering at California State University, Fresno and its five ABET-accredited engineering programs and the pre-engineering programs at College of the Sequoias, Fresno City College, Reedley College, West Hills College, and Willow International Center).
- Identify common core courses (fundamentals and engineering).
- Create a common numbering and naming system for common core courses.
- Articulate common core courses and list in assist.org along with academic roadmaps.

- Reconfigure upper division programs in disciplines to accommodate common core courses and reduce credits to graduation.

Conclusions

This paper has addressed some factors that have led to the gradual erosion of the lower-division core curriculum and the effects that these curriculum changes have on students, faculty, and pre-engineering programs. In addition, the paper explored the implications on the future of the engineering educational system, the cost to taxpayers, and the system's effectiveness at producing the engineers that are needed to ensure the viability of the engineering profession.

Some salient conclusive points include the following:

- Common course core for engineering education is required to better prepare well-rounded 21st century baccalaureate engineers for practice in a global profession (note: discipline specialization can still take place in upper division courses and can be accentuated in graduate programs).
- Common course core allows more transfer students to complete all lower division courses in less expensive and more flexible pre-engineering programs offered by community colleges.
- Common course core strengthens pre-engineering programs at community colleges by concentrating enrollments in these courses, thereby providing sufficient enrollment for these courses to run regularly and predictably.
- Common course core allows four-year institutions to concentrate on upper division and graduate engineering programs.
- Common core courses, transfer issues, academic roadmaps, etc. can be addressed by local teams of educators such as the proposed Central California Engineering Education Coordination Council.

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Biographical

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Thomas L. Nguyen is a senior consultant at Levitas Consultants. Dr. Nguyen received his BSME from California State Polytechnic University, his MSME from University of California, Davis and his PhD from Purdue University. He has over ten years of industry experience in design, analysis, product development and testing with companies that include Aerojet Techsytems Company, TRW Electronic Systems Group, Bendix Oceanics Division, Keebler Company, and MHCI. In addition, his academic experience includes such universities as University of California, Merced, University of Portland, Bucknell University, California State University, LA, and California State University, Fresno. His research and teaching interests include design, manufacturing, CAD/CAM, vibrations, measurement and control systems, mechatronics, and materials engineering.