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Vertical Integration of the Liberal Arts in Engineering Education

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Vertical Integration of the Liberal Arts in Engineering Education

WIP: Implementation of Project

Abstract

The objectives of our educational research are as follows: 1) Faculty from engineering and faculty from the social sciences and humanities shall develop strong working relationships and together implement and evaluate strategies for working across disciplines. 2) Students of engineering and their counterparts in the liberal arts and humanities shall engage in peer-to-peer learning and work together to solve problems. 3) Liberal arts and humanities content will be better integrated into the engineering curriculum. 4) Engineering students will understand the value and relevance of their General Education. 5) The engineering programs will be better positioned to assess their performances on the "soft skills" ABET outcomes (above) and improve these performances.

We plan to accomplish the objectives of this initiative through the following strategies: 1) Establish Faculty Learning Communities (FLC) within each campus, comprising approximately 12 faculty in total taken from engineering and a number of different disciplines within the humanities. 2) Utilize and expand existing G.E. Paths to meet the needs of engineering students and the goals of this program. 3) Create new minor in Urban Sustainability/Citizenship/Engaged Citizen and incentivize engineering students to take it through advisement. 4) Identify engineering courses with potential for liberal arts integration and adopt a variety of strategies (team teaching, FLC development, online modules) for accomplishing this. 5) Develop new courses for engineers that integrate liberal arts using FLCs.

Keywords
Liberal arts, engineering education, faculty learning communities, general engineering paths, sustainability

Introduction

Engineers are charged with creating, developing and implementing technological solutions to contemporary challenges, and innovating solutions for tomorrow's. Yet, engineering training is primarily focused on comprehension of the mathematical, physical and sometimes, chemical equations governing the behavior of systems and their components and applications of these, often with little attention to humanistic inquiry. This can lead to engineers who are not trained to think critically about human and social dimensions of challenges nor integrate them fully in decision making. The Teagle Foundation plans to address this problem through their "Liberal Arts in the Professions" program [1], in which liberal arts education will be embedded into the curriculum of undergraduates preparing for the professions. Under this project faculty will be able to develop a suite of measures to integrate liberal arts teaching into the undergraduate engineering curriculum.

Over summer 2015, during the planning phase of this project, faculty teams from the four campuses (California State University Northridge, Los Angeles, Chico, and California State

Polytechnic University Pomona) have met with each other and held discussions and meetings on their own campuses to evaluate the feasibility, utility and efficacy of a variety of approaches to the integration of the arts into their engineering programs. At the conclusion of this phase we have developed plans for implementation on each of the four campuses with common goals utilizing common and shared strategies where possible. The independent nature of each campus makes the development of a single common strategy to meet the goal infeasible, but there are many commonalities across campuses, which together with opportunities for future course sharing capability across the CSU system that facilitate the development of a common structure into which each campus can fit.

In revising or extending the curriculum of engineering students it is particularly important to pay attention to the unit demands of the major and the timely graduation of undergraduates. Engineering degrees are some of the most demanding in terms of course requirements and pre-requisites. Because so many students arrive on campus under-prepared in mathematics, English, chemistry and physics, remedial courses in these disciplines are often required which extend time to graduation. Without developmental courses, engineering degrees typically require 120 – 130 units of coursework.

Table 1. Number of semester units required for degree

University	Northridge	Los Angeles	Chico	Pomona
Engineering Management	120	N/A	N/A	123
Manufacturing Systems Engineering	121		N/A	123
Civil Engineering	127-128	129	128	128
Construction Management	127	N/A	120	N/A
Mechanical Engineering	126	129	127	130
Electrical Engineering	126	129	127	128
Computer Engineering	123	N/A	126	128
Computer Information Technology	120	N/A	120	123
Computer Science	120	120	120	123
Sustainable Manufacturing	N/A	N/A	120	130
Computer Animation	N/A	N/A	120	123
Concrete Industry Management	N/A	N/A	120	N/A
Mechatronic Engineering	N/A	N/A	128	N/A

Add to this preparatory courses in English, algebra, geometry, trigonometry, chemistry, and/or physics and the total number of units quickly escalates to the university's 140-unit cap, which restricts a student's ability to add electives, a minor or a second major. Typical time to graduation is five or six years. Thus, we seek solutions to integrate humanities and social sciences into the curriculum without significantly increasing the number of units to graduation.

There are obvious benefits of producing engineers who are critical thinkers, engage in humanistic inquiry, have awareness of ethical and social justice issues, and are innovators and good citizens. In fact, these qualities have been included in the "A to K" learning outcomes defined by the Accreditation Board for Engineering and Technology (ABET) for all engineering

programs [2]. Of these eleven learning outcomes, there are four that are most relevant to liberal studies education:

(f) an understanding of professional and ethical responsibility;
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
(i) a recognition of the need for, and an ability to engage in life-long learning;
(j) a knowledge of contemporary issues

These four outcomes correspond to the so-called "soft skills" required by engineers, as opposed to "hard skills" such as knowledge of engineering science and mathematics. Taken together, they define the ways that engineers must understand the relationship between their professional practice and its impact on society at large.

In November 2014 the ABET Board of Directors approved changes to these criteria as follows [3]:

1) An ability to use the principles of science and mathematics to identify, formulate and solve engineering problems.
2) An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet constraints and specifications. Constraints and specifications include societal, economic, environmental, and other factors as appropriate to the design.
3) An ability to develop and conduct appropriate experimentation and testing procedures, and to analyze and draw conclusions from data.
4) An ability to communicate effectively with a range of audiences through various media.
5) An ability to demonstrate ethical principles in an engineering context.
6) An ability to establish goals, plan tasks, meet deadlines, manage risk and uncertainty, and function effectively on teams.

Although the new criteria have not currently been approved by the ABET Board, the one-year comment period has expired and it is likely that the new outcomes, or a slightly revised version of them, will be instituted soon. We do not anticipate the proposed changes having any effect on this proposal or on our efforts to incorporate liberal arts thinking into the engineering program.

All accredited engineering programs are required to demonstrate, via their assessment process, that their students have sufficient mastery of all learning outcomes. The four outcomes listed above (f, h, i, j) are often the most difficult to assess, given that relevant coverage of these topics is spread diffusely throughout required major courses, and may not be well represented by specific assignments completed by students. We anticipate a similar challenge with new outcomes (2, 4, 5, 6). While courses taken for General Education can clearly contribute to the mastery of these outcomes, the current GE structure does not lend itself well to a coordinated assessment of engineering student performance in these areas as students tend to select their General Education courses to fit their schedules rather than to accomplish a coherent path or learning strategy.

2. Methodology

The objectives of this initiative were accomplished through the following strategies. Each campus will pursue some, but not necessarily all, of these.

1) Establish Faculty Learning Communities (FLC) within each campus, comprising approximately 12 faculty in total taken from engineering and a number of different disciplines within the humanities.
2) Utilize and expand existing G.E. Paths to meet the needs of engineering students and the goals of this program.
    a. identify existing GE Paths that would be a good fit for our objectives
    b. if only a subset of courses in a path is desirable, identify that subset
    c. if new courses need to be added to a path work with faculty to meet Student Learning Objectives (SLOs) and include in path
    d. identify any new courses that should be created for a path, and develop these
3) Create new minor in Sustainable Innovation and incentivize engineering students to take it through advisement
4) Identify engineering courses with potential for liberal arts integration and adopt a variety of strategies (team teaching, FLC development, online modules) for accomplishing this.
5) Develop new courses for engineers that integrate liberal arts using FLCs.

2.1. Establish Faculty Learning Communities (FLCs)

The goal of the program is to educate students to become citizen engineers who are capable of applying critical thinking and problem solving to identify and address a broad range of engineering challenges both in their professional roles and as citizens in their local and global communities. The citizen engineers should be able to appreciate the social, cultural, and ethical dimensions of their profession and be able to communicate effectively to both technical and non-technical communities.

This will be the goal of the Faculty Learning Communities established under this strategy. In creating FLCs, we will attempt to answer the following research questions:

- Can an FLC structure be established that 1) develops strong relationships between the liberal arts and engineering faculty, 2) provides strategies for teaching liberal arts within engineering, and 3) provides foundational thematic knowledge (e.g. foundation knowledge of urban sustainability)?
- Can a thematic structure such as sustainability/citizenship be used as a vehicle for embedding liberal arts into the profession?
- Can the same FLC structure be successfully applied to different parts of the curriculum in order to embed liberal arts across the curriculum?
- How can the relationships, knowledge, and skills gained in the FLCs be sustained and broadened to include to all faculty involved in teaching the identified courses and minor?

FLCs will be created under this grant and be responsible for the following tasks:

- Integrate liberal arts into core major courses (Engineering Ethics, Engineering Economics, and Technical Writing) (Strategy #4)
- Integrate liberal arts into “bookend” courses: Introduction to Engineering and Technology and Professional Practice Program (Senior Design) (Strategy #4)

- Create an interdisciplinary minor that brings together engineering and liberal arts majors (Strategy #3)
- Bring together faculty from all courses within a given G.E. Path to discuss ways to improve the path and ensure cohesion (Strategy #2)
- Identify potential new courses for engineers that would integrate liberal arts thinking

FLCs will meet twice per semester and discuss critical thinking and problem solving from a liberal arts perspective and an engineering perspective. They will discuss existing course outcomes and how to relate these to ABET outcomes, and discuss and identify related curriculum and effective teaching pedagogies.

FLCs will include faculty from the Sustainability Center, Philosophy, English, Engineering, Economics, faculty teaching G.E. courses popular with engineering students, faculty teaching Technical Writing or Communications classes. Both full-time faculty and part-time faculty will be included, and support from existing Centers for Effective Teaching (or similar) from each campus will assist in supporting the Communities. In the case of campuses pursuing G.E. Paths, an FLC will be created for each path. For all campuses there will be an FLC created to develop the minor. Each FLC has a suggested size of 12.

Table 2 Three FLCs models on each campus

University	Northridge	Los Angeles	Pomona
Approach	Integrating liberal arts and engineering with a G.E. Path theme (Social Justice, Sustainability or Global Studies)	Integrating Liberal Arts Across the Curriculum with an Urban Sustainability Theme	Integrating Liberal Arts into upper level engineering courses with the energy Theme
FLC I Focus		Integrating Liberal Arts into Engineering Core Courses including Engineering Economics, Engineering Ethics, and Technical Writing	Integrating Liberal Arts into Engineering Ethics (Course: EGR402)
FLC I Participants		Urban Sustainability Center Faculty, Philosophy Faculty, English Faculty, Engineering Economics Instructors, Engineering Ethics Instructors, Technical Writing Instructors	Philosophy Faculty, History Faculty
FLC II Focus		Integrating Liberal Arts into Introduction to Engineering and Technology Course and Senior Design Courses	Integrating Liberal Arts into Senior Design Courses (EGR481 & 482)
FLC II Participants		Faculty from Urban Sustainability Center, Intro to	Faculty from Liberal Arts (such as

		Engineering and Technology Instructors, Senior Design Faculty, Faculty from Liberal Arts (such as sociology, philosophy, economics)	sociology, philosophy, economics), Faculty from Engineering
FLC III	Developing a minor in Citizenship for all majors that will meet G.E. requirements for engineering majors	Developing an Interdisciplinary Urban Sustainability Minor for STEM and Liberal Arts Majors	Redeveloping energy Sustainability minor for Science & Engineering students
FLC III Participants	Faculty from G.E. Paths and Engineering faculty	Broad call to faculty in Humanities, Social Sciences, Science, Math, Technology, and Engineering including faculty from Urban Sustainability Center	Call to faculty in Humanities, Social Sciences, Science, Math, Technology, and Engineering

2.2. Utilize and expand existing G.E. Paths

Due to the heavy unit load that exists for engineering undergraduates one of the best strategies for integrating liberal arts and humanities into the experience of engineering students is through the optimum use of General Education (GE). Because each campus has slightly different GE requirements and engineering curriculum partially fulfils these in different ways, our program design will be flexible enough to accommodate these. Below is a table showing the GE requirements of each campus and which of these are met by the existing engineering curricula.

Table 3 GE requirements of each campus

	# units required (a)	# units met by major (b)	# units to be met within GE (c)
Northridge	**48**	**20**	**28**
• Basic Skills (Section A) – Reading and Writing, Oral Communication	12	6	6
• Natural Sciences (Section B)	8	8	0
• Arts and Humanities (Section C)	6	0	6
• Social Sciences (Section D)	6	3	3
• Lifelong Learning (Section E)	3	3	0
• Comparative Cultural Studies (Section F)	6	0	6
• U.S. History and Government	6	0	6
Chico	**48**	**28**	**20**

• Oral and Written Communication, Critical Thinking, Quantitative Reasoning (Group A)	12	12	0
• Natural Sciences with Laboratory (Group B)	6	6	0
• Arts and Humanities (Group C)	6	0	6
• Individual & Society and Societal Institutions (Group D)	6	4	2
• Learning for Life (Group E)	3	3	0
• Upper-Division General Education Pathway	9	3	6
• American Institutions	6	0	6
Pomona	**45**	**11**	**34**
• Basic Skills (Area A) –Communication & Critical Thinking	9	3	6
• Mathematics & Natural Sciences (Area B)	11	8	3
• Humanities (Area C)	10	0	10
• Social Sciences (Area D)	12	0	12
• Lifelong Understanding & Self Development (Area E)	3	0	3

General Education paths have been designed and developed at some CSUs (including CSU Northridge and Chico) to provide coherence between what can appear as a smorgasbord of unrelated courses, and bring relevance to the general education experience of undergraduates. This is particularly important for engineers who may not understand the importance of general education and how it fits in with their work. The paths of Social Justice, Sustainability Principles and Global Studies are particularly relevant to this program's objectives and help bring context and critical thinking to such issues as understanding cultures that are part of the global supply chain, social and environmental justice, religion, ecology etc. G.E. paths include course offerings at the freshman, sophomore and junior levels.

In addition, we have identified other G.E. courses that would be desirable to include in existing G.E. paths. Under this grant, we plan to work with the faculty teaching the courses to integrate content that allows SLOs to be met, and engage the faculty in our FLC.

Where existing courses that meet our needs do not exist, we plan to develop new G.E. courses that connect the liberal arts and engineering, which can be team-taught by faculty from those disciplines. Course development will take place through a FLC.

2.3. New minor in Sustainable Innovation

A new minor, Sustainable Innovation, which meets the goals of this program will be developed. The new minor Sustainable Innovation will include technological, environmental, economic and social aspects of innovation. The technological innovation will be covered in the modified engineering curriculum, while environmental, economic and social aspects of innovation will be focused through the well selected General Education courses in the new minor program. Current engineering students just took the General Education randomly and can't be fully beneficiated

through the GE. Through the new minor, the knowledge of liberal arts for engineering students will be well prepared through the well-designed program. It will include the following elements:

- societal impacts of technology
- critical thinking
- problem solving in a societal context/holistic thinking
- understanding other cultures and working in a global society
- communicating effectively to a range of different audiences, including non-technical ones
- working in teams that include members from non-technical disciplines
- understanding how human activities impact the environment and take active rule into becoming part of the solution
- exploring ideas and concepts from different perspectives through working in a multidisciplinary environment

The minor will be developed through a community of faculty working across disciplines within our campuses, which will comprise our faculty learning community (FLC). The minor will be composed of 18 semester units, of those 9 would be upper division (300 Level or above). Campuses will agree on common objectives, core competencies and elements of the minor (above). Each campus may choose its own curriculum offerings to meet these. Although each campus will manage their individual curriculum, they will accept course offerings from across the CSU system through articulation agreements with other CSUs and with the Community College system for lower division courses.

All campuses will develop a capstone which will comprise the design/development of a solution for a specific problem by a team of students from a variety of disciplines working together. For example, this could be a solution for a problem in the developing world which has the capacity to include many elements of liberal arts, humanities and social sciences such as historical context, anthropology, geopolitics, economics, sustainability, environment, politics and political structure and a complete understanding of the society's culture and ethics. Engineering solutions are but one piece of the project solution, and students will work in teams with others from different disciplines.

The minor will fulfil the GE requirements for engineering students while adding the benefit of a coherent path and learning opportunities incorporating the elements delineated above. It is possible that the minor we propose here would fall within the structure of the new system-wide sustainability minor that is currently in development at the Chancellor's Office. That minor will have a common gateway course which covers the broader issues of human environmental interactions and their consequences, one course in each of 3 core competencies: Earth Sciences, Technological and the Built Environment; Socio-economic Institutions, Policy and Equity; and Communication, Culture and Ethics, an additional course within these competencies, and a capstone project which provides an authentic civic engagement opportunity. We will continue to work closely with the Chancellor's Office on aligning the priorities and structures of these two initiatives so that each can benefit from the pool of resources made available (including course development, video and multimedia formats, course sharing, and the associated FLC). If our minor can be aligned with this structure, there would be added capability to offer across the entire CSU system and to share course modules created by all campuses.

2.4. Identify engineering courses with potential for liberal arts integration

There is potential for integration of humanities into some common existing engineering courses, but these courses differ from campus to campus. These modules include topics: ethics, environmental economics. The major focus is on integrating the *Ethics, Innovation, Civic Engagement, Global Cultures, Science and Society* etc. into the existing upper division courses such as EGR 402/403, EGR 481/482. Specifically, Integrating Liberal Arts into Senior Capstone Design will be the main theme. Three major tasks will be performed by active collaboration with faculty members from Social Sciences, Liberal Arts and Humanities. Seminars will be arranged at the beginning of the semester. History, philosophy, sociology, economics, political science, geography, and anthropology will be covered. Learning outcome due to the introduction of liberal arts in the upper level engineering courses will be evaluated.

3. Conclusion

Followed by the methodology developed in this manuscript, the following achievements are expected to be accomplished:

- Faculty from engineering and faculty from the social sciences and humanities shall develop strong working relationships and together implement and evaluate strategies for working across disciplines.
- Students of engineering and their counterparts in the liberal arts and humanities shall engage in peer-to-peer learning and work together to solve problems.
- Liberal arts and humanities content will be better integrated into the engineering curriculum.
- Engineering students will understand the value and relevance of their General Education.

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