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Prototype to Production: Conditions and Processes for Educating the Engineer of 2020 (NSF DUE-0618712)

Influences on Engineering Faculty Members' Emphasis on Interdisciplinarity in Undergraduate Courses

1 Problem Statement

Solving many of today's technological and social challenges will require interdisciplinary thought and action (NIH, 2006), and the growth of interdisciplinary engineering programs suggest that the field is acknowledging its role in preparing students to tackle these complex problems and develop innovations that will advance quality of life, economic growth, and national security (Coso and Bailey, 2010). Efforts to enhance students' interdisciplinary knowledge and skills include the development of interdisciplinary design courses through the NSF-funded SUCCEED Coalition and ABET's later accreditation mandate for undergraduate programs to prepare new engineers to work on multidisciplinary teams (Ollis, 2001).

Richter and Paretti's (2009) review of engineering journals and conference proceedings identified more than 1,500 articles on interdisciplinary courses and projects published in an 8-year time-period. During this same period, two reports on engineering education—*The Engineer of 2020* (2004) sponsored by the National Academy of Engineering and *Creating a Culture for Scholarly and Systematic Innovation in Engineering Education* (Jamieson & Lohmann, 2009) published by American Society for Engineering Education—placed the responsibility and challenge of promoting the development of future engineers' interdisciplinary habits of mind on engineering faculty.

2 Research Design

Our analysis draws on a nationally representative data set of 31 four-year institutions that allowed us to examine the extent to which engineering faculty members emphasized interdisciplinary skills and content in undergraduate courses.

Data Collection Strategy:

- Six national surveys assessing the alignment of undergraduate programs with the vision of *The Engineer of 2020*
- 86 undergraduate programs in 31 institutions

Stratified, random sample of institutions, including:

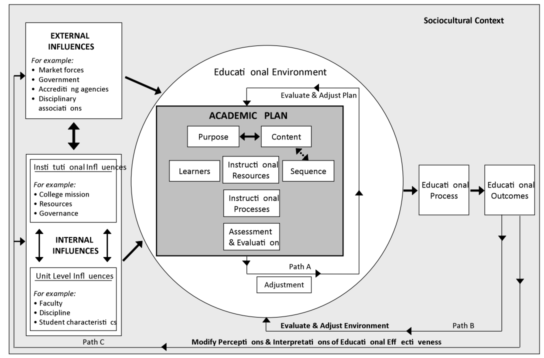
- 7 engineering disciplines (biomedical, chemical, civil, electrical, general, industrial, mechanical)
- Public/private institutions and 3 levels of highest degree offered
- Including 5 minority-serving institutions

Response Rate: 38%

- 1,119 usable surveys from 2,942 faculty members contacted
- 987 tenure-track or tenured faculty (for this analysis)

3 Conceptual Framework

The Academic Plan in Context



Lattuca & Stark (2009)

The Academic Plan model (Lattuca & Stark, 2009) serves as the conceptual framework for this study. The model posits that a variety of factors, both internal and external to faculty and their institutions, influence faculty as they plan and design courses

We focus specifically on faculty members' personal characteristics (such as gender and rank), teaching and industry experiences, disciplinary training, and beliefs about education, on their emphasis on interdisciplinary topics in a course they regularly teach. These factors are captured at the "unit-level" in the academic plan model.

4 Participating Institutions

Research Institutions:

Arizona State University (Main & Polytechnic)[a]
Brigham Young University
Case Western Reserve University
Colorado School of Mines
Dartmouth College
Johns Hopkins University
Massachusetts Institute of Technology[a]
Morgan State University[b]
New Jersey Institute of Technology
North Carolina A&T[b]
Purdue University
Stony Brook University
University of Illinois at Urbana-Champaign
University of Michigan[a]
University of New Mexico[c]
University of Texas, El Paso[c]
University of Toledo
Virginia Polytechnic Institute and State University[a]

Master's/Specialized Institutions:

California Polytechnic State University[c]
California State University, Long Beach
Manhattan College
Mercer University
Rose-Hulman Institute of Technology
University of South Alabama

Baccalaureate Institutions:

Harvey Mudd College[a]
Lafayette College
Milwaukee School of Engineering
Ohio Northern University
Penn State Erie, The Behrend College
West Virginia University Institute of Technology

[a] Institution participating in the companion qualitative study
[b] Historically Black College or University
[c] Hispanic-Serving Institution

5 Sample Descriptives

Variable	Mean/Proportion
Gender	86% male 14% female
Race/Ethnicity	55% white 9% Asian American 4% underrepresented minority[2] 32% other[3]
Engineering department	6% biomedical/bioengineering 11% chemical 17% civil 45% electrical 7% industrial 7% mechanical 20% other
Faculty rank	48% full professor 27% associate professor 25% assistant professor
Type of course taught most often	90% teach fundamental science or math course, or required or elective engineering course 10% teach first-year or capstone design course
Years teaching at the college level	17.2 years (standard deviation: 12.1 years)
Years in industry while faculty	3.6 years (standard deviation: 6.3 years)
Years in industry before faculty	3.7 years (standard deviation: 4.8 years)

6 Dependent Variable: ID Emphasis

Interdisciplinarity course emphasis scale (alpha=.86)

In this course, how much do you emphasize?[1]

- Making explicit connections to knowledge and skills from other fields.
- Integrating knowledge from engineering and other fields to solve engineering problems.
- Applying knowledge from other fields to solve an engineering problem.
- Understanding how an engineering solution can shape/be shaped by environmental, social, cultural, political, legal, economic, and other considerations.
- Understanding how non-engineering fields can help solve engineering problems.

[1] 1=Little/No emphasis, 2=Slight, 3=Moderate, 4=Strong, 5=Very Strong, 6=Not applicable

7 Control Variables

Gender (ref=male)
Asian American (ref=White)
Underrepresented Minority (ref=White)
Other race (ref=White)
Biomedical/bioengineering (ref=electrical)
Chemical engineering (ref=electrical)
Civil engineering (ref=electrical)
General engineering (ref=electrical)
Industrial engineering (ref=electrical)
Mechanical Engineering (ref=electrical)
Other discipline (ref=electrical)
Faculty rank
Course type: design (ref=All others)
Years teaching at the college level
Years in industry while faculty
Years in industry before faculty

8 Independent Variables

To what extent do you agree or disagree with the following statements about undergraduate engineering education?

- Humanities and social science courses are important in preparing engineers
- Interdisciplinary learning should be part of the engineering curriculum
- The engineering workplace requires systems thinking
- Concepts of sustainability should be a major focus of the undergraduate curriculum.

To what extent do you agree or disagree that the engineering curriculum should:

- Teach students about intercultural communication
- Teach students to consider all relevant factors (e.g., social, cultural, environmental) in designing solutions
- Prepare students to assume community leadership roles
- Prepare students to work effectively across national and cultural boundaries
- Develop students who can think like entrepreneurs
- Provide opportunities for students to prepare for occupations other than engineering (e.g., business, medicine, law)

Do you agree or disagree that as a teacher, it's your responsibility to:

- Ask students to make connections across engineering disciplines
- Help students consider the world from multiple perspectives
- Prepare students for the role of citizen
- Understand the value of diversity in its many forms (e.g., ideas, cultures, gender)
- Help students understand the value of a liberal education

[1] Scale, where 1=Strongly disagree, 2=Disagree, 3=Neither agree nor disagree, 4=Agree, 5=Strongly agree

University of Michigan

9 Results and Discussion

Overall, engineering faculty reported a **moderate emphasis on interdisciplinarity (mean=3.01; std. dev.= .97)**, and a number of variables are positively associated with this emphasis.

Disciplinary affiliation is one of several influences on interdisciplinary course emphasis in engineering, but not the strongest one.

Regardless of discipline, **industry experience** is associated with a greater emphasis on interdisciplinarity in engineering and may provide faculty with ideas about interdisciplinary connections and illustrations.

Teaching design courses is even more strongly associated with an emphasis on interdisciplinarity than work experience, and is one of the strongest relationships identified in this analysis.

The **belief that sustainability should be a major focus** on the undergraduate curriculum is strongly related to an emphasis on and may provide a practical suggestion for increasing attention to interdisciplinarity since sustainability can be incorporated into the design process via a triple bottom-line consideration.

Significant results

VARIABLES	Model 1: Controls	Model 2: Controls + Ind. Var.
CONTROLS	p<.05	p<.05
Biomedical/bioengineering (ref=electrical)	+	+
Civil engineering (ref=electrical)	+	
Industrial engineering (ref=electrical)	+	+
Mechanical Engineering (ref=electrical)		+
Other discipline (ref=electrical)	+	
Course type: design (ref=All others)	+	+
Years in industry while faculty	+	+
INDEPENDENT VARIABLES		
Statements about Undergraduate Education:		
Interdisciplinary learning should be part of the eng curriculum		+
Concepts of sustainability should be a major focus of the undergrad curric		+
Responsibility as Teacher:		
Ask students to make connections across engineering disciplines		+
Help students consider the world from multiple perspectives		+
Understand the value of diversity in its many forms (e.g., ideas, cultures, gender)		+
ADJUSTED R-SQUARED	0.10	0.26

Among the strongest relationships: Believing that it is **one's responsibility as a teacher to ask students to make connections** across engineering disciplines, and to help students understand the world from multiple perspectives. Faculty who believe it is their **responsibility to teach about diversity** in terms of race, gender, and culture report making interdisciplinary connections in their courses, but these topics do not appear widespread across the engineering curriculum

NEXT PHASE OF OUR RESEARCH: Examine the influences identified as significantly related to faculty members' emphasis on interdisciplinarity in their courses (i.e., the findings of this study) alongside "external" and "institution level" influences that are also potential curricular influences to provide a fuller picture of the factors related to faculty members' decisions to emphasize interdisciplinarity in their undergraduate courses.

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