AC 2012-4029: INSTITUTIONAL DISCOURSES IN ENGINEERING EDUCATION AND PRACTICE

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Institutional discourses in engineering education and practice

Abstract

An individual's identity is shaped by socially situated discourses—communications, interactions, language, objects, symbols, tools, ways of thinking, values, and beliefs. Discourses promoted by organizations that educate and employ engineers identify what it means to belong to the engineering profession, what an engineer should know, what values they should hold, and how they should act. This study employed qualitative content analysis to identify engineering discourses communicated by two types of organizations (i.e., universities and companies) through their websites. Findings illustrate that such institutions are clearly using their websites to promote discourses relating to their visions of engineering and what it means to be an engineer. This study begins to address the social construction of engineering identity through discourses promoted by institutions which contribute to defining engineering practice. Future work will explore the impact of these discourses on students.

Introduction

An individual's identity is formed by being recognized as a "certain kind of person" within a given context. Identities are created through discourses—socially recognizable actions, communications, interactions, language, objects, symbols, tools, ways of thinking, values, and beliefs[1]. One of the ways that engineering students are identified, or identify themselves, is through the values and objectives promoted by organizations that have a stake in engineering education. Discourses promoted by organizations that educate and employ engineers identify what it means to belong to the engineering profession, what an engineer should know, what values they should hold, and how they should act. These discourses can influence students' decisions to pursue and persist in engineering education as well as the kinds of careers that students pursue after graduation. In this study, we examine discourses about engineering identity promoted through the webpages of universities and companies. These public discourses are used to attract future students and employees, and, in an educational context, they communicate the outcomes that students are expected to achieve. This study is part of a larger study of engineering problem solving at a large public university in the United States, using materials engineering as the specific context. In future work, the discourses identified in this study will be compared to discourses acted out by students in an engineering problem solving setting.

Identity has recently emerged as a topic of interest in engineering education research and is linked to an increasing focus on situative learning in engineering education[2]. A situative perspective of learning views knowledge as distributed between people and constructed in a social context. As a result, socio-political discourses within a learning community are seen to influence students' identity construction and learning trajectories.

Within the engineering education literature, discussions of identity tend to focus on the socialization of students into the academic environment and into the profession. Implicit in the literature is concern that identity affects students' persistence in engineering education and preparation for participation in the engineering profession[3,4]. Du[3], for instance, argues that students must "develop a sense of belonging to the engineering profession in order to prepare themselves for the future workplace." (p. 35) As a result, calls are being made to examine the

"learning context" and "discover the ways in which these contexts allow participants to develop engineering-related identities."[2] (p. 166)

Engineering identity has been examined using a variety of methods. The identities and discourses expressed by undergraduate engineering students have been studied within campus cultures[5], within student design teams[3,4,6–8], as revealed in student portfolios[9], and from the perspective of an individual minority student[10]. Engineering identity has also been approached from a number of different perspectives: elementary school students have been asked for their conceptions of engineering identity[11]; engineering identity has been examined from national and historical perspectives[12]; engineering faculty members have been asked for their perspectives on engineering identity[13]; and engineering identity has been studied with engineers in industry[14]. Several discourses are prominent in this literature. Engineering practice is seen as a systematic problem-solving process involving the application of science and technology[13,15]. Engineering is also seen as goal-oriented and focused on the generation of products and product-oriented techniques[15,16]. Engineering problems are seen as complex and ill-structured, requiring design skills to solve[17].

Engineers in industry have described their work as involving many daily social interactions. However, Trevelyan[14] has found that many engineers think that authentic engineering practice is a solitary technical endeavor. Engineers tend to downplay the social aspects of their work equating engineering practice with "hardcore" activities such as performing calculations and creating engineering models. Travelyan[14] argues that, although the engineering education literature promotes the importance of communication and teamwork skills, there is tacit understanding that these social aspects are positioned somewhere beyond the technical core of engineering.

In engineering courses, the technical aspects of engineering practice often receive greatest emphasis. Hult[16] has noted that in engineering classes relationships between students and faculty tend to be vertical and that two-way communication is not emphasized. The focus in the classroom is on delivery of technical content knowledge to students. Shulman[18], who has written about "signature pedagogies" in various professions, observed both lecture-based and design-oriented engineering courses and noted that in the lecture-based courses there was a lack of interaction between professor and students as well as between students. In the design course that he observed, Shulman[18] found students working in teams and interacting regularly with the instructor. However, the focus of interactions was on technical aspects related to the artifact of design.

Several studies report that engineering students often draw a clear distinction between the classroom and the "real world". For example, Hult[16] argues that, although both freshmen and senior engineering students felt they had a clear notion of engineering knowledge and the engineering profession, they doubted whether the two were linked. In a study using portfolios to examine engineering students' perception of engineering, Dunsmore et al.[6] demonstrated that students consequently did not see school experiences as integral to engineering practice. In studying the development of professional identity among mechanical engineering students in a capstone design course, Dannels[4] found that the design processes exhibited in the classroom were primarily driven and shaped by academic discourses. Although the students were working on projects involving real-world customers, students viewed the instructor and teaching assistants as the most important customers. The primary project goal from the students'

perspective was on getting a good grade. Dannels[4] argues that students are therefore learning to be students and not professionals. Donald[15] notes that in engineering education there is "a continual tug-of-war between the theoretical and the professional." (p. 63) Students often feel that theory is emphasized over practice and wish for more practical hands-on learning experiences. Because of a perceived lack of practical experience, some graduates find the transition to professional practice to be a shocking experience.

Missing from previous literature are studies of discourses about engineering identity promoted by organizations that educate or employ engineers. It is within such organizations that engineering identities are formed and acted out. The goal of this study is to address the gap in the literature and identify discourses about engineering identity promoted by such organizations. We recognize that websites serve a distinct purpose and may not fully represent the values and beliefs of the organizations' members regarding engineering identity. Nevertheless, these websites serve in many ways as the public face of the organizations and thus serve to establish initial impressions about engineering identity and how the organization views its role in engineering. Identifying these discourses will build a foundation for future work which will examine both the discourses that influence engineering more widely and the impact of these discourses on students.

Research Question

> *What discourses about engineering identity are promoted by universities that have undergraduate programs in materials engineering and by companies that employ graduates of these programs?*

Method

Qualitative content analysis was used to search for discourses about engineering identity promoted by universities that educate materials engineering students as well as companies that employ graduates of these engineering programs. Qualitative content analysis is a method of subjective interpretation of textual communications which focuses not only on the content of communicated messages, but also on the context and methods of communication[19,20]. Data for analysis may be derived from transcripts of verbal communications, printed documents, or electronic communications[19]. As with quantitative content analysis, qualitative content analysis can involve pattern identification through code frequencies. From a qualitative perspective, code counts can been seen as a way to "summarize the patterns within what is often a unique data set, as opposed to the very different goals involved in either generalization to larger populations or tests of statistical inference."[21] (p. 116) Qualitative content analysis often relies on inductive code generation, meaning that themes emerge from the data[19]. This study employed inductive code generation because its purpose was to explore organizational discourses relating to engineering identity without imposing preconceptions about these discourses.

The sources of content for this study were the college and departmental level websites of universities that educate materials engineering students and the websites of companies that employ their graduates. Both academic and industry sources were included in this study to allow for comparison between the discourses promoted by the two types of organizations. Explicit statements of vision, mission, values, learning objectives, educational outcomes, or goals were

selected for analysis as these statements were seen to represent succinct and intentional organizational level discourses about engineering identity. At the college level, statements about what it means to be an engineering graduate from each institution were identified. At the departmental level, statements about what it means to be a materials engineering graduate from each department were selected. Broader university level webpages were not searched as it was felt that these webpages would not specifically address *engineering* identity. Discourse statements were extracted from the websites and then in vivo codes were created for each individual discourse. Short descriptive titles were then created for the in vivo codes (typically from a keyword found in each coded phrase). These codes were then grouped into higher level categories and tabulated in Table 3.

Ten universities and ten companies were selected as sources of material for this study. This study is part of a larger study that has been examining the approaches that engineering students take to problem solving. The websites of universities similar to the one attended by participants in the broader study were selected as sources of content. The purpose of selecting universities similar to the one attended by participants in the broader study was to look for discourses that could shape the identities, and subsequently the problem solving approaches, of these participants. Based on this criterion, the universities were limited to large public research universities that offer undergraduate programs in materials engineering. Materials engineering is one of the smaller engineering disciplines and many universities do not have a materials engineering department. Many universities that *do* have such departments offer no undergraduate degrees, but support only Ph.D. programs. Universities were selected that had close rankings in the 2010 U.S News and World Report rankings[22,23] to the university attended by participants in the broader study. In addition to the university attended by participants in the broader study, four institutions were selected that had close rankings in the overall engineering undergraduate program rankings and five institutions were selected that had close rankings for undergraduate materials engineering programs.

Ten companies that hire materials engineering graduates of the universities included in this study were also selected as content sources. Companies were selected to represent a variety of sizes, industry sectors, and types (e.g. service-oriented, production-oriented, or both).

Table 1. Universities included in content analysis.

University	U.S. News Undergraduate Engineering Ranking	U.S. News Undergraduate Materials Engineering Ranking
University of Illinois—Urbana Champaign		2
University of California—Berkeley		3
University of Michigan—Ann Arbor		5
North Carolina State University	26	
Ohio State University	26	
University of Florida	26	8
Georgia Institute of Technology		9
Pennsylvania State University		10
Iowa State University	37	
Arizona State University	40	

Table 2. Companies included in the content analysis.

Company	Ownership	Description
3M	Public	A producer of specialty materials
Bechtel	Private	An international engineering consulting and construction company
Cordis	Public	A medical devices company
Del West	Private	A materials consulting company
GE	Public	An international conglomerate offering technology, services, and financing in the energy, health, transportation, and infrastructure sectors
Kimberly-Clark	Public	A producer of consumer goods
Material ConneXion	Private	A materials consulting company
Schlumberger	Public	A provider of services and equipment for oil exploration and extraction
Timken	Public	A producer of bearings
US Steel	Public	A large steel producer

Findings

Statements of values, missions, goals, and expected outcomes were found on the websites of all organizations included in this study. At the departmental level, ABET outcomes were prominent discourses on university websites. In addition, universities promoted creativity, leadership, service, knowledge creation, and flexibility as important engineering attributes or program outcomes. Companies universally promoted service to customers on their websites and described developing and producing innovative products of quality and value. Many companies also described their ethical practices including valuing sustainability and protecting the environment. A focus on employees was found on many company websites with statements about providing challenging work for employees as well as opportunities for personal development.

Codes that emerged from this study can be found in Table 3. This table includes counts of the number of universities and companies in which each code was found, counts of the codes from university sources, counts from company sources, and total counts of each code. The following sections describe findings in more detail.

University Discourses

ABET outcomes

The accreditation criteria prescribed by ABET, the organization that accredits undergraduate engineering programs, shape the curriculum and learning outcomes at accredited institutions. These accreditation criteria include outcomes that graduates of accredited programs should achieve. All of the universities in this study have accredited undergraduate programs in materials engineering, and at the departmental level, all of the prescribed ABET outcomes were clearly listed on the websites of eight of the ten universities. Although two of the universities provided only partial lists of ABET outcomes, they communicated that, as accredited institutions, they conform to ABET criteria. Some ABET criteria were emphasized more than others. Popular outcomes were: the application of mathematics and science (criteria 3a), teamwork (criteria 3d), problem solving skills (criteria 3e), communication skills (criteria 3g), understanding of the context of engineering problems with particular emphasis on global context (criteria 3h), and lifelong learning skills (criteria 3i). Most of the universities also communicated ABET's materials engineering specific learning objective which describes obtaining an understanding of the relationships between material structure (at the nano/micro levels), characterization, properties, and processing and the design of materials.

Goals that extend beyond the classroom: creativity, leadership, research, service, and flexibility

Universities also presented outcomes and learning objectives for students that went beyond ABET criteria. Innovation and creativity were values espoused by many of the universities. One university's college of engineering stated that, "Our students represent the next generation of engineers who dare to dream." Another stated that, "Our graduates are innovators in a wide variety of technical fields including, but not limited to, materials, energy, electronics, medicine, communications, transportation and recreation."

Leadership was also a word that appeared frequently on university websites. One college of engineering mission was, "To educate men and women for careers of leadership and innovation

in engineering and related fields." And similarly, another college's goal was "to educate creative and productive scientists and engineers in the fundamental principles of the science and engineering of materials, who will provide future leadership in industry, academia and government laboratories." Most engineering colleges also claimed to be leading institutions—leaders in innovation, discovery, and education.

Creating and expanding knowledge, particularly through research, was emphasized by most of the universities. The vision of one college of engineering was "to produce new engineers as well as discoveries and technologies focused on research to enhance the quality of life in the U.S. and beyond," while another college stated that it valued "knowledge creation and scholarship." Although undergraduates are involved in research at many (if not all) of the universities included in this study, none of the university websites specified if undergraduate students were expected to participate in creating and expanding knowledge through participation in research.

Service was a common theme on many university webpages with mission and vision statements describing service to society and, more specifically, the government and the state. This should not be a surprise as all of the universities in this sample were public institutions. One engineering college's mission was, "To benefit the public through service to industry, government, and the engineering profession." Another described their vision as "responding to the needs of our state, the nation and the world."

A few engineering programs added flexibility as an expected outcome for graduates. One engineering college website spoke of providing "a culture that treats change as an opportunity." Another stated the goal of producing graduates who could "adapt to the rapidly changing scientific and technological landscape."

Preparation for careers in industry or academia

Several universities explained that their goals were to prepare graduates for careers in industry or academia. One university stated that their goal was, "To provide students with the necessary foundation for entry-level industrial positions in materials related industries or advanced study programs." Another stated that, "Graduates will have the strong educational foundation in materials science and engineering that promotes success in the broad range of career opportunities available in industry, graduate school, and government."

Broad education and fundamentals

Some engineering programs also had goals that included providing a "broad education" or having graduates who were able to think broadly—generating a wide range of ideas and considering multiple approaches to solving problems. Some of the same programs had the goal of providing an education which emphasized "fundamental knowledge." This kind of knowledge was never explicitly defined; however, statements about fundamental knowledge were typically surrounded by language of a technical nature.

Missing discourses

Several discourses were conspicuously missing from the departmental and college level websites included in this study. Diversity and inclusion are certainly concerns within engineering education. Although several of the college and departmental webpages displayed pictures of

minority students, explicit statements about commitment to diversity and inclusion were absent. Statements about cost, value, and quality were also missing from the websites included in this study. Discourses relating to cost and value may be present on webpages at the university level as tuition rates are typically set at that level. However, the focus of this study was only on college and departmental level webpages.

Industry Discourses

The values espoused by companies were often communicated through individual words or short statements such as: “Communities regard us as responsible”, “people, planet and products”, “building value”, or simply “innovation”, or “excellence”. An often cited article in the Harvard Business Review[24] argues that companies should adopt “a consistent identity that transcends product or market life cycles, technological breakthroughs, management fads, and individual leaders.” (p. 66) As such, the authors argue that companies should adopt only a few core values (usually between three and five) and keep the expressions of these values short and succinct. While most companies in this study presented mission and/or value statements on their websites just as universities did, they clearly did not set learning objectives for employees. The webpages of many companies did, however, describe attributes of their employees. In addition, some made statements supporting the development of their employees such as, “We hire exceptional people and invest in their growth,” and claims to “value and develop our employees’ diverse talents.” One company described valuing “employees’ leadership,” and some companies stressed that they provide employees with opportunities to take “on the world’s toughest challenges.”

Serving customers

Serving the needs of customers or clients was a major theme for companies. This is not surprising as customers provide revenue. One company stated that, “Our success begins with our ability to apply our technologies—often in combination—to an endless array of real-world customer needs.” Companies also emphasized their commitment to providing value to customers through statements such as, “We are dedicated to improving our customers’ performance,” and, “We aim to build value for our customers.”

Developing and producing innovative and quality products

The focus of many companies was on developing and producing products—particularly products of quality. This focus was found in promises to “satisfy our customers with innovative technology and superior quality.” Related to quality was excellence, with statements such as, “[We are] committed to excellence in everything we seek to do.” As with universities, innovation and creativity were common themes along with claims of leadership in their fields. Companies described producing “thousands of imaginative products” and made claims to “continually shape the world with groundbreaking innovations.”

Global

Many companies portrayed themselves as global in reach describing themselves as “world competitive” or touted their presence in more than 160 countries. Others promised to satisfy investors with “global growth,” or described how they “integrate global and local perspectives” to “contribute to a better quality of life.”

Ethical practice and valuing diversity

Many companies also focused on ethical practice, or the ethical practices of their employees, though statements such as, "[We] act with uncompromising honesty and integrity in everything we do," and, "Our heritage is one of honesty, integrity and courageously doing the right thing." Companies not only described their practices as ethical but described their operations as environmentally friendly and sustainable. Companies described their respect for the "social and physical environment around the world," or stated that they "must maintain in good order the property we are privileged to use, protecting the environment and natural resources."

In contrast to the university websites in this study, several companies emphasized their diverse workforces and respect for employees through statements such as, "We value an inclusive culture based on diverse backgrounds, experience, and views," and, "One of our greatest strengths is the diversity of our workforce, with men and women of many nationalities and backgrounds working together and sharing common objectives."

Table 3. Codes and frequency counts.

Code	University Sources	University Counts	Industry Sources	Industry Counts	Total Counts
ABET criterion 3a (Apply math and science)	9	15	-	-	15
ABET criterion 3b (Experiment and interpret data)	9	14	-	-	14
ABET criterion 3c (Design, environment, sustainability)	8	10	-	-	10
ABET criterion 3d (Multidisciplinary teamwork)	9	17	-	-	17
ABET criterion 3e (Problem solving)	9	17	-	-	17
ABET criterion 3f (Ethics)	8	13	-	-	13
ABET criterion 3g (Communication)	9	17	-	-	17
ABET criterion 3h (Global, environmental, societal context)	10	19	-	-	19
ABET criterion 3i (Life-long learning)	9	16	-	-	16
ABET criterion 3j (Contemporary issues)	8	9	-	-	9
ABET criterion 3k (Use modern engineering tools)	8	8	-	-	8
ABET Materials Engineering criterion	7	7	-	-	7
Accountable	0	0	2	2	2

Code	University Sources	University Counts	Industry Sources	Industry Counts	Total Counts
Achievement (of the extraordinary)	0	0	1	1	1
Bridge between science and design	0	0	1	1	1
Broad knowledge	4	4	0	0	4
Challenge	0	0	3	6	6
Collaborative	3	3	0	0	3
Competitive	0	0	2	3	3
Cost and Value	0	0	6	13	13
Create and Expand knowledge (Research)	9	16	2	2	18
Diverse and inclusive	0	0	4	4	4
Efficient	0	0	1	1	1
Environment and sustainability (similar to ABET 3h)	0	0	6	6	6
Ethics (similar to ABET 3f)	0	0	7	7	7
Excellence	1	1	3	4	5
Flexible	4	5	0	0	5
Fundamentals	3	4	0	0	4
Global	1	1	8	18	19
Grow as individual	1	1	2	4	5
High tech	0	0	1	1	1
Independent	0	0	1	1	1
Innovative and creative	7	13	6	12	25
Leadership	6	17	2	2	19
Making things	0	0	6	6	6
Practical experience	2	2	0	0	2
Prepared for industry job	4	5	0	0	5
Prepared for research career	4	5	0	0	5
Productive	1	2	0	0	2
Quality	0	0	6	6	6
Respect	0	0	4	4	4
Rewarding	0	0	2	2	2
Safe	0	0	4	4	4

Code	University Sources	University Counts	Industry Sources	Industry Counts	Total Counts
Science based	0	0	2	2	2
Serve Society	8	13	6	6	19
Serve Customer	0	0	9	17	17
Serve Engineering Profession and Industry	3	3	0	0	3
Serve Government	3	3	1	1	4
Serve University/Academia	3	3	0	0	3
Skilled	0	0	1	1	1
Teamwork	0	0	3	4	4
Technology	0	0	5	7	7
Understand product life-cycle	1	1	0	0	1

Conclusion

Statements promoting values and objectives related to engineering identity were clearly presented and easily obtained from the websites of every organization included in this study. Institutions that educate engineers and companies that employ them clearly use their websites to promote visions of engineering and what it means to be an engineer. Identifying such discourses provides a basis for the future study of the broader range of discourses influencing engineering and enactment of these discourses by individuals in both academia and industry.

ABET outcome criteria figured prominently in the discourses promoted by engineering departments on their websites. This is not surprising as ABET requires that accredited programs publish educational objectives that are in alignment with their accreditation criteria. The focus of many ABET criteria are on the social aspects of engineering including teamwork, communication, and an understanding of the societal impact of one's work. Companies too promoted social discourses related to service, teamwork, social responsibility, and leadership. Travelyan[14] has found, however, that engineers tend to downplay the social aspects of their work. Hult[16] and Dannels[4] also found that students tend to focus on the artifact of design and ignore non-technical considerations. Although both universities and companies are promoting social discourses as important aspects of engineering practice and identity, from the literature it appears that engineers are not adopting these discourses as part of their engineering identities. Educational institutions could likely do a better job of consistently communicating their values and objectives, not only on their websites, but in the classroom as well.

In the engineering education literature discourses about engineering as problem solving[13,15] are prominent and such discourses were found on nearly every website in this study. Problem solving is found in ABET criterion 3e (engineering students must develop an ability to identify, formulate, and solve engineering problems) and also in company discourses related to serving customers, innovation and creativity, and the use of technology. ABET criteria emphasize the complexity of engineering problems solving through an emphasis on the environmental,

economic, and social aspects of problems. Companies in this study also promoted discourses highlighting the challenges related to problem solving as well as the importance of providing goods and services of value and quality while taking into consideration environmental and sustainability concerns. Once again, findings in the literature suggest that students do not see these complex considerations as core elements of engineering identity. In addition, the majority of problems that students encounter during their academic careers may not require that that they incorporate these considerations into their solutions. Often considerations of cost, quality, or sustainability are left for capstone design courses rather than infused into the entire curriculum.

Beyond the ABET criteria, universities presented discourses about leadership, creativity and innovation, service, flexibility, and creating knowledge. These discourses align with similar discourses promoted by companies. Leadership, creativity, and flexibility are all engineering attributes promoted by the National Academy of Engineering's *Engineer of 2020*[25]. The development of leadership skills in particular is seen as an emerging goal within engineering education[26].

In the engineering literature, studies have found that students express doubt about the connection between their academic experiences and engineering practice[4,6,16]. There is clear overlap in many of the discourses promoted by both universities and companies in this study, particularly in the areas of problem solving, creativity and innovation, and service. It seems unlikely that engineering educators are unaware of these overlapping values. Perhaps engineering educators could better contextualize the problems that they give their students and thereby strengthen the connections between academic and industry values.

Four of the companies in this study communicated messages promoting diversity and inclusion. It is surprising that such discourses are not explicitly communicated on the engineering websites of universities in this study even through women and ethnic minorities are underrepresented at these institutions. Some of the university webpages did, however, appear to convey subliminal messages about inclusion by prominently displaying images of female and ethnic minority students engaged in educational activities. Perhaps industry and academia need to work more closely together to promote more diverse discourses of engineering identity.

This study begins to address the social construction of engineering identity by identifying discourses promoted by institutions that define engineering practice. This study also raises several questions about the discourses identified and their impact on the development of engineering identity. For example, which discourses promoted by the institutions in this study are students aware of? And, what impact are these discourses having on students? There is considerable debate regarding employee buy-in and the impact on company performance related to company mission and vision statements[27,28]. A few studies also question the impact of similar statements made by universities[29,30]. Such studies lead to questions of how awareness and impact of organizational objectives and values can be increased.

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