What Sociologists Know About the Acceptance and Diffusion of INNOVATION:

The Case of Engineering Education

AMERICAN SOCIOLOGICAL ASSOCIATION

CENTER FOR THE ADVANCEMENT OF SCHOLARSHIP ON ENGINEERING EDUCATION

About the American Sociological Association

Founded in 1905, the American Sociological Association (ASA) is a non-profit membership association dedicated to advancing sociology as a scientific discipline and profession serving the public good. With more than 14,000 members, ASA encompasses sociologists who are faculty members at colleges and universities, researchers, policy analysts, practitioners, and students. Members of specific sections of the Association including those concerned with Science, Knowledge, and Technology; Organizations, Occupations and Work: and Teaching and Learning engage in research that is relevant to the acceptance and diffusion on innovation within varying institutional contexts. Within the ASA Executive Office, the Research and Development Department develops and disseminates studies on the science labor force and the relationship among networks, mentoring, curriculum, and career trajectories. Also within the Executive Office, the ASA Academic and Professional Affairs Program, is responsible for encouraging the best practices in education, training, teaching, and evaluation.

About the Center for the Advancement of Scholarship on Engineering Education

Founded in 1992, the Center for the Advancement of Scholarship on Engineering Education (CASEE) of the National Academy of Engineering (NAE) represents a collaborative effort across stakeholder communities to improve the alignment of the knowledge and skills possessed by future and current engineers with the knowledge and skills sought by various stakeholders. This effort is pursued through research, development, and deployment of, innovative policies, practices, and tools designed to enhance the effectiveness and efficiency of systems for the formal, informal, and lifelong education of current and future engineers. CASEE serves to integrate, enhance, and promote engineering education by building collaborative networks with engineering schools/colleges as well as employers of engineers, forming cross-institutional/organizational learning communities of individuals exploring specific issues in engineering education. Though clearly focused on engineers and engineering education, CASEE benefits from and contributes to knowledge across a wide spectrum of the natural and social science communities, and other communities as well.

Cite publication as:
Spalter-Roth, Roberta, Norman Fortenberry, and Barbara Lovitts. 2007.
*What Sociologists Know About the Acceptance and Diffusion of Innovation:
The Case of Engineering Education*. Washington, DC: American Sociological Association.

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ACKNOWLEDGEMENTS

Partial support for this project was provided to the National Academy of Engineering (NAE) and the American Sociological Association (ASA) under grant SES-0523255 by the Human and Social Dynamics Program (HSD) of the National Science Foundation (NSF). Without the HSD grant we could not have undertaken this project.

We'd like especially to express our appreciation to the workshop participants. This cross-disciplinary workshop would not have been successful without their creativity, hard work, and willingness to listen, learn, and go the next step. A part of their work can be seen in the white papers that they submitted as background to the workshop. The views expressed in the summary report and in the white papers are those of the Principal Investigators or the individual authors and do not necessarily represent those of the NSF. We would also like to thank various staff members of the American Sociological Association and the Center for the Advancement of Scholarship on Engineering Education (CASEE) of the NAE for their tireless efforts:

William Erskine, Research Associate, ASA
Nicole Van Vooren, Research Assistant, ASA
Sylvia Pociask, Research Assistant, ASA
Lynette Osborne, ExxonMobil Scholar-in-Residence, NAE/CASEE
Sonja Atkinson, Program Associate, NAE/CASEE
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Jill Campbell was the copy editor for this report. Any remaining errors are those of the Principal Investigators.

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EXECUTIVE SUMMARY

The curricula and pedagogy of engineering disciplines face mounting pressure to change in response to the national need for engineers who can compete in the global workforce and the need to increase the racial, ethnic, and gender diversity of the profession. For over two decades, numerous organizations have issued reports encouraging greater attention to the undergraduate instruction in engineering disciplines, and yet, the curricula and pedagogy have been slow to change. Therefore, a major question is what factors increase the likelihood that the new engineering curricula or pedagogy will be adopted?

In order to understand the social and human dynamics that facilitate and inhibit the diffusion and acceptance of new engineering curricula and pedagogy, the Center for the Advancement of Scholarship on Engineering Education (CASEE) of the National Academy of Engineering (NAE) collaborated with the American Sociological Association (ASA) convened a workshop in April 2006 to learn what sociologists know about the organizational contexts, the reward systems, and the networks that could increase the acceptance and diffusion of innovations in engineering education and to develop potential joint studies to address what is not known.

PROJECT EXPECTATIONS

The Principal Investigators (PIs) had the following expectations as we launched this project.

- Sociologists and engineering faculty could bring complementary insights to understanding and addressing the problem of diffusion and change.
- Over the course of the workshop participants would develop hypotheses and study designs to answer questions about the relationships among organizational contexts, reward systems, and diffusion networks.
- Cross-disciplinary teams of engineers and sociologists would build on these ideas and develop fundable research projects.
- The resulting study designs and systematic evidence go beyond potentially biased, context-free, “best practices” and can be applied to other STEM disciplines facing problems bringing about curricular and pedagogical change.

The participants were divided among the topic areas to be discussed at the workshop (*Organizational Context and Faculty Behavior*, *Faculty Rewards*, and *Diffusion of Innovations*), and each wrote a short white paper as background.

The bulk of the two-day meeting was spent with the working groups in separate breakout sessions. Time was allotted in these sessions for the attendees to:

- Review what sociologists and engineers already know from previous research in the topic areas.
- Determine the gaps in current knowledge and what engineers and sociologists want to know.
- Develop hypotheses related to the three topic areas.
- Prioritize the hypotheses based on their importance and ability to be effectively studied.
- Develop a research agenda for each topic area, and identify methods for examining the research questions.

PROJECT OUTCOMES

The PIs were hopeful that the workshop would achieve its goal of bringing sociologists and engineering educators together to learn what is known and to develop studies for what needs to be known in order to increase the acceptance and diffusion of new engineering curricula and pedagogy. They were pleasantly surprised when the two groups came together and, after adjusting to some differences in language, found common ground and identified problems of mutual interest. In fact, engineers appeared particularly interested in working with sociologists and in using their concepts, theories, and models.

Research Agendas

Through their discussions, each of the three working groups developed research questions related to their topic area. Each selected the most promising and developed a research plan to answer the question.

Organizational Contexts and Faculty Behavior. This group asked, "How does a particular innovation and its adoption vary by location in the prestige hierarchy of engineering faculty, departments, and institutions?" They proposed to examine the adoption of integrated, first-year engineering curricula by comparing departments and institutions at different points in the prestige scale (gathered from prestige scores, Accreditation Board for Science and Engineering [ABET] self-studies, and faculty websites). A set of hypotheses would be tested using a multi-method design.

Faculty Rewards. This group asked, "What rewards will mitigate the costs of innovative teaching in environments that place highest value on research productivity and the acquisition of external funding?" They proposed to assess the relationship between a list of specific faculty rewards and measures of innovative practices in three engineering gatekeeper courses by surveying chairs, finding secondary data, and controlling for a variety of factors.

Diffusion of Innovations. This group asked, "How does the rate of adoption of curricular innovation, such as capstone courses and design labs, vary by types of networks?" They proposed to study a variety of networks, collect data from a wide variety of sources, and employ multi-method analytic approaches.

Areas of Agreement

Throughout the workshop sessions there were strong areas of agreement among the participants.

- There are structural and cultural contexts that are part of all organizational and individual decision processes in accepting innovations. Studies of best practices frequently do not examine these contexts.
- Measuring the scope and rate of acceptance of innovations requires studying a variety of units of analysis, including individuals, departments, and schools of engineering.
- Multi-method studies provide the highest level of rigor, richness, and understanding.
- Engineering faculty need to work with sociologists and other social scientists to conduct these studies.
- The more rigorous the study, the more likely the findings are to be accepted, if disseminated through mixed networks.

Almost all of the participants agreed that they wanted to continue to participate in the project, expand their research designs, and develop fundable grant proposals. Continued activity could benefit sociologists as well as engineering educators. The broader impact of this project could be an increased understanding of ways in which sociological insights can help innovate and improve the quality of the Science, Technology, Engineering, and Mathematics (STEM) workforce. Evidence from rigorous joint studies could lead to the greater adoption of new engineering curricula and pedagogy that could increase the number of U.S. engineering undergraduate majors and improve their problem-solving abilities. The resulting study designs and systematic evidence go beyond potentially biased, context-free, "best practices" and can be applied to other STEM disciplines facing problems bringing about curricular and pedagogical change.

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INNOVATION:

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Final Report

2006

AMERICAN SOCIOLOGICAL ASSOCIATION

CASEE

This report is based on a two-day national workshop that brought together engineering faculty and sociological researchers in a cross-disciplinary working group. The participants developed hypotheses and study designs to investigate what social dynamics would improve the diffusion and acceptance of new engineering curricula and pedagogy. The workshop was funded by the National Science Foundation (NSF) program on Human and Social Dynamics, grant SES-0523255.

In organizing this conference, the Principal Investigators (PIs) hoped that engineering faculty and sociologists, working together, would develop a better understanding of what is needed to bring about the acceptance of innovations. They further hoped that this interdisciplinary venture would be part of the larger science policy project of understanding human and social processes underlying successful innovation and diffusion in all the Science, Technology, Engineering, and Mathematics (STEM) disciplines.

The PIs had the following expectations as they launched this project.

- Sociologists and engineering faculty could bring complementary insights to understanding and addressing the problem of diffusion and change.
- Over the course of the workshop participants would develop hypotheses and study designs to answer questions about the relationships among (1) the types of educational institutions, status of innovators, and status of acceptors; (2) the type and distribution of rewards, the values and norms of the engineers, and the acceptance of innovation; and (3) the type of networks, innovations, and the rate of acceptance.
- The resulting studies would provide systematic evidence rather than potentially biased reports of “best practices.”
- Joint teams of engineers and sociologists would build on these ideas and develop fundable research projects.

The PIs recruited sociologists who had developed and tested theories about how scientific and educational innovations occur and are diffused through organizations, institutions, and social networks. Their studies address how factors such as status hierarchies, social networks, and professional norms can encourage or impede innovation and the diffusion of science (Burris 2004; Fox 1992, 2001; Meiksins 2002; Meiksins and Watson 1989; Sonnert 1995). Engineering faculty were recruited who could provide background information on the workings of engineering departments and schools that few sociologists knew, including information about failed and successful innovations in engineering education.

The proposed research designs can be applied to other science, technology, and mathematics disciplines that face barriers to educational reform.

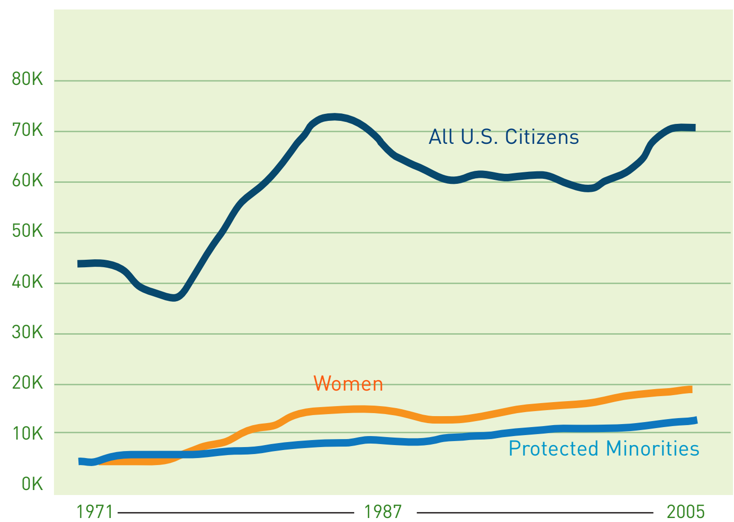
This report discusses what we know and what we need to know in order to increase the likelihood that engineering faculty and departments will adopt curricular and pedagogical innovations. It is based on the background memos and conversations about research between the engineers and sociologists during the two-day NSF-funded workshop. This report presents the stages of the project, including its background, selection of participants, production of white papers, introductory plenary session and breakout sessions, the final plenary session, and future steps. The proposed research designs can be applied to other STEM disciplines that face barriers to educational reform.

Background

In response to the national need for engineers who can compete in the global workforce and the need to increase the racial, ethnic, and gender diversity of the profession, the curriculum and pedagogy of engineering education face mounting pressure to change. As Figure 1 shows, the number of engineering degrees earned by women and minorities since 1970 is a small portion of the number earned by all U.S. citizens.

Fig. 1 Bachelor's Degrees Awarded in Engineering to All US Citizents, Women and Protected Minorities 1971–200

(Number of Engineering Bachelors Degrees)



Source: Commission of Professionals in Science and Technology, Professional Women and Minorities: A Total Human Resource Data Compendium (14th Edition) Washington, DC. CPST, 2006, Table 3_89.

For over two decades, numerous organizations have issued reports encouraging greater attention to the nature and quality of undergraduate instruction in engineering disciplines (Accreditation Board for Engineering and Technology 1995; American Society for Engineering Education 1986, 1987, 1994; Hissey 2000; McMasters 2000; National Research Council 1985a, 1985b, 1986a, 1986b, 1995; National Science Foundation 1989, 1995). As a result, large-scale efforts have been undertaken to change curriculum and educational practices. Although new pedagogic approaches are beginning to take root, *relatively little has changed in the content and conduct of undergraduate engineering instruction* (National Academy of Engineering 2004). Therefore, a major question for engineers and engineering educators is, what factors increase the likelihood that the new curricula or pedagogy in engineering disciplines will be adopted?

From the perspective of many engineering faculty, the lack of change is based on individual failure. In Menges' (2000) words, *"Why do faculty fail to use demonstrably effective teaching methods and other data-based information about teaching, and how can the situation be changed?"* [italics added]. Rather than blaming individuals, the field would benefit from analyzing the impact of structural and cultural contexts that shape individual, departmental, and administrative choices. Although innovation in engineering education requires explicit consideration of individual faculty and their motivations (Froyd 2001), analysis of social dynamics, including organizational contexts, reward structures, and diffusion networks, provides an understanding of these motivations. Studies that examine structural location—that is, whether individual engineers practicing innovative instructional methods are located at the center or the margins of different types of higher education institutions, networks, or resource systems (Schneiberg and Clemens 2006)—are needed. Although engineering educators speak of engineering culture, there is limited systematic analysis of the cultural tensions that occur within the modern university, within and between engineering disciplines, and between professional norms and curricular pedagogy. Engineers know the disciplinary organizations, journals, and members of their field; however, very few systematically study the paths and strategies to diffuse and accept innovations in engineering education.

"Why do faculty fail to use demonstrably effective teaching methods and other data-based information about teaching, and how can the situation be changed?"

Recently, the engineering accreditation process has changed to focus on student learning outcomes rather than educational credits [Accreditation Board for Science and Engineering (ABET)]. This change provides a positive context for new approaches to engineering education. Engineering faculty—including faculty on campuses that participated in the NSF Engineering Education Coalitions—have written about the changes that are necessary to implement new engineering curricula and pedagogy. Together, these changes suggest that the engineering community is now prepared to benefit substantially from a sociological examination of the structural and cultural conditions that impede or encourage the diffusion and adoption of its instructional practices.

Opportunity for a Workshop

Norman Fortenberry, director of the National Academy of Engineering's Center for the Advancement of Scholarship on Engineering Education (CASEE), was interested in taking advantage of social science research to increase the spread of innovation in engineering education. In turn, Roberta Spalter-Roth, research director of the American Sociological Association, was interested in the application of sociological theories and methods to explain the social dynamics that encourage or impede the innovation and diffusion of scientific findings.

At an NSF workshop on the pathways to STEM careers (Martin and Pearson 2005), Fortenberry and Spalter-Roth discussed potential projects that could draw their respective communities together. An opportunity to hold such a workshop was provided by the program on Human and Social Dynamics Program (HSD) sponsored by NSF. As defined by the HSD initiative (National Science Foundation 2005), "Aspects of social dynamics include knowledge about organizational, cultural, and societal adaptation that increase our ability to understand…social structures that create, define, and result from change…and the dynamics of human and social behavior at all levels" (p. 2). Fortenberry and Spalter-Roth, along with sociologist Barbara Lovitts, a senior program officer at CASEE, applied for and received an HSD grant for a two-day workshop. The goal of the workshop was to develop models that will allow exploration of whether an understanding of social dynamics can increase acceptance and diffusion of enhanced curricular and pedagogical methods.

"Aspects of social dynamics include knowledge about organizational, cultural, and societal adaptation that increase our ability to understand…social structures that create, define, and result from change…and the dynamics of human and social behavior at all levels"

The Process

Bringing engineers and sociologists together in a workshop was in itself an innovative strategy. The workshop process began with the selection of 19 participants (9 engineers and engineering educators and 11 sociologists). Applicants were solicited from a variety of sources including engineering and sociology section members, NSF awardees, and relevant published scholarship. Engineering applicants were required to submit statements on challenges they face in their local environments and how they hope to apply what they learn at the workshop to the resolution of those challenges. Sociology applicants were required to submit statements on how their empirical findings on structure, rewards systems, and networks could encourage the diffusion and adoption of new engineering curricula and pedagogy (see Appendix I for the list of participants).

The guiding questions for the workshop were:

- How do new knowledge, curricula, and pedagogical practice spread and become accepted?
- How can we model the social dynamics that impede or facilitate individual and institutional diffusion and acceptance of change?

In other words, what do we know from research and practice, and what else do we need to know about the structural, political, economic, and socio-cultural factors and processes that result in fostering individual, departmental, institutional, and disciplinary change?

Another purpose of the workshop was to build a cross-disciplinary community that would develop joint projects to be pursued after the workshop. As Figure 2 shows, before the workshop few engineers or sociologists knew each other, with sociologists more likely and engineers less likely to know either sociologists or engineers.

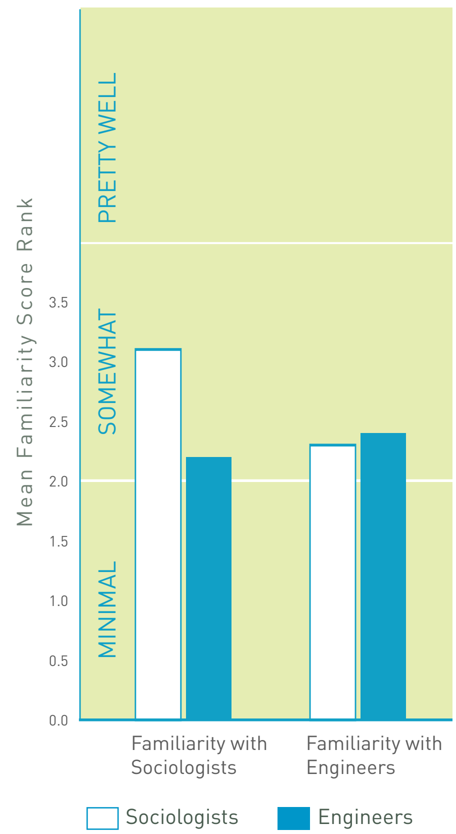
Once selected, the PIs divided the participants into three working groups based on the existing literature for understanding the social context for individual acceptance of change. Appendix II contains a bibliography of relevant works. These three working groups each had to take into account specific aspects of social contexts and dynamics in order to understand individual behavior.

ORGANIZATIONAL CONTEXTS AND FACULTY BEHAVIOR: Despite strong evidence that faculty behavior influences student retention, most faculty members are uninvolved in activities aimed at improved undergraduate retention (Kramer 2001; Massy and Wilger 2000; Wankat et al. 2002). Why is this? Are faculty members making poor individual choices and resisting change, or does the organizational context in which faculty are socialized and teach affect their acceptance of innovation or resistance to change? An individual learning perspective does not take systematic account of characteristics such as institutional prestige, influence, and networks that affect faculty ability to accept innovation. In addition, an individual perspective does not account for how race and gender hierarchies affect choice or the changing context of the discipline as a whole. Finally, it does not take collective resistance into account.

FACULTY REWARDS: Faculty members, chairs of departments, and deans of schools have many competing demands on their time. They must be convinced, therefore, that the benefits of change are worth the investment of their time and energy. What set of contradictory demands, norms, resources, power, and rewards affect faculty acceptance of innovation? What set act as barriers to acceptance of innovation? Does acceptance vary by type of institution or department? What are possible strategies to increase the likelihood of accepting innovation? What are the power, resource, and cultural shifts necessary for strategies to work?

DIFFUSING INNOVATIONS: Diffusing innovative practices that enhance instructional effectiveness and student learning within undergraduate engineering education has received little exploration. What structural and organizational characteristics and processes advance the diffusion of innovations in engineering education across many campuses? These can include the type and prestige of communication patterns and networks that can facilitate or impede acceptance and diffusion among individuals, departments, and institutions.

Fig. 2 Average Familiarity with other Participants before Conference



LEVEL OF FAMILIARITY SCALE

1 = "I do not know this person."
2 = "I have only heard of this person."
3 = "We talk once a year."
4 = "We talk a few more times a year."
5 = "We talk monthly or more."

Orienting Memos About What We Know and What We Need to Know

All participants were required to submit an orienting memo showing how available scholarship, along with their own work and experience, bears on the research questions and to suggest new hypotheses for their working groups. (See Appendix III for these orienting memos.)

The orienting memos shed light on the problems faced and the reasons for resistance to change. The PIs formulated the analyses into a series of hypotheses about social dynamics or processes in each of the three topic areas for participant discussion.

ORGANIZATIONAL CONTEXT AND FACULTY BEHAVIOR—HYPOTHESES

1. Faculty behavior and organizational contexts cannot be separated. Faculty members respond to cues, rewards, trends, and fads within their specific institution. This is especially true in engineering, which is highly dependent on resources and teamwork.
2. Outside social movements and social pressures (e.g., professional associations, employers, civil rights movements, state legislators) can push for new curricula. They may be the agents of change in bringing about dissemination and use.
3. Increases in institutional and faculty resources lead to increases in diffusion, which, in turn, lead to broader acceptance of innovations.
4. Institutions of higher education place contradictory demands on faculty in terms of research, teaching, and service.
5. The division of labor in teaching affects the use of new engineering pedagogy. Large required courses tend to be taught by senior faculty who do not do research but tend to uphold traditional methods of teaching and traditional curricula.
6. Implementation of new engineering pedagogy will decrease bias and increase diversity.

FACULTY REWARDS—HYPOTHESES

1. Faculty members who get pleasure from doing a good job teaching and developing colleagues with the same interests will be more likely to use new engineering pedagogy.
2. Increases in salaries and awards will increase diffusion.
3. Fear of losing turf and losing control lead to resistance to the adoption of new curricula and pedagogy.
4. New pedagogy will be disseminated and used to the extent that it fits with norms of what is good engineering and what makes a good engineer.
5. Collective rather than individual mentoring can be used to bring about curricular and pedagogical transformation as well as increase diversity.
6. Especially in research universities, faculty members are still evaluated by grants and publications, even though teaching has become a higher priority.

DIFFUSION OF INNOVATIONS—HYPOTHESES

1. Endorsement of new curricula and pedagogy by those in higher administration (e.g., presidents and provosts) and other strong players increases the likelihood of acceptance and diffusion.
2. Those in the middle of organizational hierarchies will have the most practical power in implementing technology. Support by department chairs and deans will increase the use of new engineering pedagogy.
3. The pattern of network ties will affect diffusion. For example, structural equivalence may be the most important network factor in explaining dissemination of new engineering instructional technologies.
4. A combination of links within well-populated networks and links that bridge isolated networks is needed to diffuse innovations.
5. Dissemination is most likely to occur between similarly placed, central actors in networks.
6. Multiple pathways within networks increase dissemination.
7. Greater acceptance by opinion leaders (usually those at the center of networks) will result in greater dissemination.
8. The typical responses to new engineering curricula are neither acceptance nor rejection, but other responses such as assimilation, partial acceptance, or lip service.

These hypotheses from the orienting memos were carried into the workshop for further discussion.

The Workshop

PLENARY SESSION: WHAT WE KNOW

The workshop began with a series of paired plenary speakers (a sociologist and an engineer) who provided the assembled engineering educators and sociologists with an overview of what we know about the complexities of change in the social structures, cultural values, and networks that could be used to create or impede change in engineering education. (See papers by speakers Ambrose, Burris, Croissant, Frank Fox, Froyd, Meiksins, Plank in Appendix III.)

The Structure and Culture of Higher Education. Universities with various missions and prestige rankings are part of a larger system of higher education. The system communicates its values, beliefs, and priorities to members by how it structures power and authority and how it allocates rewards and status. The modern research university does the following:

- Emphasizes the academic discipline and the work of the individual faculty member, especially in terms of bringing in outside honors, prestige, and research dollars.
- Awards internal prestige and offers rewards to individuals whose research brings outside funding.
- Makes graduate education and the training of researchers a priority.
- Focuses on specialized rather than general knowledge.
- Attempts to be responsive to state legislative demands for student outcome assessment.

Power and authority within institutions of higher education are highly decentralized. This allows universities to be flexible and respond rapidly to issues raised by individual groups. At the same time, it decreases universities' capacity to forge broad, unifying organizational strategies. Other than department chairs, administrators have relatively little influence over faculty teaching decisions. We need to know more about the size of institutions, autonomy of faculty, style of leadership, level of impetus for status-maintenance or mobility, subfields of faculty (older versus newer, basic versus applied, more research versus less), and faculty and student composition (by citizenship, gender, race, and ethnicity). How do these factors affect innovation?

Factors comparable to those discussed for higher education as a whole exist within engineering colleges/schools and departments. These units often feel the need to satisfy a number of stakeholders given their dependence on a positive relationship with industry for employment of their graduates and a relatively unique system of national accreditation for individual engineering programs.

The Complexity of Rewards in Academic Engineering. From the late 19th Century to the present, engineers' views on the nature of engineering and engineering knowledge evolved from that of "shop culture," with its emphasis on training engineers through a kind of practical apprenticeship in industrial settings to a "school culture," with its emphasis on college-level training premised on acquiring scientific knowledge. With this shift came the occupational identity of "engineering science" and the achievement of professional status. As a result of the shift, research and researcher training replaced teaching and internships as the most highly valued aspect of the academic engineer's job.

Contemporary engineering culture and its associated values contain elements that are both hostile to and consistent with new approaches to engineering education.

Contemporary engineering culture and its associated values contain elements that are both hostile to and consistent with new approaches to engineering education. Elements that work against change include status and prestige concerns of engineers and their views of what constitutes "good engineering science." At the same time, engineers' values also contain elements that encourage a focus on less "pure" scientific research and on the kinds of activities associated with practical engineering work that engineering curricula seek to encourage—teamwork and solving real-world problems.

Institutional Rewards are powerful determinants of faculty behavior, and the institutional reward structure provides the blueprint for how faculty spend their time. Most engineering programs are in research universities, where faculty are still evaluated primarily on their research productivity such as proposals generated, research funding, and scholarly publications. However, there has been growing criticism of academics' narrow focus on traditional research, and universities are under increasing pressure from state legislatures, accrediting agencies, parents, and students to demonstrate the "value added" from a university education. These pressures have led to a noticeable shift toward holding educators accountable for their students' achievement of measurable learning outcomes and a resulting resurgence of interest in high-quality teaching at research and comprehensive institutions. However, faculty are receiving multiple and mixed messages. They are simultaneously asked to care more about teaching and to spend less time on it, because instructional costs represent a very large portion of most universities' (shrinking) budgets.

Some department chairs, deans, and administrators at research universities have come to view the current balance between research and teaching in the reward structure as inappropriate and in need of modification. They are starting to place more emphasis on innovative educational practices. This new emphasis on education—both within universities and from external change agents as well—has led to some changes in the rewards offered to university faculty:

- Major foundations have made resources available for research on teaching and learning.
- Many universities have made efforts to reward good teaching (e.g., teaching awards, small grants for innovative teaching).
- Publishing outlets for research on engineering education and for scholarship of teaching and learning have proliferated.
- Some universities have modified their tenure and promotion criteria.

Still, many faculty remain skeptical about administrative sincerity in the absence of material support for curricular and pedagogical change, such as paying for faculty to attend workshops on pedagogy, in light of unchanging expectations of high research productivity. They perceive that articles, grants, or awards related to teaching and/or advising mean little or nothing for career success.

Faculty Workloads. Because the institutions in which most engineering departments are located favor funded research, many academic departments have adopted a faculty workload model that may support, but often ends up undermining, the diffusion of innovation in engineering education. Lighter teaching and service loads are given to faculty whose tenure and promotion depend heavily on externally funded research. Heavy teaching and service loads are given to faculty who have explicitly expressed no desire to engage in research or are currently not involved in research. Under this arrangement, there is an unspoken agreement that the teaching faculty will be left alone because they are responsible for generating the largest percentage of student credit-hours in the department.

The belief system of the teaching faculty—who are most likely to be the instructors of gate-keeping courses and serve on department committees that govern the engineering curriculum—can positively or negatively influence the diffusion of innovations in engineering education. For example, if the teaching faculty hold innovative beliefs about the role of teachers and students, they are probably willing to experiment with and adopt new pedagogies or instructional methods. Conversely, if the teaching faculty hold traditional beliefs about curriculum and pedagogy, they are likely to see themselves as guardians of high academic standards who must resist pressures to incorporate new instructional practices that they perceive as diluting the curriculum and lowering academic standards.

“The diffusion of an innovation often occurs through what can be described as a two-stage proces…”

Diffusion of Innovation

Everett Rogers, in his widely cited book *Diffusion of Innovations* (2003), defines diffusion as the process by which an innovation is communicated through certain channels over time among the members of a social system. How can the pattern of connections among individuals in a departmental or disciplinary network help facilitate the spread of new curricular developments across that network? While the diffusion of an innovation typically follows an S-shaped curve in which the rate of adoption begins slowly, then accelerates as it spreads to a majority of the population, and finally tapers off again as the point of saturation is approached, this pattern has not occurred with relation to new engineering curricula and pedagogy.

The diffusion of an innovation often occurs through what can be described as a two-stage process: first, the innovation must be accepted by a sufficient number of “opinion leaders”; the opinion leaders then encourage other members of the population to adopt the innovation. These individuals can be part of the following kinds of social systems:

1. All engineering faculty within an engineering discipline (department) within a single institution;
2. All engineering faculty within an engineering discipline across a set of universities;
3. All engineering faculty across a set of engineering disciplines within a single college or school of engineering;
4. All engineering faculty across a set of engineering disciplines within colleges or schools of engineering across a set of universities.

Whether opinion leaders accept an innovation is a function of their reaction to the innovation and the degree to which they belong to diverse sets of networks. Reactions to an innovation largely depend on the opinion leaders' knowledge, attitudes, and beliefs. The particular challenge here is that engineering faculty, in general, have received little preparation for scholarly teaching and lack rigorous knowledge of teaching and learning scholarship. Further, because research on teaching and learning is fundamentally grounded in social science methods for examining dynamic social systems, faculty who are most familiar with quantitative research on relatively stable inanimate objects and systems may be reluctant to accept its findings. Additionally, practical issues also may prevent the exploration of innovation. For example, a curricular innovation that is implemented via modules within existing courses can diffuse more rapidly than one requiring wholesale curricular change.

The diffusion of educational innovations also depends on the networks in which opinion leaders participate. Actors' decisions with respect to adopting or not adopting an innovation can be explained, at least in part, by the pattern of interconnections among them. How closely actors are related to one another and whether individuals or groups belong to a common, densely knit community affect the scope and rate of diffusion. Also important are the types of ties that bridge networks. Strong ties link any two members of a densely interconnected community. Weak ties link isolated clusters or communities.

Relatively dense communities of strong ties offer many pathways for diffusion; however, such densely knit communities also exhibit resistance to change or innovation. Adoption of innovation by central actors in the network can be crucial to overcoming this resistance, both because of the large number of ties that they maintain and because of the prestige that typically accompanies their central role within their community. Strategically located actors with ties to other communities also play a pivotal role in the diffusion of innovation. Such actors are frequently the first ones to become exposed to new ideas, and the fact that they bridge multiple communities makes them less bound by the traditional norms and practices of any given community and more prone to be early innovators.

In understanding the role of networks in diffusion, it is important to move beyond a simple binary notion of adoption or non-adoption. The following range of behaviors is part of the diffusion process (see Plank's orienting memo):

- *Accommodation.* Engaging the innovations in ways that represent a fundamental revision of one's pedagogical views and practices.
- *Assimilation.* Making an attempt to accept and implement the reforms, but only after transforming the tenets or interpretations of them to fit one's pre-existing pedagogical beliefs and ways of doing things.
- *Parallel structures.* Taking the reform seriously but adopting its practices only some of the time or in some contexts, thereby leaving intact and unchanged other (possibly conflicting or antithetical) practices at other times and in other contexts.
- *Decoupling/symbolic response.* Giving lip service or making superficial changes to give the appearance of compliance, without changing previous practices in any serious way.
- *Rejection.* Refusing outright to engage or adopt the reform; outright dismissal of a mandate.

BREAKOUT GROUPS

In the remainder of the two days, members participated in the separate breakout sessions to which they were assigned (on organizational context, faculty rewards, or diffusion of innovation). The working groups were assigned the following tasks:

- Review what is already known by sociologists and engineers from previous research in the topic areas.
- Determine the gaps in the current knowledge and what engineers and sociologists want to know.
- Develop hypotheses related to the three topic areas.
- Prioritize the hypotheses based on their importance and ability to be effectively studied.
- Develop a research agenda for each topic area, several hypotheses, and identify methods for examining the research questions.

Engineering faculty and sociologists engaged constructively in these working groups. Participants implicitly understood what each group brought to the table. The sociologists brought the base of theory and research to bear on the problems faced by the engineering educators.

The sociologists also provided the expertise in research methods and experimental design. The engineers provided the background, topography, politics, and operations of the engineering colleges that the sociologists lacked. The engineers had knowledge of state-of-the-art engineering education research, the history of failed and successful innovations in engineering education, and familiarity with the avenues of dissemination, such as relevant journals and conferences. Engineers used the sociologists as consultants, and sociological concepts, theory, language, and methods framed much of the conversation.

The highest-priority questions concerned variation in innovation and acceptance of innovation by location in the prestige hierarchy.

All three working groups raised questions about the definition of innovation including:

- Have we defined innovation?
- How will the innovations be measured?
- How do we identify courses that are associated with innovation?
- Is there a shared understanding of innovation?

Each group had free-wheeling, rich, and deep discussions as they developed common understandings and worked toward developing study hypotheses and designs.

Organizational Context Group. This group grappled with defining and measuring innovation and with comparing the impact of organizational context for the acceptance of innovation. First, they agreed on the importance of defining the target unit of analysis for studying pedagogical and curricular innovations. Some important units of analyses included the type of institution (e.g., public or private); the type of department, including whether or not sub-disciplines are housed in separate departments/schools (e.g., chemical engineering, electrical engineering, mechanical engineering, civil engineering); and the rank of faculty members. This group agreed that accrediting data could provide information for comparing departments and institutions.

The group prioritized their questions and discussed methods of investigation. The highest-priority questions concerned variation in innovation and acceptance of innovation by location in the prestige hierarchy. The prestige of schools and departments, the hierarchy and stratification of prestige, and the place in the national rankings are key means of judging how innovations spread (i.e., from top to bottom, from bottom to top, or from middle to either top or bottom). Given their priority, they suggested the following specific research questions about the effect of organizational context and prestige on innovation:

- What are the effects of institutional prestige on innovation; the agents of change in different types of institutions?
- Are the innovations of low status individuals or departments emulated?
- Do people in stronger or weaker systems adopt innovations?
- Is the middle of the range the best place to innovate?
- Are promising practices adopted across a range of institutions?
- How do race, ethnicity, and gender fit into the relationship between organizational context and acceptance of innovation?
- What are the perceived costs and risks to adoption at different levels in the hierarchy?

The group agreed that multi-method approaches including surveys and ethnographies were the way to answer these questions.

The *Organizational Context and Faculty Behavior Group* developed a study design to begin to answer the questions they had posed.

Proposed Study: Why is there resistance to change within departments, institutions, and disciplines such that new engineering curricula and those who teach them are not valued? How can this situation change?

HYPOTHESIS: Prospects for innovation vary with the type of institution, and characteristics of faculty and students within them.

a. The more prestige an institution has, the more it is likely to create rather than adopt innovation.
b. Non-PhD-granting institutions are more likely to adopt innovation.
c. Women faculty members are more likely to adopt innovation.

MEASURING CONTEXT: Effects of context can be measured by comparing differences among types of institutions or by selecting different disciplines (e.g., biomedical engineering versus civil engineering) within different types of institutions or vice versa

Study Method:

- Collect data (prestige, innovation, and control) on all institutions. Data sources include documents, websites, ABET self-reports, and a survey.
- Collect faculty characteristics from websites and a survey.
- Analyze data, e.g., contingency tables, multivariate modeling.

> *Outcomes:* Describe and explain the variation in creation and adoption of innovation by prestige level and type of institution.

A final question posed was, how does this advance interesting questions in sociology as well as engineering education?

Faculty Rewards Group. The members of this working group agreed that job rewards are complicated, contradictory, and change over time. For example, universities want faculty to produce more grants but are also under pressure to meet teaching outcomes by state legislatures and accreditation bodies. The group asked, "What rewards will mitigate the costs of innovative teaching in environments that place highest value on research productivity and acquisition of external funding?" Many administrators and engineers do not believe that the scholarship of teaching and learning is rigorous. As a result, it does not receive the prestige that other kinds of research receive. Junior faculty may be more willing to try different teaching innovations but do not have time to innovate because they want to obtain tenure. Senior faculty members who adopt changes become marginalized.

Junior faculty may be more willing to try different teaching innovation but do not have time to innovate because they want to obtain tenure. Senior faculty members who adopt changes become margin-alized.

Can rewards help? And if so, what kinds of rewards? Workshop participants identified a series of rewards, some at the individual level and some at the department or college level. These included:

1. Increased enrollments—Increased enrollment in engineering programs and increasing the number of U.S.-born engineering students in graduate school.
2. Personal gratification—Some individuals may receive intrinsic rewards from being good teachers.
3. Altruistic reasons—Innovations are adopted for the larger good.
4. Prestige—Promotions and perceived importance of place in a stratification or ranking system may provide incentive for curricular innovations.
5. Mentoring—Younger faculty may receive rewards, help, or attention from more seasoned faculty. Does mentoring motivate the acceptance of innovation?
6. Monetary rewards—Salary increases and internal or external grants provide tangible rewards.
7. Time—Released time for developing or testing new curriculum can encourage innovation.
8. Collegiality—Collegiality makes faculty happy. Do faculty members have people they can talk to about teaching, and from whom they receive help?
9. Other resources—Teaching assistants or graders can alleviate an increased workload.

Workshop members discussed many strategies for studying the effectiveness of different types of rewards in different contexts. They suggested the following kinds of research projects:

- Compare departments that have been funded by the NSF to pursue innovative educational projects. Did funding result in change? Were rewards a driving motivation during this innovative change? Did rewards (like teaching development or more money) help with the changes?
- Learn what people value so what they value can be offered. Why are faculty members doing innovative teaching? Is it because their research isn't going well or because they receive positive rewards? Study faculty who go against the grain, and do case studies to find out what motivates them.
- Match institutions to find out if there are structural or cultural issues that motivate some departments to change. Compare the missions of institutions that want to change with similar institutions that do not.
- Survey faculty to determine what they actually do in their classrooms, and compare the innovative institutions with the non-innovative institutions to determine whether there are differences. Look at the three gate-keeper classes—statics, thermodynamics, and circuits.

The *Faculty Rewards Group* then narrowed their questions and began to develop a study to examine the effect of teaching awards (i.e., teaching grants and faculty rank) on innovation adoption in classrooms.

Proposed Study: Do different kinds of faculty rewards matter? This study will examine the effect of the following independent variables (rewards) on innovation adoption in three gatekeeper courses (statics, thermodynamics, and circuits):

- Release time for teaching development
- Travel money
- Screening of candidates
- Regular seminars or teaching workshops
- Teaching mentorship programs
- Peer observation of teaching or teaching portfolios
- Provision of teaching assistants

The method for this department-level study is to conduct a survey of chairs, gather data, and conduct regression analysis of variables that correlate significantly with faculty innovation, especially those having to do with rewards, controlling for whether departments received an NSF grant for instructional innovation as well as other institutional characteristics. If these factors are significant, then other departments can adopt those rewards that were related to innovation.

The major controls for this study are institutional variables including departmental prestige, size, and type of institution. Individual control variables include rank of faculty member, gender race, ethnicity, and place of degree

Diffusion of Innovation Group. The engineering faculty in this workshop agreed that two of the primary methods of dissemination—journal articles and presentations at professional meetings—occurred in forums not seen by most engineering faculty (e.g., most engineering faculty are not members of the American Society for Engineering Education). They concurred that additional links between engineers were needed and asked how to increase the number of links so that there was greater diffusion of pedagogical and curricular innovations. They listed the following innovations:

- Outcomes-based assessment
- Developing student self-identity
- Student teams and team training
- Design decisions using computation
- Active/cooperative learning
- Capstone project courses
- First-year design labs
- Building learning communities among students
- Technology

...additional links between engineers were needed and asked how to increase the number of links so that there was greater diffusion of pedagogical and curricular innovations.

The group agreed that the diffusion of these innovations did not mean that they were accepted, used, or had positive effects on student learning and retention (especially of women and minorities). In fact, the sociologists reiterated that diffusion is not binary (that is, a yes or no outcome). Rather, as noted, diffusion includes *accommodation, assimilation, parallel structures, or symbolic responses as well as acceptance or rejection*. Nonetheless, diffusion is a necessary, if not sufficient, cause of acceptance of innovation.

Are disciplinary societies the best diffusion channel? Or is another alternative, the coalition model, the best? In the coalition model several institutions develop and implement a curriculum, which helps to jumpstart diffusion. However, according to group members, curricula do not diffuse well, but teaching methods and practices do.

The *Diffusion of Innovation* group then proposed to examine the effects of networks on the dissemination of innovations. Group members agreed, however, that in some cases the network is the independent variable that predicts diffusion while in other cases networks could be the dependent variable or desired outcome. They also discussed the study designs and measures that could be used to make the study operational.

…diffusion includes accommodation, assimilation, parallel structures, or symbolic responses as well as acceptance or rejection.

Innovations to study:

- Capstone or design lab courses because they are more binary and more easily researchable

Networks to study:

- Connections among education and technical research professors in departments, centers, and schools
- Students from one school who bring practices to the schools in which they are teachers
- Citation and co-authorship analyses
- Departments of equivalent size and prestige

Study designs or measures:

- Explore the boundaries of the social network (e.g., community of practice) before beginning.
- Examine diffusion of an innovation (such as first-year engineering) among the ~300 engineering departments, noting which departments adopted and when.
- Compare well-funded innovations with those with less funding.
- Conduct three case studies: one successful, one not, and one in progress.
- Determine which departments or schools are early adopters, middle adopters, and late adopters.
- Look at people and departments who adopted and then abandoned innovations.
- Compare "S" curves of various innovations.
- Examine PhD networks (i.e., "genealogical" lists of faculty and their doctoral students) to show affiliations and isolation.

Data sources:

- Department self-studies for ABET
- Second-hand sources: course catalogs, papers, and articles
- Citation analysis
- ASEE *Profiles of Engineering and Engineering Technology Colleges*
- Surveys of department heads or undergraduate directors

Control factors:

Control factors will include the size of the department, ranking, location, coalition membership, control (i.e., public, private, or for profit), ABET accreditation, student demographics, and centralized or decentralized structure.

The second phase of the research will include the creation of links (develop or rewire effective networks) based on what had been learned as a result of the first phase.

Closing Plenary Session and Next Steps

At the closing plenary session, reporters for each of the working groups presented emerging research questions, hypotheses, and study designs that workshop participants had been inspired to pursue after the workshop. Following these presentations, workshop participants discussed the next steps for the project. The project PIs were tasked with producing a final monograph (including participants' white papers) that would be disseminated to deans of engineering and sociology sections such as the *Section on Science, Knowledge and Technology*, and relevant others. Follow-up surveys of workshop participants would determine whether they were continuing to converse with one another to refine and develop ideas and joint and individual proposals, replicate the workshop model, or make presentations at professional meetings. The PIs also hoped to engage in these activities.

Project Outcomes

The PIs had been hopeful, but not particularly confident, that the workshop would achieve its goal of bringing sociologists and engineering educators together to learn what is known and to develop studies for what we need to know to increase the acceptance of diffusion of new engineering curriculum and pedagogy. The PIs were concerned that the sociologists would not find the research questions presented by engineers to be particularly compelling from their point of view and that the engineers and engineering educators would not accept sociological research as valid and useful. However, they were pleasantly surprised when the two groups came together and, after some adjustments for differences in language, found common ground and identified problems of mutual interest. In fact, engineers appeared particularly interested in working with sociologists. In the words of one engineering educator,

> "Engineers do not know how to do pedagogical research, so the suggestion is that they work with social scientists.... Conceptually, the information from social science is important. Rigorous evaluation is necessary. Cross-disciplinary work is necessary."

AREAS OF AGREEMENT

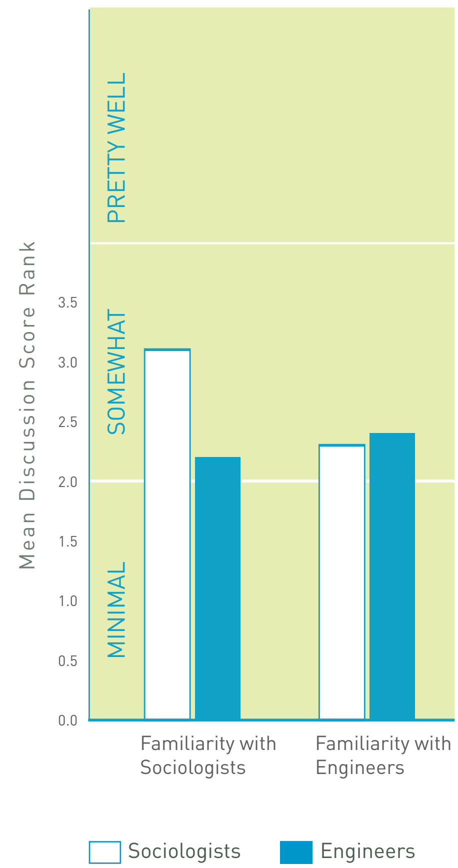
Throughout the workshop sessions there were strong areas of agreement among the participants.

- There are structural and cultural contexts, such as prestige hierarchies, reward systems, and networks that are a part of all organizational and individual decision processes in accepting innovations. These factors are frequently ignored in "best practice" studies.
- Measuring the scope and rate of acceptance of innovations requires studying a variety of units of analysis, including individuals, departments, and schools of engineering. In addition, these units need to be stratified by factors such as size, prestige, and level, in order to understand similarities and differences.
- In addition to quantitative analysis, case studies (as long as they are comparative) and other methods such as content analysis need to be included. Multi-method studies provide the highest level of rigor, richness, and understanding.

- Engineering educators need to work with sociologists and other social scientists to conduct these studies.
- The more rigorous the study, the more likely the findings will be accepted, if disseminated through mixed networks.

Groups of engineers and sociologists are continuing to have conversations. Figure 3 shows an increase (compared to Figure 2) in conversations among and between sociologists and engineers. Almost all of the participants agreed that they wanted to continue to participate in the project, further expand their research designs, and develop fundable grant proposals. Since the conference at least one research proposal has been sent to NSF. Continued activity could benefit sociologists as well as engineering educators. The broader impact of this project could be an increased understanding of ways in which sociological insights can be beneficial for enhancing innovations to improve the quality of the STEM workforce. Evidence from rigorous joint studies could lead to the greater adoption of new engineering curricula and pedagogy that could help increase the number of U.S. engineering undergraduate majors and improve their problem-solving abilities. The resulting study designs and systematic evidence go beyond potentially biased, context-free best practices studies and can be applied to other STEM disciplines facing problems bringing about curricular and pedagogical change.

Fig. 3 Post-workshop discussion rank scores for Engineers and Sociologists



MEAN DISCUSSION SCORE RANGES

0–3: No discussion with other participants

3–6: At least one discussion with other participants

7–10: A few discussions with other participants

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APPENDIX 1:
Workshop Participants & Attendees

ORGANIZATIONAL CONTEXT AND FACULTY BEHAVIOR

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APPENDIX 2:

Workshop Agenda

Social Dynamics of Campus Change: Creating an Interdisciplinary Research Agenda

Members Room – National Academy of Sciences Building
2101 Constitution Avenue, NW
April 26-27, 2006

AGENDA

Wednesday, April 26

8:00	**Welcome and Charge – Members Room** Norman Fortenberry, CASEE Roberta Spalter-Roth, ASA
8:30	**Panel Presentations and Discussion – Members Room** FACULTY REWARDS: Susan Ambrose, Carnegie Mellon University; Peter Meiksins, Cleveland State ORGANIZATIONAL CONTEXT AND FACULTY BEHAVIOR: Jennifer Croissant, University of Arizona; Mary Frank Fox, Georgia Tech DIFFUSING INNOVATIONS: Jeffrey Froyd, Texas A&M University; Val Burris, University of Oregon
9:45	Break
10:00	**What Do Engineers Want to Know?** FACULTY REWARDS: Rm. 148 ORGANIZATIONAL CONTEXT & FACULTY BEHAVIOR: Rm. 180 DIFFUSING INNOVATIONS: Rm. 250
12:00	Break
12:15	**Working Lunch – Members Room**

1:30	**What Do Sociologists Know?** FACULTY REWARDS: Rm. 148 ORGANIZATIONAL CONTEXT & FACULTY BEHAVIOR: Rm. 180 DIFFUSING INNOVATIONS: Rm. 250
3:30	Break
3:45	**What Do Engineers and Sociologists Want to Know?** FACULTY REWARDS: Rm. 148 ORGANIZATIONAL CONTEXT & FACULTY BEHAVIOR: Rm. 180 DIFFUSING INNOVATIONS: Rm. 250
5:45	**Adjourn to Member's Room for Dinner (6:30 pm)**

Thursday, April 27

8:00	**Developing Research Questions and Models** FACULTY REWARDS: Rm. 148 ORGANIZATIONAL CONTEXT & FACULTY BEHAVIOR: Rm. 180 DIFFUSING INNOVATIONS: Rm. 250
10:00	Break
10:15	**Developing Research Agendas and Study Methods** FACULTY REWARDS: Rm. 148 ORGANIZATIONAL CONTEXT & FACULTY BEHAVIOR: Rm. 180 DIFFUSING INNOVATIONS: Rm. 250
12:15	Break
12:30	**Working Lunch – Room TBD** Discussion of possible follow-on activities
1:45	**Closing Plenary: Sharing Work and Identifying Next Steps**
4:00	**Adjourn**

APPENDIX 3:
Papers Presented by Workshop Participants

Engineering Education Innovations: Modeling the Influence of Organizational Context and Faculty Behavior

David M. Bowen

California State University, East Bay

ABSTRACT

What aspects of Universities' organizational context play a role in facilitating or obstructing the creation, dissemination, adoption and institutionalization of Engineering Education Innovations (EEI's)? What faculty behaviors and organizational context combinations result in successful EEI implementation? First, we introduce a multi-stage model as a conceptual framework for organizing research, and for identifying linkages between different processes as key transition points. Specific research areas are then identified and discussed in relation to the framework, with emphasis on those of particular concern to small school programs.

The progression from engineering education innovation to institutionalized best practice is a multi-stage process typically involving multiple individuals and institutions. In order to organize and create an agenda for research efforts to better understand the progression and influential contexts and behaviors, it is beneficial to model this process and then be specific as to which stage of the process each research question is addressing.

The main agents in this process are innovators, disseminators, contemplaters, adopters, adapters and deserters. Others may influence them, but it is this set of agents that are the direct actors in the process.

Innovators create the innovation. Disseminators (often the innovator, but in a role distinct from innovating) publicize the innovation, make any supporting materials or information available and otherwise promote the innovation. Those who become aware of the innovation, through the efforts of the disseminator or otherwise, can be considered contemplators. Contemplators who decide to implement the innovation as originated are adopters. Contemplators or adopters who create and implement a variation of the innovation are adapters. Innovators, contemplators, adopters or adapters who decide to stop using the innovation are deserters. Innovators, contemplators, adopters and adapters who integrate and imbed the innovation into curriculum and pedagogy are institutionalizers. Eventually, as new innovations replace prior innovations, institutions desert an old innovation when institutionalizing a new innovation. These relationships are depicted in Figure 1.

As with most complex systems, the institutionalization of EEI's can stall many places within the process. Good dissemination plans built around wanting innovations will ultimately fail in spite of those plans, though the plans might be successful in attracting many contemplators and adopters. Once adopted, a resource intensive innovation may disappoint and languish when supporting resources are not maintained. Adopters may be isolated within their institutions, and consequently unable to influence department or college curriculum and pedagogy to institutionalize an innovation.

The many ways that the process can fail to result in institutionalization of EEI's requires that our research efforts address the entire process, to understand germane barriers and catalysts in each part of the process. Only in this way can we build a foundation sufficient to support policy and policy makers in more rapid and ubiquitous acceptance of beneficial EEI practices by academic institutions.

Particularly vulnerable to failure are the transition points in the process where one agent's behaviors and actions are required to influence the next agent's action and behaviors for continuation of the process towards institutionalization. An example is when a disseminator needs to capture the attention and imagination of contemplators for the innovation to germinate in other settings, or when adopters need to influence others beyond their classrooms to install innovations into the instructional fiber of the institution. The sociological issues driving behaviors at these transition points need to be better understood.

Fortunately, these transition points have the potential to be influenced by policy. For example, the NSF requires dissemination plans in engineering education funding proposals, and encourages multi-investigator and multi-institutional collaborations. These policies serve to strengthen successful navigation of transition points by obliging innovators to become active disseminators, and by predefining a set of contemplators who are pre-disposed to becoming adopters of innovations in multiple institutions, each with unique organizational contexts.

Small School Perspective

Institutions each have their own context which may make certain transition points more or less difficult to traverse than others. For example, while smaller schools are likely to face less institutional inertia for adopters wanting to institutionalize an innovation, they are also likely to find identification and selection of innovations to contemplate for adoption more difficult.

Associated with a 'small' context is the circumstance that there is not a large group of faculty to parse the search for Engineering Education Innovations (EEI's).

The task of identifying EEI's and determining which to pursue can be time consuming to the point of abandoning the adoption effort altogether. Short of that, time consumed by identification and selection leave less time to spend on planning and implementing the EEI chosen for adoption, resulting in a reduced likelihood of success. Obviously, a coordinated effort at a large school would consume a smaller proportion of time for each involved faculty member.

Further, smaller engineering programs tend to offer single sections of each course once a year, and possibly less frequently for some electives. This means their feedback loop on implementation of EEI's is long and the rate of learning about the success or failure of an attempted EEI implementation is correspondingly slow. Likewise, the opportunity to 'tweak' an innovation to modify it to fit particular small school circumstances or to improve it from the previous offering, presents itself long after the initial implementation.

Contemplaters at small schools would like to have access to a list of the most important recent innovations instead of having to commit limited resources to carefully consider each potential innovation to determine if it might be applicable to their situation. If research that identified the 'best' recent innovations was readily available, that would provide a significant service to those who want to adopt innovative practices, but who don't know where to start. If the research could provide further information about the context(s) in which each innovation has been successful, as well as the faculty behaviors necessary for success, this would be a tremendous benefit.

Information about past experiences with contexts and behaviors contributing to failed implementation attempts would also be very valuable information to small school faculty for deciding which innovations to pursue, which to avoid, and which to assign to a 'wait and see' status. Other information about specific innovations that would be useful for contemplaters includes:

- Necessary educational foundation (e.g., does utilizing the innovation require programming in a particular language or other software knowledge?)
- Likely resource requirements (start-up and sustaining), such as time commitments, space requirements, materials and technical support
- Degree to which the innovation is discipline specific or independent (e.g., discipline specific innovations might include lab equipment/activities, content modules, demonstrations, while discipline independent innovations might include use of teams, games/competitions, design activities, use of new technology, student centered learning approaches, 'game show' environment, etc.)
- Measured benefits (positive outcomes) that previous adopters have experienced.

If such research based information could be made readily available it would greatly facilitate contemplaters from small school contexts. One promising venue for such information presentation would be a type of 'Innovation Tracker' website, serving as a clearing house for innovators to make their EEI ideas and materials available. Adopters could use the site to rate and comment on their 'user experiences.' Contemplaters could use this information in their selection process—similar to e-shopping websites. If a sophisticated enough tool were produced, contemplaters could put in organizational contextual descriptors. Using this information, the website could recommend appropriate innovations based on a contemplator's organizational context. This could be a living research document. Periodically, the 'top ten' innovations or 'editors choices' could be designated, based on review of user comments, on rate of adoption, or awards bestowed by professional societies.

Current State of Research

While research describing specific innovations abounds (e.g., the most recent ASEE conference had over 1,500 papers presented!), research describing relevant organizational contexts and faculty behaviors are less well documented, appearing primarily as anecdotes and hints buried within reports on specific innovations.

There are some notable exceptions to this, including work by the Foundation Coalition (http://www.foundation-coalition.org/), and SUCCEED (http://www.succeed.ufl.edu/default.asp), both NSF sponsored multi-university coalitions focused on engineering education.

Other notable exceptions are reports of the NSF sponsored 1997 Engineering Education Innovators' Conference, specifically, in the summary of the sessions:

> BUILDING EFFECTIVE DISSEMINATION PROCESSES (http://www.nsf.gov/pubs/1998/nsf9892/dissem.htm), and
>
> INSTITUTIONALIZING ENGINEERING EDUCATION INNOVATIONS (http://www.nsf.gov/pubs/1998/nsf9892/inst.htm)

In these workshops, attendees identified the following as a summary of the most important issues and recommendations for dissemination:

- Dissemination of innovations should be planned up-front, as part of the design, taking into account the intended audience
- Innovations should be modular, so that users can choose all or part of the innovation
- Personal interactions between users and developers (through workshops, conferences, etc.) are very important for dissemination
- There needs to be better documentation of the processes through which innovations are developed.
- Motivation for innovation dissemination is weak at present but can be improved by NSF insisting on solid, innovative dissemination plans for educational developments
- Faculty could be rewarded for adopting or adapting innovations made elsewhere.
- There is a need to change the faculty culture and faculty reward system to increase the recognition of the value of innovation

Workshop, attendees similarly identified the following as a summary of the most important issues and recommendations for institutionalization:

- Understand, involve and motivate stakeholders at an early stage including identification of internal and external "champions"
- Develop a credible justification for change, e.g., industry representatives

- Formulate a step-by-step plan for implementing change, including identifying required resources and flexible strategies to deal with resistance
- Communicate through all possible and reasonable means.
- Conduct independent, data-based benchmarking, assessment, and evaluation.
- Reward innovation and use strategic initiatives for internal funding in order to achieve "bottoms-up" innovation
- Make innovation an integral part of the institutional mission.

Embedded in the 'best practices' outlined above are many potentially relevant faculty behaviors and organizational context factors. Given the experience and stature of the 1997 workshop attendees, their observations provide a good starting point for forming testable hypotheses. Combining these observations with the innovation model presented in Figure 1 will help to build a research agenda and focus research efforts through creation of specific, testable hypotheses.

For example, do innovations that had a dissemination plan 'up-front' get contemplated by more faculty than innovations that did not have such forethought applied toward dissemination? Does this 'wider net' result in more adopters/adapters, or just more contemplators that eventually desert the innovation?

If there are institutions that reward faculty for adopting and/or adapting innovations created elsewhere, how do these rewards influence the rate of adoption/adaptation compared to institutions lacking such reward mechanisms? Can industry representatives and external champions help adopters/adapters achieve institutionalization? For example, can we report relative rates of institutionalization of innovations for organizations with as compared to those without support for the innovation from Industrial Advisory Boards?

Data Sources

Supporting research on the process of institutionalizing engineering education innovations requires compelling data. Two largely untapped data resources for research on EEI's are; ABET self-reports and feedback from professional conferences.

California State University, East Bay recently acquired ABET accreditation under the ABET's EC 2000 criteria. The process of designing and documenting the continuous improvement process regarding teaching, required by ABET, was enlightening.

Collectively, similar documentation from other institutions has the potential to provide an important source of researchable material regarding diffusion of engineering education innovations and organizational context. These ABET self reports regularly appear on departmental websites. This is a largely untapped resource.

One of the primary dissemination vehicles for EEI's is 'presentation at professional conferences.' This is a standard part of virtually all dissemination plans, and often the number of papers and presentations are quoted as an indication of dissemination. However, other than individual faculty exchanging individual communication, there is a significant lack of a formalized feedback mechanism regarding outcomes from this process.

Most conference sessions conclude with evaluation forms being provided, usually with questions regarding the usefulness of the presentations. However, at most conferences, presenters do not receive feedback from those evaluations. Did audience members find the material useful? How likely are they to incorporate lessons learned into their own pedagogy, or to communicate ideas from the session to other faculty members not in attendance?

If executed appropriately, conference session evaluations could be a rich source of valuable information regarding the first impression the innovation had on potential adopters. Furthermore, it could be used to identify individuals for a short follow-up survey to find out if they did in fact end up incorporating any of the innovations they were exposed to into their educational practices, or if they served as disseminators and passed the ideas on to colleagues. This could provide valuable information in researching the transition from contemplation to adoption.

Conclusions

Improving engineering education and creating engineering graduates able to navigate and thrive in evolving environments is a critical task for maintaining and strengthening competitiveness. Improvements in engineering education are driven by innovations that utilize new technologies, better understanding of student learning processes, and that better model new work environments' levels of collaboration and communication.

However, innovations may not diffuse. Inferior innovations may stifle superior innovations. Innovations developed at non-Ph.D. granting institutions may not be experienced by the next generation of university professors. Innovations successful in the original organizational context may fail in other contexts, and these failings may not be understood as contingent, but rather serve to taint the innovation for all future contemplators.

Much research is needed to develop a better understanding of the creation-to-institutionalization process. A first step is to validate the model and determine its efficacy by identifying a number of engineering education innovations and treating them as case studies. This would include instances where innovations developed to the point of institutionalization, as well as innovations that stagnated at a stage prior to institutionalization.

Can we identify the original creator of an innovation and quantify the dissemination efforts? Can we document why certain contemplators decided to adopt while others deserted the innovation? How long does it take for innovations to progress from one stage to another? Can we investigate a particular innovation and identify specific organizational contexts and faculty behaviors that lead to ultimate institutionalization at one location and desertion at a different location?

Are there certain, 'bellwether' individual innovators, publications or institutions that greatly influence agents at particular stages of the process? What motivates disseminators who are not the original creators? What venues provide information to contemplators? Utilizing the model and case study methods including in-depth interviews allows exploration of these fundamental relationships.

In this paper, we propose a conceptual model for organizing research on engineering education innovations. The model allows researchers to address more focused and sophisticated questions. Instead of broadly asking whether certain organizational contexts and faculty behaviors positively or negatively influence innovations, we can ask focused questions regarding critical transition points in the process bridging the creation, dissemination, adoption, adaptation, desertion and institutionalization phases of the process.

By better understanding the complex interrelationships between the stages in the process and the influence of organizational contexts and faculty behaviors, we can provide policy makers, deans, department chairs and faculty with tools to successfully promote engineering education innovations.

Acknowledgements

I would like to acknowledge and thank the National Science Foundation for sponsoring, and the American Sociological Association and the National Academy of Engineering's Center for the Advancement of Scholarship on Engineering Education for hosting the Social Dynamics of Campus Change workshop.

I would similarly like to express my gratitude to Jennifer Croissant, Mary Frank Fox, Cheryl Leggon, Sandra Hanson, Michael Loui and Willie Pearson, the members of the 'Organizational Context and Faculty Behavior' panel of the workshop, for their participation in discussions allowing me to better articulate some of the ideas presented in the paper.

The author is solely responsible for the material, views and opinions expressed in this paper. ❇

Organizational Contexts and Faculty Behavior: Frameworks for Research on the Social Dynamics of Campus Change

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There are several sets of disciplinary frameworks and hypotheses that guide potential modeling of organizational change with regards to the development and implementation of new ideas about curriculum and pedagogy. Each discipline or area of study brings a set of assumptions and guiding images which enable the study and application of theories of organizational change, and also inhibit examination of other core issues. The primary resources discussed in this short paper include organizational theory, theories of technological change, theories of curricular change, and consideration of professional and occupational change.

Neo-institutionalism is an examination of the ways that organizations respond to their external environment (DiMaggio and Powell 1983). The premises of neo-institutionalism include an observation of the homogeneity of institutions, which needs to be explained, and presuming a bounded rationality within institutions, which means that instrumental, social, and cultural logics all constitute the decision processes of actors within organizations. There are three primary mechanisms of institutional isomorphism: normative, mimetic, and coercive. Coercive isomorphism is the imposition of characteristics due to legal or regulatory mechanisms, such as the appearance of Federal regulations governing human subjects protection leading to the almost instantaneous proliferation of Institutional Review Boards and Human Subjects Protection Programs at research universities. Normative isomorphism is the result of the exchange of ideas, primarily through personnel, who bring with them a stock set of ideas generally imparted in their education or through professional associations. Business fads (quality circles, for example), are often propagated through this mechanism, as well as other kinds of institutional arrangements and policies. Finally, mimetic isomorphism is the name for processes whereby personnel at institutions gain information about other firms perceived to be successful in the same or closely related fields or sectors and try to imitate them. For example, Technology Transfer Offices have proliferated across universities based on the success of a very few institutions, on the perception that these are the best organizational mechanism for capturing rents from university-generated intellectual property. These offices have generally started from the initiative of upper administration, although the emergence of a new set of professionals (evidence by an association such as AUTM, the Association of University Technology Managers) means that normative isomorphism is most likely in effect as these offices are implemented.

The mechanisms of neo-institutionalism are not often considered in conjunction with analyses of internal technological change, that is, the implementation of new workplace technologies. Why this is important is not so much that the process of curricular change necessarily requires technology, although that is little explored with the development of information technology for instruction, but that curricular change might profitably be seen as analogous to technological change, at least along specific dimensions. What we do know about technological change in organizations is that it is subject to complex internal dynamics of social power (Vallas 1993; Thomas 1994). For example, one heuristic that emerges from Thomas is the idea that one should "look to the middle" for the dynamics of intra-organizational technological change. That is, those in the middle of organizational hierarchies will likely have the most practical power in implementing technology. Upper-level executives will lack specific technical knowledge although providing overarching visions for a firm, while the production workers who will be using the technology as a feature of their work will likely face a similar lack of both knowledge and also limited power to influence decision processes. Taken as an analogy, then, it could be expected that mid-level administrators (Department Chairs and Deans) or perhaps emerging educational paraprofessionals in University Teaching Centers would be taking the lead on implementing campus change. We should then be exploring the various kinds of social power amongst groups constituting curricular change dynamics.

From other disciplines, such as history or archaeology, we may also find value in theories of technological change. For example, frameworks such as Schiffer's (2005) implementation of a life-history and performance matrix approach to material artifacts may provide useful heuristics for the study of organizational change processes. The life history approach traces an artifact's specific biography from the collection of raw materials to final discard, coupled with a performance matrix which allows for the evaluation of various social groups' (Bijker 1995) perspectives as to whether or not the technology meets various kinds of material, economic, and social or ideological needs.

Curricular change itself is a field of inquiry, although most scholarship has been focused on pre-college curriculum and less on post-secondary education. Slaughter (1997) has provided perhaps the most compelling qualitative model of curricular change. After focusing on standard models of change (such as demographic models and change orienting in learned disciplines), the focus is on the multiple external social issues as well as internal and professional issues which constitute curricular formations. In this model there is attention to both the concerns of external entities, such as corporations or funding agencies, as well as discipline-driven scholarly concern, and demands on universities arising from social movements concerned with equity of access and representation in curricula.

Finally, in considering the social and organizational dynamics of changing curricula and pedagogy, ideas regarding professional and occupational change may be relevant. For example, there has been the proliferation of highly trained non-faculty workers on many different kinds of campuses. There are media specialists, instructional specialists, many kinds of adjuncts, fixed term lecturers, and affiliated quasi-administrators and staff positions that have occupational agendas and professional goals. They also seek power and influence on curricula, and are of course often on the front lines of retention efforts, such as in student services or college- or school- level advising offices.

Role proliferation is co-occurring with a systematic unbundling (Rhoades 1998) of faculty work, as the research-service-teaching Humboldtian integrated model is replaced by faculty as "content providers" for instructional specialists, experts who are queried by extension professionals, and as faculty become increasingly managers of research rather than working at the bench themselves. None of these are particularly new trends, but they do suggest that there are complex dynamics of faculty work which will change faculty interest in and power to constitute curricular and pedagogical change. The changing nature of faculty work at universities, particularly "unbundling" (Rhoades 1998, Finkelstein 2003) runs counter to the kind of integrative responsibility assumed in the most theories of curriculum and pedagogy.

The study of the diffusion of curricular innovations would clearly benefit from consideration of a multidisciplinary set of questions about both organizational change and its interconnections with technological change. However, even perfunctory study of these issues suggests that the final task that remains is a critique of diffusionist language. Like metaphors of evolution applied to social processes, diffusion is a term that both provides insight as well as obscuring certain processes. For example, Rogers's (2003/1962) seminal work establishes a change-oriented bias in the literature on diffusion. Like the diffusion of gasses, taken to be inevitable even if varying over certain properties, the diffusion of innovations is taken to be purely a matter of the transformation of ideas, and expected to be inevitable even if temporarily impeded. The language of "laggards" and examples that represent non-adopters as irrational or superstitious consistently impede the systematic understanding of evaluations of technologies such as provided by Schiffer (2005). Further, Rogers's model is weak in its conceptualization of material constraints, such as relevant manufacturing or use infrastructure, or the presence of established material practices for which change would be disruptive of power dynamics, in his considerations of the rejection of innovations. Rejection of change may be in any given actor's self-interest, despite potential organizational benefits.

With this challenge in mind, there are four broad areas for consideration in developing a research agenda for studying curricular and pedagogical change on university campuses. More detailed research on mechanisms such as institutional isomorphism, issues of power and work practices in the adoption of innovations, intra- and extra-mural interests shaping curricula, and changing occupational demographics and university structures and their effects on faculty work are all elements that require more detailed assessment across disciplines and kinds of university structures. Such a complete research program would then provide useful heuristics for the productive implementation of change projects.❇

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Institutional Transformation in Academic Science and Engineering: What is at Issue

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Scientific and engineering work takes place within organizations that may either stimulate or inhibit the development of ideas and positive outcomes of participation and performance (Blau, 1973; Long and McGinnis, 1981; Pelz and Andrews, 1976). The organizational and institutional context of work is important across academic fields, but it is particularly important in science and engineering. Scientific work is conducted within organizational policies and procedures. It relies upon the cooperation of others. It requires human and material resources. Further, the scope and complexity of research and the use of advanced technology heighten reliance upon facilities, funds, apparatus, and teamwork. In this way, science and engineering are essentially more "social" and "organizational" than fields outside of sciences. Compared to sciences, the humanities, for example, are more likely to be performed solo rather than as teamwork; to be carried out in the absence of equipment and instrumentation; to require modest funding; and in short, to be less interdependent enterprises (Fox, 1991, 1992).

The participation and performance of engineering faculty—in pedagogy, curricula, and other areas—then become institutional and organizational issues, subject to change. Just as an organization is structured, so too it may be restructured in administrative priorities, reward structures, allocation of resources, and patterns of collaboration, communication, and exchange. The re-shaping of an institution constitutes institutional transformation—and the potential for transformation underlies programmatic initiatives, including NSF ADVANCE for Institutional Transformation and the ASA/CASEE agenda for "Social Dynamics of Campus Change."

In this paper, my questions are: 1) What do we know about institutional context—and in turn, the potential of *institutional transformation*—for outcomes including innovative participation and performance among academic scientists and engineers? 2) What do we need to know further about institutional transformation—with implications for practices and policies to support "new engineering curricula and pedagogy"?

Institutional Context, Transformation, and Outcomes

Much of what we know about institutional context for outcomes among academic scientists and engineers centers upon "performance," particularly publication productivity. This is because publication is a central social process of science (Merton, 1973; Mullins, 1973), and is critical to academic reward structures, across "institutional types and missions"[1] (Fairweather, 1993).

In understanding performance in scientific fields, personal/individual factors, such as motivation or creativity, play a part. But these individual characteristics do not exist in a social vacuum, and by themselves, explain little in outcomes of performance (with implications for outcomes in other ways, as well). For example, no direct relationship has been found between measured creative ability or intelligence and outcomes of research productivity (Andrews, 1976; Cole and Cole, 1973). Rather, organizational conditions in the workplace, such as a pool of resources in excess of minimum needs (Damanpour, 1991), are important. The presence or absence of such organizational conditions may enhance or block the translation of people's creative characteristics into productive or innovative "outputs."

Fundamentally, it difficult to separate the behavior and performance of individual scientists from features of their social and organizational contexts (Allison and Long, 1990; Blau, 1973; Fox, 1991, 1992, 1998, 2001, 2003, 2006; Hagstrom, 1967; Long and McGinnis, 1981; Reskin, 1977). Behavior is tied to the organizational signals, priorities, and flow of human and material resources that provide the ways and means for performance. The notion of scientists in spontaneous intellectual creation outside of administrative or organizational frameworks is illusory.

What factors may then operate toward transforming institutions for "innovative" outcomes in academic engineering? I will focus here upon three factors: leadership, reward structures, and patterns of information, communication, and exchange.

First, leadership is critical to institutional transformation because leaders shape organizational visions, send institutional signals and messages, and have power to implement change. In academic institutions, the support of central administration is frequently indispensable for institutional transformation because high-level administrators can make decisions, set policy, and allocate resources in favor of transformation (for examples, see Asmar, 2004; Lindman and Tahamont, 2006).

This administrative role is particularly instrumental for transformation in academic settings with more, compared to less, bureaucratic structures, and decision-making that operates relatively "top-down" (Damanpour, 1987). Prestigious research universities (and other settings), however, tend to be driven strongly by the professional and expert authority of the faculty; and this may reduce the impetus and impact of upper-level, administrative decision making (Birnbaum, 1988), including that keyed to institutional transformation.

Science and engineering faculty, in particular, are strong "players" in research universities, because the high costs of laboratory staff and graduate training, as well as scientific apparatus, are funded substantially by research grants awarded to individual faculty. This decentralizes influence in academic institutions, so that

[1]Fairweather's (1993) study of faculty and chairs at over 400 institutions, across institutional types (research, doctoral, comprehensive, and liberal arts) indicated that faculty who follow a research-oriented model are paid the most at each type of institution, including comprehensive and liberal arts institutions.

authority resides with principal investigators situated in their individual "laboratories," as well with those in higher administrative ranks (Fox, 2000). Decentralization of authority and decision making has organizational advantages: it enables flexible and rapid response to issues by individual groups, and it may enhance responsibility. However, for institutional transformation, decentralization entails cost: decentralization tends to reduce capacity to forge a broad, unifying organizational strategy in education and other areas (Fox, 2000: 57-58; Harrison, 1994: 102).

The capacity for innovative institutional transformation rests, in part, upon "finding ideas that fit needs" (Daft, 2004: 427; Daft and Becker, 1978). In universities, in which research values predominate, this may mean that the acceptance of strategies for institutional transformation is enhanced when the innovation has a research-basis or strong research component (for example, see Allan and Estler, 2005: 230), or when the innovation is carried out in ways perceived to be "rigorous" and "theoretically sound" (Asmar, 2004).

Relatedly, institutional transformation is enhanced by positive "incentives" that support innovative practices and behavior. Resistance to innovation tends to come from those who are invested in the status quo. An institutional reward structure can enhance transformation by reducing individuals' risk and resistance, "aligning" individuals' efforts toward transformation with positive recognition and rewards (salary and advancement).
Further, in order to reward faculty's involvement in innovative institutional transformation—such as "new curricula and pedagogy"—an institution needs means to assess or measure such involvement and to make clear the guidelines to be used in evaluation (Branskamp and Ory, 1994; Seldin, 1984). Institutional transformation is enhanced when desired innovations "count" for individuals as well as the institution at large, and when criteria for evaluation are clear (Fox, Colatrella, McDowell, and Realff, forthcoming; Whitman and Weiss, 1982). Networks of communication and exchange for innovative, institutional transformation are important as well. Implementation and adoptions of institutional innovations are supported by effective networks for innovation through means including: 1) coalitions developed among persons at various ranks within the institution who can help steer the process of change and develop commitment to change; 2) early and continuing information conveyed about the need for change and the steps needed to ensure change, without adverse consequences for faculty, students, and administrators; and 3) training made available for innovation (Daft, 2004: 426-428).

Further Understanding of Institutional Transformation

In order to understand, implement, and sustain institutional transformation, we need to know more about the ways in which transformation relates to particular characteristics of organizations, and the students and faculty within them, including:

1. Size of institution: are smaller, compared to larger, institutions "amenable" to institutional transfor-

mation—and how may the process of positive transformation vary with size of institution?

2. Autonomy of faculty: how may style of leadership for institutional transformation operate effectively within organizational settings in which faculty freedom and autonomy are high, and in which faculty identify more strongly with their broader research communities compared to the institutional locations in which they are appointed?
3. Level of institutional impetus for status-maintenance or mobility: given that perceptions about an institution's national ranking often take precedence over other measurable factors in governing institutional decision-making (Alvesson, 1990; Gioia and Thomas, 1996), how does an institution's level of "strive for standing" affect momentum for transformation in curricula or pedagogy?
4. Subfields of faculty: is institutional transformation—in curricula and pedagogy—facilitated/impeded by the characteristics of the engineering subfields in which faculty teach and do research; for example, subfields that are relatively new (compared to old), experimental (compared to theoretical), or applied (compared to basic)?
5. Faculty and student composition: does diversity in composition of the faculty and/or students, in gender and race/ethnicity, interface with capacities for institutional transformation in curricula and pedagogy?

The aim then is to better understand complex considerations of the ways in which characteristics of institutions, and of the students and faculty within them, affect strategies and practices for implementing and sustaining positive institutional transformation. ❇

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Lessons from Multi-Cultural Feminism for Changing Science and Engineering

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As we enter a new millennium, girls and women have earned a permanent place in the previously male domains of science and engineering. However, barriers to access still exist. The President of one of the most elite universities in the U.S. B Harvard University B recently addressed a group of economists. In his comments, Lawrence Summers referred to an innate difference in science ability favoring boys. Those of us who have been studying gender and science over the past few decades were chilled by these comments. A large body of research exits which provides overwhelming empirical evidence that young boys and girls start out with very similar interests and abilities in science. School systems, occupational systems, and a culture of femininity in the U.S. and elsewhere work to systematically encourage this interest and ability in boys and discourage it in girls. This Acooling out@ process results in a scientific labor force which is largely male and women remain under-represented in science and engineering occupations B one of the most elite and influential sectors of the U.S. Labor Force (National Science Foundation, 2004). The shortage of women is a reflection of the continuing bias and gender inequity in science and engineering.

The U.S. science and engineering system is not just a male system. It is a white male system. Non-Asian women of color remain under-represented in science and engineering. Research on women of color in science and engineering is limited. Historically, studies of science as well as feminist theory and research tended to have a white, middle-class bias. Thus, women of color are largely invisible in these literatures. The multi-cultural approach to understanding gender stresses the intersection of race, class and gender. It is this combination of statuses that makes for a particular group=s attitudes, position, and opportunities (Lorber, 2001).

In this paper I will provide some background on a multi-cultural feminist approach to studying the structure of science and engineering education and occupations. Much of my work has been on African American women in science education systems, hence that will be my primary focus. In spite of the barriers which the white male science system sets up for women, minorities, and minority women, my work has shown high levels of interest and involvement in science and engineering among young African American women. The multi-cultural gender approach recognizes the quandary involving the high level of interest and involvement in science and engineering among young African American women in the context of a science system which does not recognize those who are not white and not male as candidates for competence and success in science. Implications of the multi-cultural feminist approach for policy, practice, and needed research in the U.S. science and engineering system will be provided.

A MULTI-CULTURAL FEMINIST LENS

Increasingly, research on gender has moved away from seeing gender as a learned trait and a property of individuals who are socialized into a particular gender role. More recent theorizing about gender sees it as a macro structure that hierarchically stratifies society. Power and conflict are taken into account in understanding gender and gender is viewed as something that is constructed (Connell, 1987; Grant et al, 1994; Lorber, 1994; Thompson and Walker,1995; Ferree, 1990; Osmond and Thorne, 1993). Gender is seen here as a principle of organization rather than a characteristic of individuals. Thus the study of gender is a study of the production and reproduction of power hierarchies and of the unequal distribution of resources in families, schools, work organizations, and communities that reflects and helps maintain these hierarchies.

These macro-structural theories make a contribution by recognizing gender as a structure based on power relations. Feminist theory is similar to other macro gender theories in seeing unequal power relations (male hegemony) as a critical component of the creation of gender in a society and a central feature of all social organizations. However, feminist theory takes a distinctive approach to understanding gender. The approach includes issues involving history, agency, and ideology. Feminist perspectives avoid a deterministic notion of women as passive victims by pointing out the fact that gender is constantly being re-constructed and negotiated as well as constructed. A dialectic between structure and agency is posed in which structure conditions life but people change social conditions (Agger, 1998).

The combination of history and agency provided by feminist theories has implications for change. Sometimes structures are questioned and historical and structural conditions combine to create a sense of agency for women leading to victories that may or may not restructure the gender hierarchy but do contest it (Connell, 1987). The combination of individual agency and historical consideration provide for elements of choice, resistance, and transformation in gendered science systems that are not inherent in either structure or biology.

Feminist theory also incorporates ideologies to a greater extent than structural theories and shows how dominant groups rule by consent not by force. Thus gender hierarchies are maintained in part by ideologies or dominant belief systems that favor the dominant group and justify the gender order as a natural one (Sage, 1990). These ideologies are a form of cultural power that create a patriarchal definition of the situation for men and women (Connell, 1987). Ideologies about science as a white male domain are presented to young girls and early on in the educational system. Ideologies about women's family and work positions are also present in science education and occupation systems. Feminist theory has gone a long way in advancing our understanding of gendered systems. However, early work on gender (including that using a feminist approach) suffered from a white, middle-class bias.

The multi-cultural feminist approach to understanding gender comes out of relatively recent work by women of color who have attempted to correct past biases in the social sciences (Collins, 1990; Zinn and Dill, 1996). An awareness of biases present in much work on gender led to a focus on the intersection of race, class, and gender (Anderson and Collins, 1995; Glenn,1985; Rothenberg, 1992; West and Fenstermaker, 1995). Here there is no argument that it is race, class, or gender as the primary basis of hierarchy. Instead, it is argued that it is the combination of statuses that make for a particular group's attitudes, position, and opportunities (Lorber, 2001). Collins (1990) has been particularly effective in describing this approach. She suggests that no one form of oppression is primary. Rather there are layers of race, class, and gender oppression, within individual, community, and institutional contexts. And she argues that each of these locations are potential sites of resistance. The approach also emphasizes the unique subcultures of minority women and the role of these cultures in affecting both the structures that limit and direct women's lives as well as the agency which allows them to retain some control and influence within these structures (Hanson and Kraus, 1998; 1999). The unique subculture of African American gender systems is important background for understanding the science and engineering experiences of young African American women.

Research has suggested that gender systems in African American subcultures might provide young women a unique set of resources B resources that might be important for generating interest and success in science. The cultural context of the African American community is one which historically saw women working and heading families (Anderson, 1997). African American women continue to have high rates of labor force participation. Work and family roles are not seen as conflicting (Collins, 1987). Instead of work being in opposition to motherhood, here it is seen as an important dimension of motherhood. And it is the perceived incompatibility between science careers and family pursuits that keeps many women from entering and persisting in the pursuit of science degrees and occupations (Matyas, 1986; Ware and Lee, 1988).

Historical analyses have suggested that the tradition of male dominance in white families in the U.S. has not been replicated in African American families. In part because of the legacy of slavery, the African American family has been typified by greater equality in family decision making and division of labor (Gutman, 1976; Hill, 1971; Kane,2000). As a result of these arrangements it has been suggested that gender roles are more egalitarian here than in white families (Wade, 1993). Wilcox (1990) found that African American women are more dissatisfied than white women with the amount of power women have in society and Dugger (1988) found that they were also more aware of gender discrimination. These patterns contribute to greater self esteem, independence, and assertiveness as well as high educational and occupational expectations among young African American women (and their parents) relative to other women (Anderson, 1997; Hanson and Palmer-Johnson,2000; Hill and Sprague,1999; National Center for Education Statistics, 2000a). All of these characteristics have been shown to be related to success in science and engineering (Hanson, 1996). In my earlier examination of the high school science achievement process (Hanson and Palmer-Johnson, 2000), my colleague and I found that African American families compensate for disadvantages on some resources (e.g., socioeconomic status) by providing young women with an excess of other resources (e.g., unique gender ideologies, work expectations, and maternal expectations). And unlike white parents, they sometimes provide more of these resources to their daughters than their sons. Along the same line, Higginbotham and Weber (1992) found that African American families put a greater stress on education and occupation as sources of mobility for their daughters (relative to white families) since marriage is not seen here as a source of mobility (as it is in white families).

IMPLICATIONS

Although research on women in science has proliferated, the focus is often on differences between men and women with little attention to subgroups of women. It is a mistake to think of women as an undifferentiated group. Researchers increasingly have come to the conclusion that not all women have the same experiences in science and engineering education and occupations (Hanson and Palmer-Johnson, 2000; Mau et al., 1995). In fact, preliminary research has suggested that young African American women are particularly interested in science (sometimes more so than their white counterparts) (Hanson and Palmer-Johnson, 2000; Hanson,2004; National Center for Education Statistics, 2000a).

In spite of this interest on the part of African American women, they find it difficult to persist in science education structures (including engineering) that are based on white, male models. These structures are seen as hostile to women and people of color in general. Bias exists at multiple levels. Asres (1999), Schiebinger (1999), and others argue that science is Adiversity stupid. Education institutions have been designed to value and transmit a certain culture: white and male. They have not become this way by accident. We need to change our mental models of knowledge and include diverse sources of knowledge from multiple cultures. Asres (1999) argues that we need science and engineering education that reflects our society and the contributions of all groups. Currently, the contributions of women and people of color are largely hidden. Both material and intellectual resources are needed, Asres argues, in making these institutional changes. Without them, technical and economic advance will be more difficult. It is clear that we need to broaden our talent base in science. As Schiebinger (1999), Hanson(1996) and others argue, we are missing out on new scientific advance by limiting the pool of science talent to white males. Schiebinger (1999) shows how advances in science have developed and progressed in areas such as medicine once women became engaged in the profession. Thus these white male institutions, by definition, are discouraging minorities, women, and minority women from participating. Consequently, the flow out of science programs and engineering programs is high (and getting higher) amongst these groups while enrollment rates are low (and getting lower) (George, 1999; Bonous-Hammarth, 2000; Asres, 1999). A focus on recruiting women, minorities, and women of color is important. However, I have argued there is both talent and interest there. The more important change needed is in the structure of science and engineering institutions. Changing our mental models of science talent and of diversity is important. When this happens, women, minorities, and women of color will feel more comfortable in the science and engineering classroom . There will be a consequential increase in the number of women, minorities, and women of color teaching in the classroom.[2] Currently, these numbers are alarmingly low. Data on chemistry classrooms and physics classrooms in the high school setting show that women are becoming more visible (e.g., 40% of high school physics teachers are female) but African Americans are not (e.g., 1 % of high school physics teachers are African American) (Horizon Research, 2002).

With regards to engineering and the high drop-out and low enrollment rates among minorities, women, and women of color in this area of science (Brainerd et al., 1999; George, 1999; Bonous-Hammarth, 2000). A recent tally of high school graduates planning on a major in engineering revealed stability in gender representation, but improvement in minority representation (Noeth and Harmston, 2003). Again, the problem is not a lack of talent and interest amongst female students, minority students, and women of color. These groups are making tremendous gains in science knowledge, interest, and education (NSF, 2004). Rather, a multi-cultural feminist perspective argues that it is a problem with institutions and a white male bias in engineering that needs to be addressed. Engineering is a creative activity. One's creativity is a product of one's experiences. Without diversity we limit creativity in engineering (Wulp, 1999). A recent study of the climate in engineering found that women enter the engineering classroom with considerable confidence and interest but that this dips by the end of the freshman year (Brainerd et al., 1999). When faculty, course-content, textbooks and mental models reflect a value on cultures that are not white and are not male, classroom climates will shift and all individuals will feel welcome in engineering.[3]

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[2] See Toro-Ramos (1999) for a description of the success of an engineering program designed for Hispanic women. Success here was a result of a cooperative learning environment, supportive peers, recognition of and value on diversity, an outcomes-based curriculum (not just lecture oriented), use of research teams, women and minorities in leadership roles, a strong relation with industry, and small class sizes.

[3] Individuals can contact Dr. Asres for a list of non-white inventors at asres@engr.wisc.edu

Data on minority women in science and engineering are hard to come by. The National Science Foundation and the National Science Board (National Science Board, 2000; National Science Foundation, 2004) have gone a long way in providing increasing amounts of information on diverse populations in science and engineering education and occupations. However, the data are often provided for race groups and gender groups, but not for race/gender subgroups. Even when subgroups are mentioned, the information provided is often minimal. Organizations, agencies, and individual researchers need to collect and present data on science and engineering that go beyond white vs. black and male vs. female contrasts. Acknowledgment of the variations within race groups (by gender) and within gender groups (by race) is needed.

Contemporary feminist frameworks that use a multi-cultural lens do not see women and African Americans and African American women as merely victims of racism and sexism. Sometimes structures and status quos are questioned and challenged. Thus, it is not just structure that is important for understanding African American women's experiences in science but these young women's responses to race and gender structures. Sometimes young people do not absorb all the culture's gender and race messages and obediently comply. And it is often unique cultures and histories that are the sites of resistance. My research on the high level of interest and involvement among young African American women can only be understood within the context of the unique gender culture and history of the African American family.

Recent data from the National Science Foundation suggest that experiences in science from post-secondary school through occupations are distinctly different for women from different race/ethnic groups (National Science Foundation, 2004). The data suggest that increasingly, African American females are present in science. For example, African American women (but not White women) earned more than half of the Bachelor's degrees in science and engineering awarded to their race/ethnic group in 1997. During the same year, African Americans were the only race group where women earned over half of the Master's degrees in science and engineering. African American women earned 46% of the Ph.D.'s awarded to African Americans in science and engineering in 1997 while White women earned 38% of the degrees awarded to Whites. Finally, data from the National Science Foundation suggest that African American women make up a much larger portion of African American scientists (36%) than is the case for White women (22%).

Thus, we cannot assume that African American women will be more discouraged in science than White women. That is not to say that these young women avoid racism and sexism in their pursuit of science. Existing studies of African American women in science document considerable barriers that these women face (Kenschaft, 1991; Malcolm, 1976; Ovelton Sammons, 1990; Vining-Brown,1994). Researchers have found that young African American women report a sense of feeling unwelcome in science and engineering classrooms (Cobb, 1993; Vining-Brown,1994; Clewell and Anderson, 1991; Malcolm,1976; Hueftle et al., 1983). The limited literature on African American women in science suggests that they are aware of both race and gender barriers but perceive race as a larger barrier than gender (Rayman and Brett, 1994; Hanson,2006).

Although young African American women show high levels of interest and involvement in science, most research on minority women's science experiences has not found them to show higher science achievement than other young women (as measured by grades and standardized exam scores, especially in the high school years) (Hanson, 1996; Catsambis, 1995; Clewell and Anderson, 1997). These differences mirror race trends in the broader achievement literature and can be seen as coming out of biased practices that affect opportunities for minority students. Testing biases which favor middle-class white students are most likely part of the explanation for differences in standardized exam scores (Lomax et al., 1995). Ogbu (1978; 1991) has argued that African American students' achievement may be lower than that of whites since they see fewer returns, a biased system, and so pull back their efforts. Mickelson (1990) adds to this by suggesting these young people believe in education in general but not for themselves, thus predicting poorer performance. Ainsworth-Darnell and Downey (1998) have shown that it may not be so much frustration and lack of hope that work against African American students' school achievement and for white middle-class students' achievement, but the lower resources for success (including poorer schools and higher rates of poverty) that work to keep these race differences in place. Finally, race differences in achievement are no doubt kept in place by stratification within schools involving tracking and differential learning opportunities (Cooper, 1996; Oakes and Lipton, 1992). All of these factors, along with evidence of racism in the school and classroom (Persell, 1977; Anderson, 1988; Feagin et al., 1996) have implications for education and testing policies and ultimately for the opportunities that young African American women experience in science and engineering. It is important that researchers focus on these biased educational structures and vehicles for change within them.

Findings from our recent survey of young African Americans' experience in the science classroom suggest that teachers play a large role in encouraging or discouraging interest in science (Hanson, 2006). In answers to open-ended questions, when the young women talk about teachers, it is often the case that they might like science but their teachers did not make it fun. Many reported that they did not like the teacher and that the teacher did not teach them much. Replies of this nature seem to go hand in hand with the ones that suggest science is too hard or not interesting. These replies involving teachers often suggest a potential love for science but bad experiences with teachers that took away from a development of science interests. The implications of these responses for the science classroom involve the relationship between perceived abilities (and confidence) in science and one's positive attitude toward science. Young people's feelings about abilities in a subject are often influenced by teachers and peers. These self-fulfilling prophecies in science often revolve around race and gender. When teachers walk into the science classroom expecting talent from every student, it is likely that the self-fulfilling prophecy will be one of talent development rather than talent loss. More research on the dynamics of race and gender in the science and engineering classroom is needed.

The multi-cultural gender lens used here helps us understand young African American women's interest and involvement in science and engineering through an examination of the unique history and norms about femininity in the African American culture. Research using a multi-cultural feminist lens helps us understand the strengths and abilities that sometimes exist among groups of young people who have statuses (or multiple statuses) which we would expect to universally work against them. Double jeopardy arguments assume that African American women will be doubly disadvantaged in the White male science system. We may find double jeopardy in terms of resistance within the science and engineering system, but that does not necessarily convert to double jeopardy in interest and involvement. Thus, this approach and the work coming out of it, is a work of hope and optimism in the context of continued racism and sexism in science.

SOME SUGGESTED QUESTIONS FOR FUTURE RESEARCH

1. What are the institutional processes (involving pedagogy, curriculum, peer environments, textbook content, instructor's attitudes, instructional strategies, testing strategies, etc.) that deflate the interest and engagement of women (and minority women) in engineering?
2. How can engineering content and classroom environment be made less Adversity stupid?
3. What are the characteristics of engineering programs that have been successful in recruiting and retaining women (and minority women)? Are the factors that help recruit and retain White women the same as those that help recruit and retain minority women?
4. How can high school science classes incorporate strategies (involving teachers, climate, content, etc.) that encourage all students, regardless of race or sex, in science and engineering?
5. What changes are needed in order to create standardized science exams (e.g., the SAT and ACT exams) that are not race, class, and sex biased?
6. What are the new inventions, ideas, questions, and answers in engineering that might come out of a culturally diverse talent pool?
7. What are the costs (in efficiency, knowledge creation, technological advance, economic progress, etc.) that are associated with a White, male bias in engineering?
8. Is the new engineering pedagogy less biased towards women and minorities,

and do schools and departments that adopt it have a lower drop out rate for these groups?

9. Are engineering faculties aware of the diversity in science/engineering interest across groups of women? Are they aware of the relatively high level of interest amongst African American women? If not, how can this awareness be cultivated? ❇

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Participation by Minorities in STEM and the Differences that Participation Makes

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Science and engineering are forces driving sustainable economic development worldwide. Consequently, to enhance its position in the global economy, it is more imperative than ever that the United States (US) develop its human talent in science, technology, engineering, and mathematics (STEM) fields. Traditionally, the pool from which the US drew STEM talent was largely comprised of non-Hispanic white males, and any shortages in STEM talent were met by importing talent from abroad. Within the past two decades, there has been a decrease in US citizens' participation in STEM due in large part to declining interest in STEM among non-Hispanic white males coupled with the decreasing viability of importing STEM talent and heightened security concerns resulting from the events of September 11, 2001.

Despite the significant increases in the proportions of the US population comprised by Asians, African Americans and Hispanics, the US STEM workforce remains overwhelmingly white (BEST 2006; Ong and Park 2006). In 2003, African Americans, Hispanics, American Indian/Alaska Natives comprised 40% of the 24 years of age and younger US population, and are estimated to increase to almost 50% by 2020 (Childstats.gov, 2005). In urban centers, the majority of K-12 schools are comprised of racial/ethnic minorities. These groups have a tradition of underparticipation and underachievement in STEM due largely to unequal access to high quality education (Orfield and Yun 1999). Consequently, an increasingly larger proportion of the school age population at all levels is becoming more racially and ethnically diverse, while the US STEM workforce in general, and the professoriate in particular, are not.

The timeline for some targeted programs has been sufficiently long to enable identification of what does—and does not—work to increase racial/ethnic diversity among the US STEM workforce.[4] Characteristics of effective policies, programs and practices have been gleaned from program evaluations and various evaluation research literatures (e.g., sociology and education), as well as from program evaluation reports (Pearson et al 2004). Higher education design principles are prominent in both the BEST report (BEST 2004) and the final NSF workshop report on pathways to STEM careers (Martin and Pearson 2005).

[4] Efforts targeted to increase racial/ethnic diversity in STEM are examples of the "canary-in-the-mine" phenomenon: that is, what works for one group tends to work for other groups (non-Hispanic white women and men) as well.

In STEM fields, introductory courses—such as calculus, for example—function as gatekeepers insofar as they "weed out" students from the major. Research findings indicate that introductory courses that are inter-disciplinary, cross-disciplinary, and/or multidisciplinary, and that place STEM in a larger societal context work to diversify STEM majors at the undergraduate level (Margolis 2002; BEST 2004). This is consistent with research that indicates that one important factor in selecting careers for racial/ethnic minorities (and women) is the extent to which a field contributes to the larger society and/or their racial/ethnic community (Eccles 1994; Margolis and Fisher 2002). Therefore, curricula emphasizing problem-solving applications of STEM are effective in both recruiting and retaining students from racial/ethnic groups under represented in STEM fields relative to their proportion of the general population (Leggon 2003).

Another characteristic of effective curricula and pedagogy is to provide hands-on learning experiences in environments that are encouraging and supportive. Some research findings indicate that for students from under represented groups in STEM, a lack of encouragement has the same effects as discouragement insofar as it reinforces students' doubts about their own ability to pursue a STEM career. Environments must be supportive financially as well. Under represented students from undergraduate institutions lacking the infrastructure to provide research experiences benefit from summer research experiences, which should provide a stipend for these students to compensate for foregone income. Most students from racial/ethnic groups under represented in STEM need to work to pay for tuition and living expenses because African Americans, Hispanics, and American Indians are overrepresented in lower socio-economic status groups; there is insufficient research on the interactive effects of race/ethnicity and class. STEM academic environments must be intellectually supportive to recruit and retain students from racial/ethnic groups under represented in STEM, as recommended in a recent report (Foundation 2005, p. 5): "Doctoral education and the various disciplines may engage in habitual practices—from the nature of student orientation programs to what is considered important in an academic field—that serve as a subtle discouragement to interest for students of color. The image of the doctorate, (STEM) discipline by discipline, must become less abstract and more socially responsive in a non-reductive way."

Racially and ethnically diverse STEM faculty can not only enhance the recruitment and retention of students from under represented race/ethnic groups in STEM fields (Foundation 2005), but also can enrich the pedagogy, curriculum and culture of STEM disciplines. The enrichment infuses vitality and creativity into the STEM enterprise, thus enhancing the US's competitiveness in the global economy.

Just as it is crucial for a curriculum to provide the research experience and analytical skills for a STEM profession, it is also crucial for a curriculum to "socialize" students into a STEM profession. Therefore, an integral part of an effective STEM curriculum is to teach students the "unwritten" rules of the profession: how to navigate the undergraduate, graduate, and postdoctoral education processes as well as the job market. Pearson's (2005) research on chemists indicates that African American students have a very different experience from that of non-Hispanic white students in the same courses at the same institution; for example, many African American graduate students do not know the importance of having pre-doctoral publications. Nor do many students of color know how to select the "right" postdoc (Lichter 2003). This is a sociological challenge because postdocs are selected by the PI, who may or may not practice inclusivity. Socialization into STEM professions includes problem choice and retention, how to present papers and posters at professional meetings and the appropriate behavior for professional social events (Pearson 2004).

With few exceptions, such as the Leadership Alliance and Meyerhoff Programs, programs designed largely to broaden the participation of racial/ethnic minority groups underrepresented in STEM, research findings concerning increasing participation in STEM fields have neither been sufficiently disseminated nor integrated into planning new programs and evaluating exiting programs (BEST 2004; BEST 2006; Martin and Pearson, 2005; Leggon 2006). Some mechanism at the national level to facilitate and enhance the sharing of strategies and information among programs, consortia and institutions would minimize duplication of efforts and gaps. Many effective practices come from data that provide "snapshots" of different groups at different points in the career path. What is urgently needed are longitudinal data that follow individual participants in targeted programs throughout undergraduate and graduate schools, postdoc(s), and careers in the full-time paid STEM workforce. Many efforts to diversify the US STEM workforce focus overwhelmingly on the inputs—i.e., enhancing the intellectual capital of individuals aspiring to a STEM career—and increasing output. These efforts often neglect the quality of preparation and experience, both of which impact attainment of tenure in academic environments and/or avoiding academic careers in research universities altogether. It is equally important to better understand how STEM careers develop and unfold and how ascriptive statuses such as race/ethnicity and gender impact careers and educational experiences; longitudinal data are crucial to enhance this understanding. STEM curricula and pedagogy should be informed by the needs of present employers in the global STEM workforce and should be sufficiently flexible to prepare today's students for tomorrow's jobs in the global STEM workplace, which is becoming increasingly diverse in terms of race and ethnicity.

Advances in science and technology are occurring at unprecedented rates, and make the value of human capital greater than ever. No nation can afford to use its human resources inefficiently and ineffectively. To promote innovation and foster creativity in STEM fields, it is absolutely imperative for the US to develop and nurture talent and encourage all of its citizens to participate in STEM careers. Increasing the participation of under represented racial and ethnic groups the STEM workforce increases the variety of perspectives in STEM fields, thereby enriching the vitality, creativity and quality of the science and technical enterprise. According to Science Indicators (NSB 2006), most growth in STEM in the last decade has been among underrepresented minorities and women. Women of color continue to comprise a higher proportion of STEM degree recipients within their racial/ethnic group than do European American or white women of whites; however, there are striking field differences. For example, in fields where women tend to be extremely underrepresented—such as engineering, computer science, and physics—women of color's representation in these fields relative to their male peers exceeds that of women in general; why this is the case has not been the subject of much research. Perhaps, Hanson will speak to this. Gender plays a significant role in the participation of African Americans and Latinos in STEM. Unfortunately, most studies of women do not disaggregate gender data by race/ethnicity (Leggon 2003, 2006). Yet, the literature reveals that women of all racial backgrounds share some common experiences with respect to participation in STEM education and professions. All are severely underrepresented among tenured faculty at research universities (Nelson 2006; Pearson 2006). Some have gained tenure on a second attempt after being denied earlier.

We continue to lack a full understanding of the impact of the underrepresentation of women and minority faculty on increased participation of these rapidly growing segments of the population. Despite recent increases in degree recipients, the percentages of underrepresented racial/ethnic college and university faculties remains relatively unchanged at less than 3-4 percent over the last few decades. Other areas of further research include: institutional climate issues; effects of critical mass on recruitment and retention of underrepresented racial/ethnic groups; career satisfaction; interactive effects of race/ethnicity and gender (Pearson 2005, 2006; Leggon 2006). ❇

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Moments of Inertia: Toward an Agenda for Sociological Research on Why Engineering Professors Resist Changes in Pedagogy and Curriculum

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March 22, 2006; revised May 27, 2006

Q. How many professors does it take to change a light bulb?
A. *Change?* What is *change?* — Old joke

INTRODUCTION

In engineering, the area moment of inertia measures the resistance of an object to bending and deflection. Engineering education suffers from large moments of inertia: engineering instructors resist the changes in pedagogy and curriculum recommended by repeated efforts to reform engineering education, including several large demonstration projects supported by the National Science Foundation (NSF). In fact, most engineering instructors are unaware of these recommendations, even though they have appeared in numerous outlets. As Froyd (2005) observed, traditional dissemination mechanisms such as journal publications and conference presentations do not reach most engineering instructors. Even if engineering instructors knew about these recommendations, however, it is not clear that they would change their practices.

In this white paper, I identify aspects of the organizational context of engineering education and the typical behaviors of engineering instructors that may impede the adoption of enhanced pedagogical practices and innovative curricular ideas. To dramatize the context and behaviors, I describe two fictional but typical engineering professors, a mid-career Professor M and a young Professor Y, at a typical engineering school in a fictional but typical research university.

Toward the end of this paper, I suggest questions for sociological research that could provide insights into organizational context and faculty behaviors. For example, social class and acculturation could explain why engineering instructors valorize the technical and disparage the nontechnical, and why they resist change in educational practices. The application of the sociological imagination may eventually identify the levers that could overcome the moments of inertia in engineering education.

MEET OUR CHARACTERS

Our mid-career faculty member, Professor M, was born and raised in Asia. Upon completing his baccalaureate degree, he came to the United States and entered Northeast Institute of Technology, where he earned the doctorate. During his graduate studies, he was supported entirely by research assistantships provided by his doctoral advisor's grants, except for an industrial internship in one summer. Although most doctoral graduates from his department took jobs in industry, M decided he could best continue his research at a university. When M joined Great Prairie University in 1993, there was no orientation for new faculty members, and he walked into his first classroom with no prior preparation or experience in college teaching.

Our young faculty member, Professor Y, was born in the United States. Although she came from a working class family, an uncle who was an electronics technician encouraged her to study engineering. She entered Desert State University, where she earned the B.S. and continued directly to its Ph.D. program. During her doctoral studies, she was supported by an NSF graduate research fellowship. Because she planned an academic career, she decided to spend one year as a teaching assistant; she led the laboratory sections of a sophomore-level course. The TA training program at Desert State consisted of a one-day workshop, primarily on grading assignments and on campus policies, such as the policy on student cheating. The supervision of TAs was spotty; she saw the course coordinator only a few times during the year, and he never observed her lab sections. When she accepted a faculty position at Great Prairie University in 2004, she had wanted to attend the week-long Science and Engineering Education Scholars program offered at Pennsylvania State University, which prepared twenty-nine new faculty members from eight different institutions for teaching responsibilities, but Great Prairie would not pay for the program. Great Prairie had offered its own program on teaching for new faculty for a few years, but with large budget reductions university-wide, it had cut the program in 2003. When Y entered her first classroom at Great Prairie in the fall of 2004, her preparation for teaching had consisted of only the one-day workshop at Desert State.

ORGANIZATIONAL CONTEXT

The largest undergraduate engineering programs in the United States are located at large public research universities like Great Prairie University. Its engineering school is consistently ranked among the top twenty in the nation for research quality. The engineering dean has set a goal of reaching a rank in the top ten within five years. The dean and the department chairs continually exhort the faculty to write more research proposals. The steady erosion of the state budget has placed even more pressure on the engineering school to bring in external funding.

Professor Y received some start-up funding from the engineering school, but she is working on an NSF CAREER proposal. Senior professors have told her that she needs to win a CAREER award to earn tenure. Consequently, they have advised her to focus on research for the CAREER proposal rather than on undergraduate teaching. They have urged her not to make any changes in the undergraduate courses that she is teaching, because the time required for changes would detract from her research. For the education part of the CAREER proposal, Y plans only to mention that she is developing a new graduate course in her research specialty.

Professor M has been fortunate to obtain research grants during his entire career at Great Prairie. Because his current funding will end within ten months, however, he is working on new individual grant proposals to support his six graduate students. Since his research specialty is no longer fashionable, the funds available for this specialty are declining. He is trying to find a way to fit his interests into an interdisciplinary proposal that he and several colleagues plan to submit to a special NSF initiative.

Research accomplishments and external funding are the most important criteria for promotion and tenure decisions at Great Prairie University. For promotion cases, Great Prairie evaluates teaching by using only the results of standard rating forms completed by students. Great Prairie does not use any peer review of teaching for promotion decisions or even for improvement of teaching. A fortiori, because of its strong tradition of academic freedom and professorial autonomy, instructors never observe each other teach.

Like traditional engineering curricula at many institutions, the engineering curricula at Great Prairie University include many technical requirements. Among required 128 semester credits, students take only 16 semester credits of humanities and social science electives; there are no other nontechnical electives. The engineering curricula prepare students for all parts of the Fundamentals of Engineering Exam, the first step toward professional licensure. The curricula include all of the knowledge and skills that professors at Great Prairie believe students need to become practicing engineers. Engineering instructors assume that engineering B.S. graduates from Great Prairie will primarily go to industry—software, electronics, automotive, chemical, manufacturing, aerospace, etc.; civil and environmental engineering graduates will enter private practice. The instructors are not aware that as the undergraduate student body has gradually become more diverse, increasing numbers of graduates choose careers in financial services, government, consulting, patent law, and even teaching.

The required engineering courses at Great Prairie—statics and dynamics, electric circuits, thermodynamics, etc.—are invariably taught in large auditoriums with fixed seats. In teaching these courses, instructors lecture in order to cover a large amount of material efficiently. A few years ago, when the budget was in better shape, the university invested in the latest educational technologies: desktop computers, video players, and LCD projectors were installed in the large auditoriums, and a Web-based course management system was chosen. With recent budget cuts, Great Prairie has struggled to maintain these services, and network outages are common.

The engineering programs at Great Prairie have been accredited by the Accreditation Board for Engineering and Technology (ABET) for many years. Department chairs endeavor to meet the

ABET requirements with as little effort as possible. While accreditation is necessary, engineering administrators feel that more effort should go into improving the research profile of the school. Engineering professors are generally dismissive of ABET: they don't feel that they should listen to ABET visitors who come from lower-ranked schools.

FACULTY BEHAVIORS

Professor M has never read a book or newsletter on college teaching. Professor Y has read only an earlier edition of Teaching Tips by McKeachie, when she was a graduate teaching assistant. From the book, she knows that she could use active and cooperative learning strategies, which promote student learning better than traditional lectures. But if she used active learning strategies, she would cover less material. Colleagues who teach more advanced courses would criticize her for not preparing students properly.

Professor Y has heard about the American Society for Engineering Education (ASEE), but Professor M has not. In any case, Y and M do not know how they might benefit from membership in ASEE. Neither Y nor M has ever seen an ASEE publication or an article from an ASEE conference, and they are unaware of NSF-supported work in engineering education. Professors Y and M feel they can barely keep up with research publications and conferences in their own engineering societies.

Professor Y does not attend workshops on teaching offered by the university's Center for Teaching and Learning because she feels that she cannot spare the time. She also worries that senior colleagues would think she spends too much time on teaching. Professor M attended a workshop on using PowerPoint in which the presenter cited results from recent educational research. He did not accept the research results, however. The qualitative part of the research study had no numbers, and the quantitative part did not resemble a properly conducted scientific experiment. In any case, the research study did not seem particularly applicable to engineering.

Professor M likes to use PowerPoint because he believes that he should transfer as much of his knowledge as possible from himself to the students. He thinks he could earn higher teaching ratings by spending more time to polish his PowerPoint presentations, perhaps by incorporating video clips. Because his ratings have been satisfactory, however, M feels that enhancing his presentations would not be worth the large additional effort.

On the few occasions when Professor M talks with other engineering instructors about teaching, they invariably complain about the inability of students to understand abstract concepts and to solve unusual problems. Professor Y listens to these conversations, but she hesitates to contradict the common wisdom.

Professor M believes that engineering instructors are gatekeepers to the engineering profession, rather than developers of student potential. Consequently, in required technical courses, he grades on a competitive curve, with limited percentages of A and B grades. He expects a sizable percentage of students to fail each required course.

DIRECTIONS FOR SOCIOLOGICAL RESEARCH

I hope that my description of engineering education at the imaginary Great Prairie University is only a slight exaggeration of the reality at most institutions. (Of course, the climate for innovative education at some institutions could be even worse!) I propose that changes in engineering education are impeded by the organizational culture of the engineering school and the individual behaviors of the engineering faculty:

Organizational impediments

- Because few doctoral students in engineering take academic positions, doctoral programs do not prepare students for academic careers.
- The training of teaching assistants is often limited to policies and procedures. The training programs do not introduce the research literature on college teaching.
- Engineering schools at research universities emphasize research accomplishments and grant funding over teaching.
- Teaching is evaluated only by student ratings, not by peer review, unlike the evaluation of research.
- Budgetary constraints may limit the upkeep and use of educational technologies.
- When courses are large, it is difficult to implement pedagogical innovations.
- When curricula have many required courses, it is difficult to change curricula.

Behavioral impediments

- Professors are ignorant about the good practices in college teaching (McKeachie 2006). They do not read about college teaching, and they rarely attend workshops. Consequently, most engineering instructors do not know about ASEE or about reforms in engineering education. They might not accept the results of educational research, which looks different from scientific research.
- Professors equate teaching with lecturing to cover content. They aim to transfer knowledge to students, rather than to encourage students to construct their own understandings. Professors blame students for failing to learn.

These organizational and behavioral impediments arise from instructors' fundamental beliefs about teaching and learning. For example, many engineering instructors believe that students are best motivated by competitive grading schemes. Unfortunately, many beliefs of engineering instructors are myths (Pendergrass et al. 2000).

Rather than try to change the beliefs of instructors directly, academic leaders might instead introduce new ways of thinking about engineering education. For example, Boyer (1990) proposed to think of teaching as a scholarly activity: at their best, teaching practices are grounded in the research literature, committed to the advancement of knowledge, and evaluated through peer review. Professors are sometimes shocked to learn that there is a large, reliable research base of knowledge about college teaching: models of student development, student motivation, classroom management, syllabus construction, effective pedagogies, teaching evaluation, etc. It seems to me that engineering instructors should learn something about this knowledge base before they contemplate large-scale pedagogical and curricular changes.

Instead of thinking of teaching as a scholarly activity, engineering instructors might accept a characterization of college teaching as a professional activity. Because engineering is a profession, engineering instructors would agree that they should model professional behavior. Ideally, like other professions, college teaching should require preparation to learn the knowledge base that supports good practice. Like other professionals, college teachers retain professional authority when they choose instructional objectives and set academic standards; they exercise professional judgment when they grade students' work. Just as doctors serve the health needs of their patients, teachers promote the learning of their students: college students are not customers, but clients who receive the services of professionals.

Here are some questions for sociological research on organizational context and faculty behavior, to explain why engineering instructors resist change in pedagogy and curriculum:

- Do the organizational impediments listed above actually obstruct the adoption of new pedagogies and curricula? Which impediments are most important?
- Do the behavioral impediments listed above actually account for the resistance of engineering faculty to new pedagogies and curricula? Which impediments are most important?
- What changes would remove these impediments?
  - –Would engineering instructors change their teaching if they co-taught courses with knowledgeable colleagues?
  - –Would tangible recognitions for excellent and innovative teaching change faculty behavior? Or would such extrinsic motivations drive out the intrinsic motivation to teach well?
  - –Under what conditions would leadership from an engineering dean produce significant changes? In 1989, the engineering dean at Carnegie Mellon University initiated a review of all curricula in the engineering school (Rutenbar 1991). This review culminated in new curricula, such as the integrated curriculum in electrical and computer engineering (Director et al. 1995).
- Do the beliefs of engineering instructors about teaching and learning account for their failure to change their pedagogies and curricula? Do demographics and characteristics of engineering faculty account for different beliefs?
- In general, would women born in the U.S. like Professor Y be more receptive to educational change than men from overseas like Professor M?
- Do engineering faculty who have read books or attended workshops on college teaching—as doctoral students or in their first year—believe that pedagogies and curricula should change?

ACKNOWLEDGMENTS
I am grateful for the perceptive comments of Jonathan Kimball, Anthony Marchese, and Craig Zilles on a draft of this paper. Kimball observed that whereas professors aspire to excellence in research, as judged by external peers, they strive only for adequacy in teaching, as measured relative to local colleagues: teaching is good enough if the student ratings are close enough to the departmental median. Marchese surmised that the new engineering programs at Olin College, Rowan University, and Smith College could be more innovative in both curriculum and pedagogy than older programs because they started from scratch. Zilles reminded me that most instructors think that to improve teaching, they need to expend more effort, rather than to change pedagogies. He also suggested co-teaching as a possible route toward improving instruction. Finally, he noted that instructors' misconceptions about teaching are as difficult to dislodge as students' misconceptions about mechanics (Hestenes et al. 1992). ❇

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Criteria for Good Engineering and their Importance for Pedagogic Innovations

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The guiding questions for this workshop aim at identifying facilitators and impediments for the diffusion of new engineering curricula and pedagogical practices. As is properly pointed out in the workshop description, the relevant factors cover different levels of individual, departmental, institutional and disciplinary change, as well as the political, structural, and cultural domains.

This contribution draws attention to a cultural factor—the fundamental beliefs held by engineers about what is good engineering, and what makes a good engineer. It cuts across the three divisions of this workshop—Organizational Change, Faculty Rewards, and Diffusing Innovations. With few exceptions,[5] little systematic research exists on this topic; the beliefs about good engineering held within the engineering community have remained something of a "black box." It may be time to take a look into that black box, because these beliefs may be central in several respects, not the least by being a framework variable for the success and speed of the diffusion of new engineering curricula and pedagogical practices. In short, it is my hypothesis that the normative ideas that faculty members hold about what is good engineering have a potentially critical impact on the success or failure of innovation efforts.

Normative beliefs and innovation

I expect the largest part of this workshop to be devoted to questions of how to set up incentives and disincentives for faculty to adopt and propagate new curricula and teaching methods of engineering, and how to build institutional structures that support the process. These appear to be the most obvious targets—variables that can be most directly influenced–if one wants to change faculty behavior. The simple underlying model is that incentives (rewards), disincentives (punishments) for certain behaviors will affect the occurrence and frequency of such behaviors.

However, going back to Max Weber's classical analysis of power in human society, sociologists commonly distinguish between legitimate power (authority) and illegitimate power (coercion). This distinction alerts us to the fact that one can make faculty members do all sorts of things by applying appropriate sets of incentives and disincentives–but the difference is what happens when nobody looks. If behavior is caused by external mechanisms of reward and punishment, it is not maintained in the absence of these mechanisms. There is a whole

[5] E.g., Lovitts 2005.

arsenal of passive resistance to change that can be employed if the instituted changes do not coincide with what the involved individuals consider their core values about good engineering: from sabotaging, ridiculing and making disparaging remarks, to getting by with the absolute minimum of effort.

It therefore appears advisable to survey the normative landscape of the engineering community so as to be better aware of potential roadblocks as well as advantages for pedagogic innovations. More specifically, the legitimacy and acceptance of new curricula in engineering will be heavily influenced by its match or mismatch with faculty members' beliefs about good engineering. If there is a mismatch—i.e., if these new curricula are considered not helpful or even harmful to what is considered good engineering—it will be more difficult to disseminate these new curricula, and this will require certain adjustments in approach and strategy.

The engineering career as a process of socialization

Values reside in the general culture of the discipline and they are imparted to individual practitioners through processes of socialization. These processes are shaped by structural factors of the institutional environment. At a very basic level, an engineering career can be understood as a process of occupational socialization, with mentors, departments, and the engineering community at large as agents of socialization.

The explicit mission of engineering education is to teach students engineering knowledge and skills. In the process of education, they will also develop ideas about what kind of engineering is excellent, good, solid, or flawed. These values about engineering are rarely taught formally or separately from the engineering content in courses and projects, yet they pervade the whole educational experience. The ideas of beginning engineers in this respect are typically influenced by observing engineering faculty, their work, and their behavior. From a socialization perspective, one would expect that, over the course of their studies, students' views on the topic of good engineering should become more similar to the faculty's views—especially their mentors' and role models'–on average. Conversely, dropping out from engineering programs may in part be related to a normative mismatch (in addition to performance variables).

One would expect—and this could be investigated empirically–that socialization processes still continue among engineering faculty members and professional engineers, albeit at a slower pace and within a more limited range, on average. This is potentially important for the diffusion of innovations as well as for the likelihood and trajectory of change of faculty choice.

Robert K. Merton (1968, 1973) spoke of an "ethos of science" guiding the social system of science. It encapsulates the fundamental beliefs of scientists that, according to Merton, contain four major elements: communism (later called communalism to avoid an obvious confusion), universalism, disinterestedness, and organized skepticism. At an abstract level, the engineering community as a whole probably also subscribes to these four elements, but it seems useful to take a closer empirical look at the normative ideas held within the engineering community. Distinguishing between good and very bad engineering should not be difficult, and a consensus should be reached easily. Some engineering products, projects, or approaches turn out to be so flawed that they immediately and patently fail. By contrast, it is a much more interesting question—in terms of the underlying values about engineering—how to distinguish between excellent and very good engineering, or engineers.

Questions of the latter type are central for stratification processes in engineering (e.g., for the decisions about who gets the top jobs, who gets the marginal jobs, and who has to drop out of engineering altogether). Peer reviews of the quality of an engineer's work affect hirings and promotions, as well as the publication of articles, and the award of research grants.

Previous findings

Because underlying norms of good engineering, as mentioned, drive stratification processes in engineering, there are additional potential benefits of knowing the normative landscape of engineering and of monitoring the changes occurring in it. Normative divergence or lack of normative assimilation to reigning models of good engineering might be one cause of the difficulties experienced by members of traditionally underrepresented groups in engineering (e.g., women, ethnic minorities). In respect to gender, our own previous research on scientists already identified a number of gender differences in their open-ended responses when we asked them what they considered good science (and what they considered bad science) (Sonnert & Holton 1995a, b, Sonnert 1995)—which may well have parallels in engineering. We became aware of important gender differences in scientific styles that expressed themselves in differences in research strategies and problem choice, as well as in differences in the rates of publications and career outcomes. To cite just three of many findings, 36% of the women interviewees, but only 20% of the men, mentioned that good scientific work had to be thorough or comprehensive. Women also talked about integrity as an aspect of good work more often than men did (14% vs. 5%). By contrast, men were more likely than women to refer to creativity or originality as characteristics of good scientific work (43% vs. 30%). We also conducted a small study among Harvard science students about their ideas of science, and again found normative differences between the genders, with women being more interested in the applications of science (Branscomb et al. 2001).[6] Similar gender differences may also exist in engineering.

Moreover, the more fuzzy and implicit the criteria are, the more easily bias enters judgments. Mary Frank Fox's work has shown that progress and success of

[6] We did this study in the context of a larger effort to revise the common dichotomy of basic vs., applied science by adding a third category, which we called "Jeffersonian science"—basic science in a well-defined social interest (Sonnert & Holton 2000, also see Stokes's (1997) similar concept of Pasteur's quadrant.

women in science are helped by the presence, and hindered by the absence, of clear normative criteria—and this finding should have obvious implications for the field of engineering also (Fox 1991, 2000, 2001, Fox & Colatrella 2006).

Research suggestions

In sum, it may be helpful to identify the normative styles and presuppositions which, often unspoken and perhaps not fully realized, lie behind engineers' choices of research and work problems, selection of co-workers, job decisions, and the rhetoric in published results, because these normative presuppositions are also likely to have an impact on the efforts to institute new engineering curricula. This leads to research questions, such as: How do American engineers define good engineering, and how are differences in that definition distributed across the engineering community? What ideas about good engineering do incoming students have? To what extent and how do these ideas change in the process of education?

Finally, let me make two more concrete suggestions: a smaller and a larger project that ideally would form a sequence.

I. SELECTION CRITERIA FOR MEMBERSHIP IN THE NAE

The smaller project would investigate the real-life criteria of engineering excellence that that underlie the selection of an engineer to become a member of the National Academy of Engineering. The engineering community is highly stratified, and membership in the NAE signifies the pinnacle of achievement, the highest honor bestowed on an engineer by his or her peers. To my knowledge, the selection criteria have not yet been studied in depth, although the criteria implicit in the selection process are the most powerful real-life definitions of good engineering and good engineers, as the national engineering community understands the selection into the NAE to be the ultimate seal of engineering excellence and thus tends to orient itself along these definitions.

This project could be done by an appropriate number of confidential semi-structured interviews with members of the NEA about their ideas of engineering excellence and about the ways in which they decide whether someone is worthy to become a new member or not.

II. A QUANTITATIVE INSTRUMENT TO MEASURE VIEWS OF GOOD ENGINEERING

When first looking into a hitherto under-researched topic, the use of qualitative data—such as in Project (I) above–is appropriate, but there comes a point when a more quantitative approach becomes more beneficial (e.g., for the ease and speed of collecting data). Using standard psychometric methods, I envisage constructing a quantitative instrument that determines, by means of a simple questionnaire, various normative types that exist among engineers.

The findings of Project (I) would form an important starting point for the construction of the instrument. In addition, to tie in the new engineering pedagogy to views of good engineering and good engineers, one would need to analyze the fundamental ideas about good engineering behind the new engineering pedagogy (through examination of programmatic texts, pedagogical practices, interviews with proponents, etc.). This could result in one or more of the provisional normative types that will become an input into the second main part: the process of developing and testing a quantitative instrument.

The following is a hypothesized list of possible syndromes that might emerge from this research, based on our research on the issue of "good science." Without doubt, actual research on this topic would lead to a modified list, perhaps modified in major ways. Again, I think it would be important to know how these types are distributed in the engineering community and whether this distribution varies systematically (e.g., by seniority, work place, gender, race, and other characteristics, such as supporting new engineering curricula). Not the least, the success of disseminating new engineering curricula may hinge on the distribution of these normative types in the engineering community.

Type A: Emphasizes arduousness and overcoming hardship in achieving results.

Type B: Focuses on elements of competition between rival engineers or research groups to find the best solution for an engineering problem

Type C: Centers on challenging a prevailing engineering model or exemplar.

Type D: Centers on the hope to reach foundational/principle-oriented findings.

Type E: Emphasizes the eventual applicability of engineering efforts to technical and social problems.

Type F: Focuses on immediate economic benefits.

Type G: Focuses on the potential for wide dissemination, recognition, and reward subsequent to the publication of findings.

Type H: Rejects "androcentric" or "western" engineering and seeks alternatives to it. ❇

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Exploring the Role of the Reward System in the Diffusion of Innovation in Engineering Education

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"Trying to change an educational system is like trying to move a cemetery: there's not a lot of internal support for it." (Hearn, 1996)

INTRODUCTION

Rewards energize, direct and sustain behavior (Guzzo, 1979). Empirical evidence indicates that rewards are powerful determiners of faculty behavior (Fairweather, 1996). In fact, institutional reward structures "provide the blueprint for how faculty spend their time (Zahorski & Cognard, 1999)." I doubt that anyone would disagree with these statements, but do we understand the complex nature of this reality as it relates to innovation in engineering education? One of the questions for discussion in the upcoming workshop is whether the current reward system at research universities promotes or impedes the diffusion of innovation in engineering education. Exploration of this issue requires an interdisciplinary approach if we believe that the current system impedes educational innovation and are to convince faculty and administrators that the benefits to be derived from changing the system are worth the investment of time and energy. In order to explore the question of the impact of the current reward system on the diffusion of innovation and change in engineering education, we need to better understand

(a) what shapes our current perceptions of the academy, including present definitions of scholarship and its contingent rewards (e.g., which leads us to explore the history of higher education and the resulting culture),

(b) why institutions persist in the tradition that defines faculty rewards predominantly as they relate to research despite the other roles and responsibilities faculty have (e.g., which leads us to literatures on the psychology of human behavior and organizational development),

(c) what current forces in higher education are pressuring institutions to change (e.g., which leads us to the political and economic realities of the times), and

(d) who potential agents of change are and what they need to effectively facilitate change (e.g., which leads us to the change literature).

Given limited space, I will introduce in brief the threads we need to weave together in the hope that they might serve as fodder for discussion and exploration into the issue.

A. THE HISTORICAL CONTEXT THAT CREATED THE CURRENT CULTURE

HISTORY

Rewards are shaped by culture, and culture is both created by and embedded within an historical context. A very brief look at how the history of higher education in the U.S. evolved may shed some light on a few of the deeply held beliefs in research universities (Boyer, 1990; Glassick, Huber & Maeroff, 1997; Goodchild & Wechsler, 1997; Scott, 2006; Ward, 2003).

Colonial colleges, the first colleges created in the colonies between 1636 and 1789 with strong British roots, were devoted to the improvement of young men's minds rather than the promotion of career aspirations or social status. These men were being groomed for service as clergymen and public servants. The liberal arts dominated education as faculty worked to pass on the wisdom of the classics, and faculty were expected to engage with students in all aspects of life at the college. Students were the reason the colleges existed, and teaching was viewed as a vocation, "a sacred calling — an act of dedication honored as fully as the ministry (Boyer, 1990, p. 7)." The president was all-powerful, and faculty members were viewed and treated as hired underlings. These colleges, in other words, were characterized by their teaching mission.

In the next phase of evolution, roughly 1790 to 1869, higher education responded to the needs of the emergent nation and began "practical" training in areas such as law, medicine, commerce, navigation and, as infrastructure became more important, engineering. During this era the Morill Act (1862) created land grant colleges to link higher education to America's rapidly expanding agricultural and technological growth. Historians of higher education often note that it is during this era that "service" in building a new nation is added to the mission of colleges and universities, as is what we today call "applied research." The term service, in this era, did not mean internal service (e.g., committee work, advising students), but rather public service defined as "service to the public of the national state (Scott, 2006, p. 24)." The role of education during this time was, in general, to be useful to society. Besides expansion of the mission and goals of higher education, expansion of types of colleges occurred as women's colleges and historically black colleges and universities were founded.

Beginning in the 1870s, we see yet another type of institution emerges based on the German university, what today we call the modern research university. The overarching goal of these institutions focused on pushing a different frontier – the frontier of human knowledge. The emphasis at these institutions was on the discipline and work of the faculty member rather than the education of young people; undergraduates became a nuisance and graduate education was pushed to the forefront. According to Scott (2006), by 1910 the research mission dominated U.S. universities and "there began a decline in the teaching mission during the 20th century (p. 23)."

Institutions were no longer dominated by presidents but by willful and autonomous faculty. It is also during this era that we see the rise of national disciplinary associations, consortial groups such as the Association of American Universities, and faculty professionalization through the creation of such entities as the American Association of University Professors (Goodchild and Wechslar, 1997).

From the 1940s on universities continued to evolve as they responded yet again to the society around them, e.g., wars, Sputnik, the Cold War. These events brought about "a revolutionary shift in funding, as the federal government becomes the dominant patron of the major research universities (Scott, 2006, p. 28)." In essence, the public service mission of universities in using applied research to further national interests was reinvigorated. It is during this time as well that faculty members' commitment broadens to include their profession/discipline as well as the institution where they work, and that prestige is awarded to those individuals and institutions whose research brings in outside funding. Throughout all of these phases, however, faculty members continued to educate undergraduates, and yet as early as 1958 observers note that "while young faculty were hired as teachers, they were evaluated primarily as researchers (Boyer, 1990, p. 11)." As in previous eras, access to higher education was broadened as the government pushed for a mass system of higher education.

What do we learn from these snapshots in time that is relevant to the diffusion of innovation in engineering education? Glassick, Huber and Maeroff (1997) sum it up best:

> The priorities of American higher education have been significantly realigned since World War II. The emphasis on graduate education and research has cast a long shadow over undergraduate education . . . The prime focus at these institutions moved from student to professor, from the general to the specialized, and from loyalty to campus to fealty to profession . . . As the research model came to prevail, faculty members were too seldom recognized for their expertise in teaching or in applying knowledge in the service of society (p. 8).

Colbeck (1992) calls this the "output creep" in higher education — the shift from teaching to research that has occurred since World War II. As Boyer (1990) noted, "Almost all colleges pay lip service to the trilogy of teaching, research and service, but when it comes to making judgments about professional performance, the three rarely are assigned equal merit (p. 15)." So, while American higher education prides itself on the diversity of colleges and universities with different missions, "the professoriate tends to value research as the highest goal, even in institutions without a research mission (Altbach & Finkelstein, 1997, p. viii)." In other words, most institutions "follow the norms, and the fads, of the prestigious research-oriented universities (p. 33)."

This history explains in large part the culture of academe that exists today, and a fuller reading of this history could very well explain the depth of commitment to certain aspects of academic culture that remain intact despite calls for change. For critics who claim that change is hard for those in higher education, this history also validates that, under the right circumstances, change can occur. And yet, as we will see later in this paper, attempts over the past twenty years to review and revise faculty roles, responsibilities and rewards have had little impact on research universities.

CULTURE

How has this history shaped culture? Using the definition of Edgar Schein (1992), one of the founders of organizational psychology, culture is "a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems (p. 12)." In other words, we socialize new generations of academics into a culture that is based on how current members of the group perceive, think and feel about things. But where do those perceptions, thoughts and feelings come from? According to Schein (1992), cultures basically spring from three sources:

> (1) the beliefs, values, and assumptions of founders of organizations; (2) the learning experiences of group members as their organization evolves; and (3) new beliefs, values, and assumptions brought in by new members and leaders. Though each of these mechanisms play a crucial role, by far the most important for cultural beginnings is the impact of founders (p. 211)."

Instead of focusing on particular "founders" of the early colleges and universities, the historical overview in the previous section should serve as a basis for beginning to think about which values and traditions have become embedded in academic culture, which have not, and why. Altback and Finkelstein (1997) remind us of several aspects of that culture: "Generally, prestige is defined by how close an institution, or an individual professor's working life, comes to the norm of publication and research, of participation in the 'cosmopolitan' orientation to the discipline and the national profession, rather than to the 'local' teaching and institutionally focused norms (p. 9)." These are some of the traditional cultural values of academe that we continue to propagate by socializing graduate students to believe that, despite the broad array of faculty responsibilities, the most important – given that it is rewarded – is research (Braxton, Luckey & Helland, 2002). As a result, we shouldn't be surprised that current studies indicate that young faculty today, across gender and institutional type, want to shift time from teaching to research (Finkelstein, Seal & Schuster, 1998).

What makes any attempt to understand academic culture both intriguing and challenging is that we are not talking about one culture, but rather several cultures interacting with each other to influence attitudes and beliefs and hence drive behavior: the culture of the department (Walvoord et.al., 2000), of the institution (O'Meara, 2005), of the discipline (Bowen & Schuster, 1986), and of higher education (Berquest, 1992; Kuh & Whitt, 1988). For example, while "a discipline is the first mark of identity a professor receives (Kuh & Whitt, 1988, p. 18)," disciplinary cultures are affected by their institutional context. Because culture dictates values, traditions, organizational structures, expectations and behaviors, we need a deeper understanding of the various cultures if we are to change certain aspects of these cultures.

B. PERSISTENCE VERSUS CHANGE IN ACADEMIC ORGANIZATIONS

Why does the academy hold so steadfastly to the narrow definition of scholarship defined a century ago if, indeed, the definition does not represent the full range of faculty roles and responsibilities? Is it, as the cliché so often says, "human nature" — e.g., the fear of change, the security in familiarity? And if so, what do we know about organizations and change that might potentially help universities to move forward and implement change, in this case giving educational endeavors and innovations the prestige they deserve in the reward structure? As Marchese (1992) has noted, "The problems that exist are far less those of individual behaviors than they are of the system. It is the system that dictates what faculty do...it's a system of contradictory messages ... (p. 4)."

While universities do need to examine the plethora of research on organizations and change (March & Simon, 1958; Martin, 2002; Schein, 1992), we also need to remember that the uniqueness of academic culture requires the development of a distinctive approach to change. For example, Berquist (1992) analyzes the four cultures of the academy (in a book of the same name) in an attempt to "offer a preliminary framework that can guide and inspire new courses of action within those complicated and often closed organizations (p. xii)." Kezar (2001) takes her analysis to a more concrete level as she presents a synthesis of research literature on the organizational change process, identifies key features of higher education institutions, and offers a typology of change theories and a discussion of the efficacy of these models/theories for change in academic institutions. For example, one of the key features of universities is the interdependent nature of the organization: universities do not operate independently of disciplinary societies, the federal government, accreditation agencies, unions, private foundations, and national associations (e.g., AAU). As a result, faculty receive "multiple and perhaps mixed messages related to change," making change less likely to occur unless several of these forces overlap (Kezar, 2001, p. 62).

Over the past decade, there has been "an orientation toward more applied research, closer links between industry and the university, and more service to the private sector (Altback & Finkelstein, 1997, p. 11)." How do these developments impact faculty behavior in light of the current reward structure? The mixed messages continue! Organizations indicate what they value by what they pay attention to and measure, and how they allocate rewards and status — these are some of the "culture-embedding mechanisms" that communicate the beliefs, values and assumptions of the organization (Schein, 1992). In the case of universities, there appears to be a misalignment of expectations and rewards that calls for a reassessment of institutional missions and realignment of the reward system with the mission and priorities institutions (Braxton, Luckey & Helland, 2002; Diamond, 1999).

As Locke (1995) points out, successful change "will be possible only through reduction of the resistance produced by legitimate concerns about altering the present system…if you wish to help someone stop smoking, it generally is better to find ways of weakening or eliminating the purposes served by the habit than it is to increase the intensity of arguments for quitting (p. 507, 514)." Part of the change process, then, is identifying those legitimate concerns of the faculty and research universities (that are deeply rooted in the culture) and reducing factors of resistance. For example, if outstanding research brings fame, which results in visibility, which then attracts endowment, which is equated with prestige (Altbach & Finkelstein, 1997; Tang & Chamberlain, 1997), what are the alternatives for achieving visibility, money and prestige if we alter the reward structure to value educational innovation more? If we believe in the power of the evidence presented and process used to judge research, what equally valid and reliable evidence and process can we use to judge educational innovation? These are only a few of the questions we need to address if we are to bring about change.

C. CURRENT FORCES INFLUENCING HIGHER EDUCATION

There are several new forces/trends in higher education that affect faculty work and will interact with history and culture as universities continue to evolve, revisit their missions, and potentially redefine what scholarship is and how to reward it (Altbach & Finkelstein, 1997; Finkelstein, Seal & Schuster, 1998; Gappa, Austin & Trice, 2005; Graubard, 2001; Locke, 1995; Rice, Sorcinelli & Austin, 2000; Tierney, 1998; Walvoord 2000):

- the proliferation of non-tenure track faculty and faculty who are dispersed in terms of location and/or time of day, e.g., proportion of faculty who are part-time has almost doubled from 22 percent in 1970 to 43 percent in 1999 (Gappa, Austin & Trice, 2005);
- the advent of technologies that allow teaching to transcend time and space, but that also change the ways in which faculty members work;
- changing patterns of student demographics and expectations as the student body continues to diversify in terms of age, race, ethnicity, and educational background;
- the rise of competing educational providers;
- the emergence of new areas of specialization that are challenging the structure of traditional disciplines;
- fiscal constraints;
- public scrutiny and accountability demands; and
- an increasingly diverse young faculty, some of whom are expressing concern over the social relevance of their work and others who are expressing concern over the lack of a comprehensive tenure system that fully reflects the range of faculty roles and responsibilities.

On top of these factors that directly influence higher education, add the flattening of the world a la Thomas

Friedman (2005), and it's not surprising that faculty report being pulled in multiple directions (Gappa, Austin & Trice, 2005). As the incomplete list above indicates, many of these pressures have the potential to influence how faculty redesign curriculum, create new and revise old courses, expand their pedagogy, interact with the increasing number of part-time colleagues to assure coherency in the curriculum, etc.; moreover, they will be forced to do these things as efficiently as possible (just meeting the bar) if the current reward structure is maintained. What will this mean for faculty workloads and for the quality of the educational experience we provide? In the midst of these developing trends over the past two decades came Ernest Boyer's now infamous book Scholarship Reconsidered (1990), which recommended a reconceptualization and expansion of the definition of scholarship to include other forms of intellectual activity. Put succinctly, Boyer suggested four types of scholarship that reflect faculty work: the scholarship of discovery, the scholarship of integration, the scholarship of application, and the scholarship of teaching. A few years later Glassick, Huber and Maeroff (1997) published Scholarship Assessed to address the need for the academy to create clear standards for evaluating the wider range of scholarship proposed by Boyer, noting that we need to uphold scholarly rigor for all types of scholarship. The academy comfortably relies on peer evaluation of research as the primary basis for rewards, research that is communicated in publications for scholarly recognition (Braxton, Luckey & Helland, 2002). On the other hand, the academy has not yet defined rigorous standards for the evaluation of teaching; teaching is not typically peer-reviewed, and it does not present a "product" as easily as research does.

D. POTENTIAL AGENTS OF CHANGE

Because of the current forces we can't ignore, and in spite of the current academic culture and concomitant resistance to change, we need to move into action and think about how to enable the agents of change to evolve our current reward system to assure that educational innovation is rewarded. There are both external and internal agents of change. Over the past fifteen years, foundations, professional organizations, accreditation agencies and government agencies have not only tried to stimulate educational reform but, concomitantly, have called into question current practice around the reward structure. These entities have the potential to help educational reform gain legitimacy within the faculty reward structure. Given limited space, I won't discuss how these entities have tried to stimulate educational reform (e.g., NSF funded coalitions, centers for scholarship in engineering education), but rather I will provide a few examples of how they have supported the academy to rethink faculty roles, responsibilities and the reward structure.

EXTERNAL AGENTS OF CHANGE

With funding from the Lilly Endowment and the Fund for the Improvement of Postsecondary Education (FIPSE), disciplinary associations and accreditation agencies began in the early 1990s to reconsider definitions of scholarly, creative and intellectual contributions within their domains (Adam & Roberts, 1993), in part as a response to Boyer's call for broadening our current definitions of scholarship. Twenty-two scholarly societies, learned associations and accreditation agencies agreed to participate in articulating how faculty in the respective fields defined scholarship. This is a first step.

Simultaneously, the American Association of Higher Education created a "Forum on Faculty Roles and Rewards" to address three specific, interrelated problems: (1) the dominance of a single, powerful definition of what roles and activities were worthy of faculty time and energy, (2) how to develop mechanisms for assuring quality in all areas of faculty work (e.g., no peer review for teaching and service), and (3) how to deal with accountability imposed from outside academe (Rice, 1995). The Pew Charitable Trust followed suit a few years later and funded the Council of Independent Colleges (CIC) and the Consortium for the Advancement of Private Higher Education (CAPHE) to create a grant program titled "Faculty Roles, Faculty Rewards, and Institutional Priorities" with the overarching goal to foster institutional transformation to support learning in order to bring congruence between institutional mission and reward structures (Zahorski & Cognard, 1999).

Given this recent history, we are back to the questions of why the reward system hasn't changed to better reflect faculty roles, responsibilities and rewards, and whether the current system impacts the diffusion of educational innovations. To date, these efforts have not permeated the academic culture and the reward system that reinforces current norms (Fairweather, 1996). Perhaps that is because changing the culture requires a coherent effort from internal as well as external agents of change.

INTERNAL AGENTS OF CHANGE

Internally, we must rely on engineering department heads/chairs and deans to lead the change effort to gain legitimacy for educational reform within the faculty reward structure (Serow, Brawner & Demery, 1998). In theory this should not be difficult because, in recent years, studies have indicated that faculty, chairs, deans and administrators at research universities view the balance between research and teaching in the reward structure as inappropriate and in need of modification, giving more weight to "vigorously evaluated teaching" (Gray, Froh & Diamond, 1992; Survey Research Laboratory, 1991). So those most closely connected to the reward structure advocate, at least in theory, change. Consequently, we should examine the literature that identifies effective leadership characteristics and, as Hoppe and Speck (2003) suggest, provide experiences for academic leaders to develop the skills they need as they move from academia to administration. Minimally, we need to equip these individuals with the tools they need to

- change the mental models of faculty about what scholarship is, i.e., the way of thinking about roles, responsibilities and rewards that is firmly embedded in an academic culture that values the scholarship of discovery above all else;

o revamp graduate education to equip graduate students with more than disciplinary expertise (Rice, Sorcinelli and Austin, 2000) and inculcate them to value teaching and public service as well as research;

- examine their departmental, disciplinary and institutional cultures (e.g., artifacts, espoused values, behaviors, underlying assumptions) because the nature and structure of departments and institutions, the style of administration, and the differences among disciplines all play roles in determining how the process of change should be approached and implemented (Diamond and Adam, 1993). This is vital because effective change efforts must be integrated successfully into the existing culture and climate (Hearn 1996); and
- understand the nature of organizations and organizational change, about which much is written, and yet this literature has remained invisible to the majority of engineering deans and heads/chairs (Hearn, 1996; Kuh & Whitt, 1988; Martin, 2002; Schein, 1992; Zahorski & Cognard, 1999). However, we should heed Kezar's (2001) counsel for the development of a distinctive approach to change within higher education given the uniqueness of academic culture, because "using concepts foreign to the values of the academy will most likely fail to engage the very people who must bring about change (p. vi)." In fact, the American Council on Education (Eckel, Hill & Green, 1998, 2001; Eckel, Hill, Green & Mallon, 1999) and the Higher Education Research Institute at UCLA (Astin & Astin, 2001) have published reports on institutional change/transformation in higher higher education that could be helpful to engineering change agents.

We also need to acknowledge faculty as change agents in a variety of different ways. For example, money and status – but not necessarily job satisfaction – come with research productivity (Leslie, 2002). In fact, evidence suggests that faculty job satisfaction is tied more to collegiality, quality of life, and personal fulfillment than it is to prestige, security and authority, a shift (since circa 1988) noted by researchers who study why faculty members stay at or leave an institution (Barnes, Agago & Coombs, 1998; Johnsrud & Rosser, 2002; Manger & Eikeland, 1990). How might this trend influence change in the academy?

CONCLUSION AND FUTURE RESEARCH

I do believe the reward structure at research universities impedes the diffusion of innovation in engineering education. The important questions in addressing the issue are why that is true and how we can influence change. The threads I have identified in this paper hopefully indicate that real change may have a better chance of occurring when we more deeply understand (1) the historical roots of academic culture that are responsible for current values, traditions and beliefs; (2) educational institutions as organizations with unique features that will impact the change process; (3) current forces that challenge academic culture; and (4) how to better equip engineering leadership with the knowledge, skills and tools they need to act as agents of change. ❇

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Social Dynamics of Campus Change: Suggestions for a Research Agenda Faculty Rewards Working Group

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The purpose of this short white paper is to suggest an area for research that may be undertaken by the Faculty Rewards group. The idea—to explore both the intrinsic rewards that motivate faculty to embrace pedagogical change as well as the fears and anxieties that keep them from doing so—comes from two sources. The first is a preliminary review of the literature which yielded more studies on the impact of the external reward system on faculty behavior than on internal factors. The second source is my own experience at MIT, an institution that has recently been through a six-year period of intense innovation in pedagogy. Both sources are described in more detail below.

PEDAGOGICAL INNOVATION AT MIT

In 1999, MIT received two generous grants that allowed it to embark on a wide-scale series of innovations in undergraduate education. The first was from then-chairman of the MIT Corporation, Alex d'Arbeloff, and his wife, Brit d'Arbeloff; they created the d'Arbeloff Fund for Excellence in Education. The d'Arbeloff Fund underwrites projects "designed to enhance and potentially transform the academic and residential experience of MIT's undergraduate students" (http://web.mit.edu/darbeloff). The second grant, from the Microsoft Corporation, funded iCampus, a five-year, $25 million research alliance that was "aimed at achieving a broad, substantial, and sustainable impact on higher education through information technology" (http://web.mit.edu/icampus).

In total, there have been close to one hundred projects underwritten by either iCampus or d'Arbeloff funding. (While the iCampus initiative has ended, the d'Arbeloff Fund continues to make awards. The latest set of funded projects will develop a set of freshmen project-based courses.) Together, these efforts represent a rich array of educational experiments. They include transforming MIT's required two-course sequence in physics from the standard lecture/recitation model to a studio physics format; developing a freshmen course that requires students to work in teams to tackle a large-scale, open-ended problem; and experimenting with different ways to bring small-group tutorials into upper level courses. It could be argued that the jewel in MIT's educational crown during this period of innovation has been OpenCourseWare, the Institute's effort to publish all its courses on the Web (http://ocw.mit.edu/ index.html). According to an article written by journalist Sally Atwood for the May 2002 alumni edition of *Technology Review*, "It has been 30 years since MIT last saw such a groundswell of educational innovation, and it's beginning to transform the classroom experience."

HAVE WE "TRANSFORMED THE CLASSROOM EXPERIENCE"?

Is Atwood's enthusiasm justified? Although in no way do I wish to belittle the enormous effort that many MIT faculty have invested in these educational initiatives, I believe a case can be made that six years, 100 projects, and millions of dollars later, MIT undergraduate education has not been essentially changed. Large lectures still predominate the freshmen year, as well as a number of upper level courses. Recitations continue to mimic the lecture experience in that recitation leaders (both faculty and graduate students) stand in front of the chalkboard and work problems. In my experience, it is rare to find faculty members who think beyond the topics on their syllabus when asked what their learning objectives are. I believe most MIT faculty approach teaching and learning in the same way Derek Bok (2005) describes the vast majority of the professoriate do. "Few faculties," he writes:

> engage in a continuing effort to assess how much their students are learning, identify deficiencies, develop and test possible remedies, and ultimately adopt those approaches that proves most successful. (p. B12)

Why is this the case? The most common explanation places the blame on the faculty reward system. As the argument goes, if tenure were not based on publications and if success in the classroom were equally important, faculty would "follow the money." Educational researchers William Massey and Andrea Wilger (2000) sought to determine whether or not this belief could be substantiated by data. They interviewed 378 faculty at 19 colleges and universities representing all categories of the (former) Carnegie classification system. Their research supports the prevailing thinking: Tenure and promotion tops the list of incentives respondents considered to be the most important regardless of institutional type. And, they write, "overall the importance of research-based activities overshadows factors related to teaching" (p. # not accessible).

Yet other major studies undertaken since as early as the 1970s report that faculty find teaching important. Smith and Geis (1996) cite several that reached that conclusion (Blackburn et al, 1980; Carnegie, 1989), as well as others that found teaching is a "major source of satisfaction" for faculty (Wilson & Gaff, 1971; *The Chronicle of Higher Education*, 1990). A 1992 survey of 23,000 faculty chairs, deans, and administrators at research universities concluded that "a majority of faculty would like to reverse the push towards research and restore the balance by increasing the emphasis on undergraduate teaching" (Gray, Froh & Diamond, 1992, as quoted in Smith & Geis, 1996). An ERIC search on "faculty rewards in higher education" since 1996 found over 150 articles, many of which concerned the difficulty of trying to balance research and teaching within incentive systems that continue to favor the former. It is a situation that is unlikely to change in the foreseeable future.

WHAT'S A RESEARCH INSTITUTION TO DO?

Assuming that the research-based tenure system remains the 800 pound gorilla in the room, does that mean there is nothing that can be done to "convince [the] individual and collective will of faculty members, chairs of departments, and deans of schools that there are benefits to be derived from change that are worth the investment of [their] time and effort"? (Workshop Call for Applications, September 28, 2005). My experience at MIT tells me this is certainly not the case as evidenced by the hundred plus faculty who did devote considerable amount of time and effort to their d'Arbeloff and iCampus projects.

But why did they do so given the importance placed on research at MIT? I can imagine a host of answers: the simple enjoyment of teaching well, frustration with low attendance at lectures, concern over failure rates in some courses, a sense of responsibility to undergraduates, curiosity about how to improve learning (Breslow, et al., 2004). The faculty member who reformed freshmen physics did so in part because his son had been profoundly influenced by one of his professors at Trinity University; the MIT professor came to see firsthand the effect a teacher can have on his student. If faculty are de-incentivized by the tenure system to focus on teaching and learning, then there must be intrinsic rewards they derive from spending significant amounts of time and energy on educational innovation. What are they and can they be used to motivate more change?

A related question that comes from my work with MIT faculty is why some of them are so reluctant to change. Recently, the department head from one of the large enrollment undergraduate departments came to talk about initiating an effort in the department that would focus on pedagogy. The impetus for him doing so was the reluctance on the part of several of his faculty to allow a controlled trial of a new pedagogical method in one of the department's introductory courses. He was aghast that engineers would turn down the opportunity to collect data that could lead to better understanding!

But that situation wasn't as surprising to me. Linda C. Hodges (2005) writes that one disincentive for educational innovation is fear. "Underlying this fear [of changing pedagogical approaches]," she writes, "may be the fear of loss, fear of embarrassment, or fear of failure" (p. 121). Bonwell and Sutherland (1996) list five reasons faculty resist using active or experiential pedagogies: fear they won't cover all the necessary material, increased amount of time to prepare, difficulty understanding how to implement these pedagogies in large classes, lack of resources, and risk. (One piece of folk wisdom in academia is that experimenting with new teaching methods is sure to result in lower teaching evaluations.) I have had faculty tell me that the problem with education at MIT is that we're letting in the wrong kind of students; that "they" (whoever they are) want to turn "us" into Harvard; and that "young people" just aren't good with their hands any more. My sense is that all of those explanations are fueled by deeper biases, concerns, and perhaps even longings.

While a fair amount of research has examined the role of extrinsic rewards in the academy as motivators for faculty behavior, there seems to be less that explores both the intrinsic rewards that contribute to, as well as the anxieties that keep faculty from, changing. I would like to suggest that an exploration of both could be one of the focuses of the Faculty Rewards group. ❇

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Mentoring as a Context for Transformation in Science and Engineering

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(Revised, June 2006)

Mentoring is critical to the personal and professional development of students in science and engineering, and mentoring is a key avenue by which formal and informal knowledge about a discipline and its practices are passed from one professional generation to the next. Nevertheless, the social dynamics of mentoring in academic contexts are not often analyzed or are studied only in superficial ways.

Research on mentoring in academic settings typically has focused on the graduate level and on processes by which research skills and socialization for research-oriented careers are transmitted. Pedagogical skills and content of curriculum also are transmitted via mentoring, although the degree to which pedagogy is formally addressed varies considerably in mentoring relationships. The potential of mentoring for curricular and organizational transformation likewise has rarely been explored. Social scientific research on mentoring has explored access to mentoring by aspirants of diverse backgrounds (see e.g, Spalter-Roth and Lee 2000), quality and effectiveness of mentoring relationships (Sandler 1993), the impact of mentoring on career growth and development (Long 1990) and problematic aspect of mentoring relationships in academia and organizations (Eby et al. 2004).

Although researchers have conceptualized mentoring in various ways in research, the most typical focus is on one-to-one personal mentoring, usually explored from the perspective of the protege. Some research has examined other forms of mentoring, such as peer mentoring or telementoring (Marasco 2005). The most prominent, often implicit, model of mentoring has typically been one of a senior, knowledgeable and charitable guide who shares his or her wisdom with one or more new recruits. Viewed in this way, mentoring has a "conservative" function of preserving and transmitting values and practices revered within a discipline or a profession to new recruits who are selected, at least in part, based on their similarity to those already at the helm. But it is possible to envision mentoring in a more complex manner and as a context that provides opportunities for organizational transformation and not simply imitation and replication. Mentoring has the potential to support protégés who bring to the discipline new and distinctive insights, learning styles, and approaches to pedagogy (Herzig 2004).

In this memorandum, I first explore the context of mentoring in sciences and engineering, drawing contrasts between science and engineering disciplines and social science disciplines. I then address the role of mentoring as it affects diverse groups of aspirants to scientific and engineering careers, considering the impact of mentoring both at the individual and the organization level. Finally, I suggest ways in which mentoring practices at the individual and organizational level might be used as positive forces for transformation, including transformation of pedagogy and curriculum.

MENTORING AS A CONSERVATIVE FORCE IN SCIENCE AND ENGINEERING?

Within the context of sciences, mentoring frequently takes on a conservative cast wherein successful mentors and mentoring organizations pass on codified knowledge and social capital to new generations of recruits. The goal often is replication, or socializing aspirants to adopt values, outlooks, and professional practices that closely approximate those of the more-senior mentors. The fact that mentoring usually is linked to sponsorship and financial support in science and engineering education increases the likelihood that mentoring encourages replication rather than transformation (Grant and Ward 2004; Rosser 2000; 2004).

Recruits to scientific and engineering professions are carefully screened prior to entry so that they share common experiences and perspectives even before they start their formal disciplinary education. Entry into engineering programs at the undergraduate is highly competitive. In comparison to applicants entering many other fields, engineering students are expected to have pres-existing skills before they are considered viable candidates for entry. In graduate programs in science and engineering, aspirants may be admitted only if a senior faculty member agrees to take them on, and frequently also fund them, through their education. Since admission decisions are made before aspirants have opportunities to demonstrate their ability, these decisions can be influenced by network ties (e.g., recommendations of well-known persons in the field) and social capital (e.g., reputations of schools that recruits previously attended). Engineering curricula and programs tend to segregate students from same-age peers in a distinctive set of coursework. High selectivity, immersion in specialized curricula, and separation from age-peers in other fields tends to intensify the influence of the organization (in this case the university college or department) on not only the professional socialization, but also the identity, of the aspirant (Wheeler 1966).

Social scientists have argued that normative structures of scientific and engineering training programs and early selection points lead, albeit often unintentionally, to homophily, or selection bias toward those whose biographies look much like one's own (Epstein 1970). Such practices may accentuate the importance of early, but in the long-run inconsequential, differences among aspirants of different status characteristics in the profession. For example, example, boys' greater pre-college experience with computers and greater familiarity with "hacker culture" may provide advantages to them as entrants into engineering school, even though such activities are not very consequential for success (Margolis, Fisher and Miller 2000). Similarly, immersion in the "tinkering culture" of engineering, more common among men than women, may advantage men over women early in their engineering careers, even though these activities are not directly relevant to most contemporary engineering jobs (McIlwee and Robinson 1992). Students who "fit the mold" may have an easier time finding mentors as undergraduates and gaining recognition for their accomplishments. They may be recommended for top postgraduate positions, or urged more strongly than others to go on to graduate school.

At the level of graduate education, one forms a relationship with a mentor early on and remains dependent on him or her for sponsorship and financial support, the relationship may be biased toward replication, rather than innovation. Persons who don't fit well with the the discipline are apt to be screened out initially. Those who deviate later may either be chastised and brought back into line, or they may lose sponsorship and drop out of the field altogether. These social dynamics may be particularly disadvantageous for groups that have not been traditional recruits to science and engineering, such as women and minorities. They may be deviants in two respects: they don't fit the traditional image of an engineer in their persona, and/or they may hold different, noncomformist perspectives about what the goals of engineering and science should be (Grant and Ward 2004; Rosser 1990; 2004). Once admitted to programs, students are immersed in "little societies" where certain types of norms and practices are reinforced, while nonconforming practices are discouraged or marginalized (Fox 2000).

At the graduate level, dissertations in science and engineering usually are closely tied to the interests of the mentor and may even be assigned by mentors.. The protégés' need for financial support and access to resources, such as specialized lab equipment, reinforces dependency on the mentor. Science and engineering research requires interdependence (Fox and Colatrella 2006), and large, usually hierarchically organized, research teams. Even when senior faculty are open to innovation and inclusiveness, day-to-day supervision of work may be done by postdoctoral associates or more-senior graduate students who have little training for teaching or for understanding the needs and learning styles of a diverse set of more junior scholars. Therefore, protégés may not be exposed to models of effective teaching, nor have their distinctive orientations appreciated. Furthermore, teaching and mentoring typically are under-recognized and under-rewarded in academic institutions, providing little incentive for scholars to improve their abilities in these domains.

This model of mentoring and sponsorship has substantial overlap with mentoring in social science disciplines, but there are important differences. Social sciences less often require explicit sponsorship or funding linked to a particular project. Instead, most graduate programs encourage students to take a broad range of courses and work with several faculty members before choosing a mentor. If a mentoring relationship proves unsatisfactory, students generally have options to seek other mentors (Grant and Ward 2004). Students also are expected to propose their own dissertation topics, rather than to work on a project assigned by a supervisor. Under such a system, aspirants are less dependent on mentors and replication of the mentor's interests and practices is less important. Mentors may be fair or unfair, effective or ineffective under either system, but the consequences for a protege may be greater in the sciences and engineering model because dependency on the mentor is greater and intellectual autonomy is diminished. Furthermore, exposure to multiple faculty maximize opportunities for students to learn professional practices from various people, including some who are strong in pedagogy and curriculum development. Some graduate programs in social sciences even have built-in teaching mentorships (for example, the Sociology graduate program at North Carolina State University), and many departments and professional organizations such as the American Sociological Association sponsor active programs to develop pedagogical skills and to share innovative curricula.

MENTORING, DIVERSITY, AND ORGANIZATIONAL CLIMATES

Although all aspirants to scientific and engineering careers benefit from effective mentoring, substantial research suggests that mentoring is stratified, with some groups of aspirants likely to receive much more effective mentoring than others (Grant et al. 2004; Spalter-Roth and Lee 2000). Women and persons of color usually are disadvantaged in mentoring relationships, a factor that has been linked to their disproportionate attrition from the science and engineering pipeline (Jordan 2006). These disadvantages rarely result from overt bias, but reflect more subtle ones, such as a mentor's inability to see a nontraditional aspirant as a successor to himself, concerns that family commitments may limit the potential of women aspirants, or worries that mentoring relationships might be viewed as inappropriate romantic liaisons (Epstein 1970; Long 1990). Although there is evidence that women and persons of color may benefit from mentoring by persons of their "type" in fields where they are scarce (Eby et al. 2004), such expectations not only overburden the relatively few women and minority faculty but also absolve other faculty from responsibility for mentoring under-represented groups. Since women and persons of color still are scarce in most fields of science and engineering, the reality is that white men will continue to do much of the mentoring of nontraditional students (Etzkovitz, Kremelor and Uzzi 2000; Sandler 1991). Research has suggested that women find effective men mentors in STEM disciplines, often by identifying specific men who are open to working with women (Bix 2006).

When mentoring is conceived of as a collective, rather than purely an individual, activity, mentoring potentially can be transformative of organizational climates in academia and workplaces that can enhance diversity and positive change. A classic study by McIlwee and Robinson (1992) demonstrated how everyday experiences in engineering schools and workplaces reinforce women's marginality in the profession. More recently, Fox (2000) has documented how everyday practices in science and engineering graduate programs can impede progress of women. Her work also identifies characteristics of programs with more favorable completion rates for women. Among their beneficial practices are effective response to harassment faced by women, written guidelines for assessing performance, and sensitivity to the distinctive needs of women protégés. Other work has suggested that modifications in pedagogy and curriculum, along with effective and inclusive mentoring, can also help to stem greater attrition of under-represented groups (Etzkovitz et al. 2000). Although individual mentors can be useful in assisting aspirants in dealing with less hospitable environments by helping protégés devise coping strategies, tranforming such environments requires collective mentoring. Some institutions, most notably MIT, have undertaken institution-wide reforms not only to improve equity for individual women scientists and engineers but also to enhance learning environments to support the development of diverse students and faculty (Hopkins 1999).

Mentoring also has a broader focus than the learning of substantive content and technical skills. Proteges also learn styles of pegagody and what constitutes an appropriate curriculum through mentoring. Thus, mentoring provides a context for the replication of traditional practices, including the often-alienating "chalk and talk" style of delivering engineering and science education that is credited with driving both women and men from these majors (Dingel 2006). But transformative mentoring could provide a context in which creative and innovation in pedagogy and curriculum are encouraged instead.

COLLECTIVE MENTORING FOR TRANSFORMATION

Although mentoring often works to replicate practices within organizations, it can when seen as a collective responsibility be transformative. Working collaboratively, mentors can function as ice breakers in organizations, making them more receptive to nontraditional recruits and to new ideas (Sandler 1993). Such collective mentoring can engage all organizational members in dialogs about social dynamics of programs and consequences for learners. It can lead to broader approaches to curriculum and climate change, identification and remediation of subtle barriers affecting some proteges, and broad dissemination of good mentoring practices throughout the organization. With such collaboration, a scholarship of mentoring, paralleling the scholarship of teaching, can develop, and effective mentors can be recognized and rewarded for this important work. Institutions can be proactive in enhancing the effectiveness of mentoring, especially the mentoring of students from under-represented groups. I offer a few possibilities for starting points for further discussion.

1. Mentoring should be a component of professional development for faculty. It once was assumed that anyone with a Ph.D. could teach. Although some faculty may have a natural talent for teaching, it is now widely recognized that teaching skills of most can be

developed through systematic education, feedback, evaluation, and reward. The same is true for mentoring. In research my colleagues and I have conducted, scientists often talk about learning how to mentor or learning to become more effective mentors for students of differing social backgrounds from themselves. Sometimes these are scientists who had negative experiences as protégés in past mentoring relationships. They want to do better for their students, but they lack information about how to do so. Organizations might identify scientists and engineers who exhibit strong mentoring skills and use them as a resource in disseminating good mentoring practices. Effective programs developed at other institutions should be emulated.

2. Mentoring should be built into the evaluation and reward systems for individual faculty. Too often good mentoring is taken for granted and appropriated by an organization, with insufficient recognition of the mentor's expertise and with little or no reward for good mentoring. Those investing heavily in mentoring might be penalized indirectly by having too little time to devote to those activities that are rewarded by academic institutions and workplaces, such as research and grant-writing. Or another undesirable outcome might be undue exploitation of students without allocating fair credit for their work. Yet some programs have recognized and rewarded mentoring as real work (e.g., the MIT program). Rewarding mentoring in formal ways also sends a message that it is an activity that organizations take seriously. Assessing effective mentoring will present significant challenges, as our research has suggested that it is easier to recognize good mentoring from a protégé than a mentor's perspective. Often mentors do not know, in any systematic way, what type of impact they are having on aspirants. And as Sandler (1993) has pointed out, many scholars under-rate their efforts as mentors, or even shun taking on mentoring responsibilities altogether, because they fear that they cannot do everything for every student who asks. Assessment tools needs to be cognizant of the fact that students likely benefit from contacts with multiple mentors, each of whom has something different to offer. Envisioning mentoring as a collective responsibility of an organization is a first step toward resolving some of these dilemmas.

3. Organizations should provide some oversight of adviser-advisee relationships and should be prepared to intervene when relationships are not successful. As Fox (2000) has pointed out, this relationship is critical to success in scientific and engineering careers, yet it is highly privatized. In the strong dependency relationships characteristic of engineering and science that I have described above, this may leave proteges vulnerable if they encounter difficulties in mentoring relationships. There are decided advantages to maintaining flexibility in mentoring relationships,

but such relationships nevertheless might be improved by collective statements of what represents "good practices" as well as sufficient monitoring and supervision to protect proteges in very negative situations. Some oversight by departmental and college administrators is needed, so that students have options if they encounter serious problems in situations of unequal power relationships.

4. Organizations should make commitments to the systematic analysis of climates of programs in engineering and in science. Such a commitment would involve both ongoing, systematic assessment of organizational climates from the perspective of all members and identification and dissemination of good mentoring practices. Organizations should be proactive in fostering positive climates where productive mentoring relationships can flourish, rather than simply reactive when serious problems occur. Systematic assessment of organizational climates can address problems as they arise, and relieve the relatively powerless from the responsibility of bringing problems to the attention of supervisors and administrators. Interdisciplinary collaborations between engineers and social scientists who have studied educational and workplace climates can be valuable means to achieve this goal. ❇

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Greedy Institutions and Faculty Involvement in Retention

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It is no surprise to an academic audience that universities are perceived by their faculties as "greedy institutions." This term, from the work of Lewis Coser, describes organizations that "seek exclusive and undivided loyalty, and ... attempt to reduce the claims of competing roles and status positions they wish to encompass within their boundaries" (1974, p. 4). As Wright et al. argued (2004) the pressure on faculty has increased in recent years, stemming from changing expectations about teaching and research across all institutional types. Higher education has become increasingly greedy. In this review, I identify several ideas connected to the "greedy institution" perspective, and from which to draw future research questions.

INSTITUTIONS VARY

As obvious as this statement may be, there is too often a "one size fits all" tone to discourse about academic life; further, the realities of non-"Research I" institutions are often invisible to national disciplinary leaders. It is essential to deconstruct "higher education," attending to variations along dimensions of institutional culture, mission, type, and size. Wright and her colleagues used research, comprehensive, and teaching as basic types, but suggested that these be seen as continua, with many institutions striving to be seen as moving along one or more at any time. Local campaigns for change should be tailored with local conditions in mind (Hurtado, 1994).

Institutional greed also varies historically; its focus and extent are dynamic. The ways in which faculty are expected to be productive change with external and organizational trends. In research and comprehensive institutions, there is a resurgence of interest in teaching. This stems from marketing pressures (and in public institutions, from legislative interest). Particularly with increased tuition costs, criticisms of the student experience have led to a growing rhetorical emphasis on teaching. Competent undergraduate teaching is now required, but excellence in teaching does not substitute for a strong research record in personnel decisions. In a multidisciplinary study, Milem et al. (2000) found that while faculty time spent in teaching related activities had risen, time spent on scholarship had not declined to compensate for this increased work load.

ENGINEERING SCHOOLS AND DEPARTMENTS: PARTICULAR FORCES AT WORK

A serious decrease in U.S. students' interest in engineering has been exacerbated by the post 9/11 decrease in foreign student enrollments. Thus, consideration of curricular innovation is made in a context of competition for students among other institutions and other fields of study.

Changing ABET requirements (e.g., ethics; writing requirements) have constrained program planning. Although many faculty believe that formalizing a five year bachelor's program would best serve their students, the marketing consequences are seen as dire. Furthermore, for engineering faculty curricular changes is a particularly delicate matter, because many engineering courses are part of a tightly-coupled sequence, and changes in coverage will likely become public knowledge and may have practical consequences for those teaching other courses in the sequence.

Universities have long relied on engineering programs to produce income from corporate and governmental sources. Diverting faculty attention from activities that bring in funds to working on curricular and pedagogical initiatives (and then carrying them out) might endanger the production of income to departments, colleges, and universities (Hackett, 1990; Hearn, 1992). Deans will have to fight to make these changes with their superiors, in light of the long-standing reliance on engineering programs to produce income from corporate and governmental sources.

Despite their business-suited, clean-shaven, "pocket protector" caricature, engineering professors are not so monolithic nor so different from non-engineering faculty. At the same time, there are important differences among engineering disciplines, often unfamiliar to social scientists. For example, many mechanical or civil engineers dismiss industrial engineering's greater success in recruiting women by saying that it is not really engineering. Even among engineering programs at institutions that are of a similar size and sector, significant differences in experience may be related to region.

RESEARCH IS PARAMOUNT

Academic personnel decisions are widely perceived (within and outside engineering) to rest more on scholarly than on teaching achievements. Faculty perceptions of institutional demands and rewards were a major focus of my own interview study of engineering faculty at five campuses, conducted in the 1990s (Kramer 2005). While junior faculty voiced a strong commitment to teaching, they saw time devoted to teaching as undermining chances for career success; middle level faculty also saw scholarship and research achievements continuing to overshadow teaching in personnel decisions. This view was shared by more senior colleagues and those in service departments. Further, people perceived that articles, grants, or awards related to teaching and/or advising meant little or nothing for career success. Whether research or teaching expectations were seen as on the rise, there was no perception that other expectations were being lowered.

Many were skeptical about administrative sincerity in the absence of material support for curricular and pedagogical change, and in the face of unchanging expectations of high research productivity. Even if the local norms were perceived to be supportive of teaching and service, some faculty were concerned about the views of future administrators, or institutions to which they might want to move. Of course, outside offers may be seen as necessary in order to improve one's compensation.

Departments – the crucial site of professional life

Except in very small institutions, departments are the key unit of organizational culture and practice; this is generally true throughout academia (Clark 2004; Lee 2004). The department is at the intersection of the discipline and the institution – and departments vary in the relative influence of each upon them (Lee forthcoming). Departmental cultures often differ in the same institution. Indeed, in larger institutions faculty are sometimes unaware of the extent to which they differ from their colleagues. There is often a formally or informally established faculty division of labor, with a small proportion of the faculty viewed as knowledgeable about and involved in pedagogical, curricular, and retention issues. All others need not be concerned with these areas (Stassen 1995).

Departments influence the perception of the kinds of greed of the larger institution (as well as adding their own); they are critical filters of information. Thus, a relatively innovative member of a traditional department might be unaware of innovations that were commonplace in another department. In some departments, faculty who devoted time to undergraduate teaching or curricular innovation were suspected of inadequate involvement in research. This view often discouraged public discussion about teaching by junior faculty. Some senior faculty did not realize the seriousness with which junior colleagues heard such comments (Kramer 2005).

Organizational and departmental loyalties (for example, concern about resource reallocation) also influence faculty perspectives on curricular change. Serious competition for chunks of the student's academic program, and interdepartmental competition for student majors may discourage a department from making changes, or encourage it to do so. Generally, a broad review of curricula is a serious concern for those with an existing piece of requirements who may fear losing that source of students in certain courses. Fear of losing when the "can of worms" is opened may motivate faculty in at-risk departments to avoid curricular review.

Greed, faculty from nontraditional groups, and service demands

Faculty from underrepresented groups have exceptional duties in undervalued areas (committee work, recruiting, advising or mentoring of nontraditional students (Olson, Maple and Stage 1995; Turner and Myers 2000). The departmental demography is obviously significant: the fewer nontraditional faculty, the greater the burden on each individual for committee service. Where there are few nontraditional faculty but a higher proportion of students from those nontraditional groups, the burden is also heavier.

In addition to greater service demands on underrepresented faculty, equivalent performance may be differentially evaluated depending on expectations held about members of different groups. For example, a woman professor may be expected to serve as the emotional expert when there are tensions between the support staff and faculty — failure to do so may be interpreted as lack of service, while a man is not judged as uncooperative for standing back from intradepartmental conflict. Performance of other role demands (research and teaching) may also be differently noticed and evaluated because of membership in an underrepresented group. Many of the initiatives taken by various NSF-ADVANCE institutions aim to reduce or guard against such inequitable demands and evaluation.

Sociologists of work have found that inequity in task assignments is reduced when they are systematized, with the assignments and processes made transparent (e.g., Britton 2003). Similarly, when performance evaluation is systematized, there is some reduction in inequity. Transparency is important, but traditionally lacking in faculty personnel decision making processes.

HELPING NEW FACULTY COPE WITH GREEDY INSTITUTIONS

It is essential to study the variety of resources available to faculty at all stages of the career, and the ways in which allocation is tied to performance of teaching, advising and curricular responsibilities. As part of such research, I propose the exploration of the new faculty activities offered at a sample of universities and to investigate the ways in which the engineering faculty in particular are involved in these activities. Many institutions now offer some form of new faculty activities, ranging from one day orientations in which people are bombarded with information about health coverage and pension plans, and library tours to semester-long weekly or biweekly meetings in which faculty are able to get to know members of their cohort from across the campus while being introduced (in more absorbable-sized and spaced experiences) to various aspect of campus life, including infrastructure supporting research activity and pedagogical development, as well as information about the personnel practices and processes of the institution. While new faculty on a campus (especially those who are not new to faculty life) may experience the time involved as another dimension of institutional greed, programs for faculty development (especially those aimed at people in their first year) are promising routes to coming to terms with the realities that I have summarized in the previous pages:

- *Institutions vary* – and people coming from elsewhere (whether from graduate study, a postgraduate fellowship, or a teaching position) can learn more effectively the characteristics of their new academic home in something more organized than informal dependence on colleagues within the department. In engineering, faculty may come from industry, and so variations over time are also pertinent to their orientation to their new setting.
- *Engineering is different, but…*As sites where people socialize across disciplinary lines, new faculty programs provide exposure to colleagues with whom one might otherwise assume one had nothing in common. This means new faculty programs might speed the diffusion of pedagogical information, might increase respect

for other disciplines' insights, and could, for engineers, provide some informal relationships that would facilitate learning about the social scientific materials we are hoping will become more integral to the undergraduate engineering curriculum. One new faculty member may tell another about a senior colleague whose interests intersect — networking from the bottom up.

- *Research is paramount and new faculty programs may save faculty members time* by providing more information more efficiently than otherwise. For example, web sites may not be updated; departmental colleagues may not be familiar with some developments on campus that are presented to the new cohort; information that is common knowledge in one department, but not another, can be shared interdepartmentally by members of the cohort. What organizational arrangements are most effective for reducing or eliminating inequity? These should be investigated with institutional variation in mind.
- *Departments are the crucial site of professional life:* with a high degree of departmental cultural variability, new faculty are likely to find a campus wide program a useful source of insight into alternatives that their immediate (departmental) colleagues do not offer. Again, new faculty may gain from sharing the information they bring from their home departments as much as they gain from presenters at sessions.
- *Faculty from underrepresented groups, like all new faculty, may be the only new members of their home department*; in addition, they may be the sole member of their demographic group. By meeting one another across campus, new faculty learn about departmental practices of protecting junior faculty from undue service demands, and provide a sense of the normal service expectations which may give some strength to those who are being disproportionately called on for service.

Generally, participants in a new faculty program may share information about handling greed: which demands can be acknowledged but not quite fulfilled, which meetings can be skipped, which committees are particularly difficult, and which more senior colleagues, across campus, may be good sources of advice and support. In addition to this lateral communication, new faculty programs can help improve communications both upward and downward in the academic organization. Based on informal relationships and conversations, the individuals who organize and run the programs may become important sources of information for the administration about faculty concerns that might not otherwise be heard.

Data could be collected, for example, with telephone interviews of administrators charged with faculty development activities for new faculty (in the Provost's and/or the Engineering Dean's offices). This would produce a description of the varieties of activities being used at a sample of universities with large engineering programs. If this focus is incorporated into a broader study of engineering institutions, the descriptive data about new faculty programs could profitably be correlated with data about institutions, departments, and/or individual faculty members. For example, we could explore the relationship between the kinds of programs found on these campuses with usage patterns of faculty resources (such as centers of teaching and learning), and with data on faculty turnover patterns in the pre-tenure years. ❇

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ACKNOWLEDGMENTS

I had useful comments from Lisa Frehill, Laurel Smith-Doerr, and Mary Wright as I thought about this paper.

Work Values, Job Rewards and the New Engineering Curriculum

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For at least the past 50 years, engineering education has emphasized scientific fundamentals and mathematical analysis. More recently, however, responding to new technological developments and to the demands of employers, proposals have emerged for a "New Engineering Curriculum" which moves beyond the traditional emphasis on basic science and math. These proposals criticize existing engineering curricula for encouraging narrowness and specialization and for producing engineers who are ill-equipped to solve practical problems, to work in multi-disciplinary groups and to communicate. The new curriculum is designed, among other things, to encourage the development of more broadly trained engineers with a sense of the overall process, good communication skills, the ability to solve problems and the ability to work in groups (Prados 1998).

While the new curriculum has gained support from a wide variety of constituencies (from employers to granting agencies to major professional organizations), there are also significant sociological barriers to its implementation. Curricula are not simply lesson plans; they are the core of the ways in which academic activities are organized. Modifying curricula, thus, has significant consequences for the work lives of engineering educators. Encouraging the implementation of the new engineering curriculum in university engineering programs requires consideration of the sociological context for such a shift. One way to approach this question is to make use of the conventional distinction in the sociology of work between work values and job rewards. Sociologists of work note that people enter the workplace with a set of values, things they believe are important characteristics of the work they would like. These work values guide people in choosing jobs and in thinking about the jobs they actually have.

Jobs, meanwhile, offer particular rewards — these serve as motivators (whether by design or not) to get employees to do the jobs in which they find themselves. In theory, one would expect that the ideal situation is one in which there is a close fit between employees' work values and the rewards they find available to them on the job. However, Kalleberg (1977) notes that the relationship between the two is actually dynamic — it's important to know what employees' values are, if for no other reason than that you need to understand people's orientation to work. But, most people have multiple job values, and most people are able to live happily in a situation in which only some of their values are being "rewarded." Moreover, it may be that people modify their values in response to the rewards that are available, adjusting to the situation rather than rejecting it.

This paper considers the prospects for the new engineering curriculum in the context of the work values of engineers and of the rewards available to academic engineers in the contemporary university. It analyzes, first, the extent to which the professional values of engineers are compatible (or incompatible) with the new curriculum. It then considers the question of whether changes in the contemporary university are creating opportunities for the development of rewards promoting the new approach to engineering education or obstacles to its implementation.

ENGINEERS' WORK VALUES

Since an emphasis on the scientific character of engineering, and on the centrality of scientific research, has become a core value of the engineering profession, it is worthwhile asking how that came to be the case. Historians (Noble 1977; Calvert 1971; Layton 1986) teach us that, in fact, science has not always occupied so dominant a place within the engineering "sense of self."

For example, late 19th and early 20th century mechanical engineers disagreed, often quite strongly, over the place of scientific training in engineering education and over how engineers were best prepared for work in industry. On one side, there were the advocates of what was sometimes called the "shop culture," who believed that the best way to train engineers was through a kind of practical apprenticeship in actual machine shops. In this view, scientific principles and research-based knowledge took a back seat to the acquisition of experience in practical settings and to learning by doing. They feared that neglecting this practical side of an engineers' training would undercut thhe "art" of engineering and produce engineers whose ability to function in real industrial settings would be impaired.

They were opposed by a growing "school culture," which argued that engineers, as professionals, required training not alongside mechanics, but in the growing universities of late 19th-century America. Apprenticing in machine shops, from their point of view, harked back to the early days of the industrial revolution when technological progress was led by mechanics and other untrained pioneers. Now, however, technological progress depended on acquiring scientific knowledge; engineers needed to be more than sophisticated mechanics. They required formal university training to acquire the scientific knowledge that was essential to future technological development. In the end, it was the school culture's vision that shaped American approaches to the production of engineers in the 20th century.

Edwin T. Layton (1971), in a classic article, argues that at least three different views of what engineering knowledge is/was competed in 19th and 20th-century America. One view held that technological progress was driven by science – basic scientific research was the foundation on which "practical" advances in technology rested. Many of the activities in which engineers engaged were reduced, by this view, to "applied science," a kind of parasitic growth on the more prestigious activity of engaging in basic research.

A second, minority view held that the core of engineering was "design," the purposive adaption of means to reach a preconceived end. This interpretation of what engineers did weakened the connection between engineering and science — advances in design do not automatically require advances in basic scientific knowledge. Scientific research could obviously aid design, but it was not what drove it. In some ways, this view of engineering subordinated science to the "art" of design.

Finally, a third view held that engineering was neither applied science nor something distinct from science. It was, instead "engineering science," a discipline within science that differed from disciplines oriented to basic research (such as physics) but that had the characteristics of science nevertheless (scientific methods, professional scientific organizations, the accumulation of knowledge based on empirical research, etc.) While this view produced considerable confusion among outsiders, according to Layton, it arguably became the dominant view within the engineering profession itself.

That it did should come as no real surprise. Accepting the view that they were merely "applied scientists" involved accepting a subordinate status most engineers were unwilling to embrace. Defining themselves as "designers," however, involved an occupational identity rooted in something almost impossible to define and largely lacking legitimacy among the broader public. Layton notes that 19th and 20th-century American engineers were engaged in an effort to achieve professional status, to define a particular expertise that they alone possessed and to translate this claim into enhanced social status (Layton 1986; Larson 1977; Abbott 1988). Embracing an identity as a kind of science proved to be the most effective way to do this. In the end, science offered the strongest basis for the professional goals of engineers. They acquired the prestige and public approval accorded to science in general in the 20th century. Extensive funding for scientific research in the post-World War II period provided the material underpinnings for the growth of professional knowledge. And, science's emphasis on research and the pursuit of new knowledge fit well with the broader research orientation of the post-war American university in which academic engineers were located. The curricular implication of engineers' scientific identity are fairly obvious. An emphasis on courses in scientific fundamentals and mathematics follows logically, as does an emphasis on training researchers and a tendency for research, rather than teaching, to become the most highly valued aspect of the academic engineers' job.

Thus, the emphasis on engineering as science, and on the importance of scientific research to academic engineering, has roots in American engineers' efforts to achieve professional status. As such, efforts to shift engineering education away from the scientific model must consider the links between this model and the status concerns of the engineering profession.

It should be emphasized, however, that engineers' version of professional ideology is not the "pure" ivory tower model sometimes seen as inherent in professionalism per se. Some sociological analyses of professionalism (e.g., Raelin 1991) argue, erroneously, that professionalism as an ideology and a form of occupational organization involves an assertion of the occupation's right to autonomy and self-regulation and a declaration of practitioners' independence from commercial or other "non-professional" concerns. Doctors' altruistic stance and rejection of external controls and/or academics' emphasis on objectivity, peer review, and the "uncorrupted" pursuit of knowledge are what professionalism is all about, from this perspective. While it may be that some occupations have developed professional ideologies along these lines (and even for cases like medicine, there are obvious questions one can ask about the strength of altruistic or anti-commercial values), it is apparent that many professions, including engineering, develop professional ideologies that incorporate a rather different set of values. Thus, the alleged professional emphasis on autonomy and independence of political or commercial interests has not been an important aspect of engineerings' professional sense of self. Engineers have, in various ways, asserted their right to a place at the table and insisted on the importance and distinctiveness of their potential contribution to the solution of both technical and social problems (Layton 1986). They also have embraced science, its methods and forms of professional organization. But, engineers have not gone beyond this to an assertion of their exclusive right to deal with social or technical problems (Meiksins 2002). Theirs is not a technocratic ideology of engineering power; it is, rather, what has been called an "organizational professionalism (Larson 1977), compatible with working inside large organizations in collaboration with, and often in subordination to, various kinds of non-engineers.

Significantly, sociological research on engineers' work values indicates that engineers don't object to working on projects NOT of their own choosing; professional autonomy, in this sense at least, is not at the core of their identity. Rather, engineers value most doing interesting, cutting-edge work – work that makes use of their abilities and talents and allows them to grow. If this means working within corporations or government agencies on projects developed and or directed by someone else (even non-engineers), so be it (Meiksins and Watson 1989; Watson and Meiksins 1991).

Engineering professional values represent a "practical" professionalism that lives in the real world, not the ivory tower. While engineers embrace a scientific identity, this co-exists with a practical orientation to solving problems in the real world. Thus, one can argue that engineering's values also contain elements that encourage a focus on less "pure" scientific research and on the kinds of activities the new engineering curriculum seeks to encourage.

Engineering values are complex, not monolithic, containing elements both hostile to and consistent with the new engineering curriculum. Moreover, it should be added that engineering faculty are not homogeneous, and have gradually become more diverse. Values are likely to vary across different social groups within engineering. For example, it has been argued that women in technical fields are more likely to grow dissatisfied with the extreme specialization imposed by research-oriented careers (Preston 2004). All in all, an analysis of engineers' work values suggests that things could go either way for the new engineering curriculum. It thus becomes crucial to consider what rewards are being offered to academic engineers and whether changes in the reward structure create openings for or obstacles to curricular change.

JOB REWARDS AND ACADEMIC ENGINEERS

Among the more significant realities in the contemporary context of academic engineering is the relative decline of government funding of basic scientific research (Slaughter and Rhoades 2004). There has been a well-documented end to the post-war, government-funded research boom that fuelled the expansion of academic science and engineering and underwrote the scientific curricular models that are now being called into question. Researchers can no longer count on the availability of large government grants, or on the easy renewal of grants they have obtained. In principle, at least, one could predict that the limiting of basic research dollars might erode the basis for the scientific identity of engineers. As access to funding for this kind of research became more difficult, one might expect engineers (and others) to redefine themselves and to be attracted to other kinds of activities for which more plentiful rewards were available.

However, the increased difficulty of obtaining research funding doesn't automatically result in shift away from scientific research as traditionally defined. Rather, what some observers argue has resulted is an increasingly intense battle for the research dollars that are available (Preston 2004). In other words, some academic scientists and engineers have responded to the scarcity of grants by working even harder, and becoming increasingly focused and specialized in narrow areas of expertise to enhance their chances of obtaining the grants that are available. In effect, these researchers have deepened their commitment to the traditional research orientation of the "old curriculum." The fact that academic engineers and scientists persist in an increasingly difficult "game" should not surprise us given the reality that, at most major universities, career structures are still based on traditional assumptions about research productivity. Tenure, promotion, access to good students and good jobs all are linked to access to research funding. Moreover, cash-strapped universities (especially the big public universities where some of the strongest engineering programs are located) have become increasingly anxious to attract grant income (Slaughter and Rhoades 2004). Attractive start-up funding is offered to potential researchers on the understanding that they will "earn back" these funds in the form of external grants. The clear message is that funded research is important to universities and that successful researchers will be rewarded. The result is the increasingly grim contest for research dollars, federal grants, and traditional publications.

Not all university researchers continue to pursue traditional forms of research funding, however. It has also been well-documented that researchers in many scientific and technical fields have shifted their attention to private sector funding, which underwrites a growing proportion of university research (Slaughter and Rhoades 2004; Etzkowitz, Webster and Healey 1998; Brint 2002). These alternative sources of funding often encourage different kinds of research from that traditionally supported by NSF and other government agencies, research more focused on marketable products and practical outcomes.

In principle, this would seem to lead in the direction of the new engineering curriculum, with its emphasis on preparing engineers for work in the practical business of solving real-world technical problems and working in real-world organizations.

However, university reward systems frame this kind of research activity quite differently, encouraging a different emphasis among those pursuing funding.

For example, universities have begun focusing their attention on the use of research as a source of income. While they continue to encourage the pursuit of traditional kinds of external funding, they have realized, as well, that the more "practical" kinds of research that can be done in university laboratories (often the kind supported by private donors) can lead to patentable products and other outcomes that might generate income for the university. Universities have, therefore, become more and more interested in encouraging their faculty to make the development of commercial, patentable outcomes a priority and have organized themselves to take financial advantage of this kind of research (Slaughter and Rhoades 2004; Owen-Smith and Powell 2004). Engineering is one of the fields most likely to be involved in this kind of activity (Brint 2002a).

Access to private funding and the emphasis on patenting discoveries has tended to erode traditional scientific norms (such as the sharing of scientific research results and norms about conflicts of interest). It also has encouraged a kind of academic entrepreneurialism among researchers, for whom the opportunity to earn significant incomes, transform research into start-up companies and the like become attractive alternatives to traditional academic activities.

As a result of these changes, engineers dissatisfied with the difficult battle for NSF funding don't have to shift their focus away from research to training students in the ways recommended by the new engineering curriculum. They can leave the academy for the private sector OR become university-based entrepreneurs focused on the development of commercial, patentable products. Given the traditional practical orientation of engineers, this is less of a stretch than for those in the sciences, for whom commercial activity can be a new thing (Owen Smith and Powell 2004). At any rate, the interaction of aspects of engineers' work values with these new "rewards" available to university researchers does not lead automatically towards focusing engineers on practical training for undergraduate engineering students in group work, communication, and practical problem-solving!

A final, important aspect of the contemporary academic reward system involves the new emphasis on undergraduate education and on making educators accountable for their students' achievement of measurable learning outcomes. In all disciplines, there has been a noticeable rhetorical shift towards prioritizing teaching, and growing criticism of some academics' exclusive focus on traditional publishable research. Many disciplines have launched efforts to encourage new and multiple pedagogies and calls to increase the amount of contact between full-time, Ph.D. faculty and students are regularly heard. In addition, academics find themselves under considerable pressure to demonstrate their effectiveness as teachers. This goes well beyond the now familiar student evaluation of teaching and involves efforts to define specific learning outcomes and to develop methods for assessing the degree to which those learning outcomes are being achieved.

This new emphasis on teaching and accountability has multiple origins, illustrating well Sheila Slaughter's (2002) point that curricular change is the result of multiple influences, form both within and outside the university. In part, it represents a response to work sponsored by major national educational foundations, most notably the so-called "Boyer Report," which argues against academics' exclusive emphasis on basic research and sought to legitimate a greater focus on pedagogy by emphasizing the value of what it called the "scholarship of teaching and learning Boyer 1997)." Following Boyer's lead, major national accrediting bodies have created institutional pressures towards accountability and a new focus on teaching. They have been joined in this by state legislatures who, often for political (mistrust of "liberal" academics) and budgetary (concern over the cost effectiveness of publicly supported university education) reasons regularly call for more concrete evidence that a university education results in measurable learning and "adds value" to the students it produces.

For somewhat different reasons, universities themselves have come to see as desirable a focus on teaching and the ability to demonstrate that students actually benefit from a university education. A primary reason for this is universities' understandable desire to attract and retain students in an era of tight resources. Competition for tuition paying students is intense; presenting "hard" evidence of educational quality is one way to sell a school to an applicant. Universities also find themselves under increasing pressure from students themselves. As tuition rises, and the opportunity costs of pursuing a university education increase, students are more and more likely to think of themselves as consumers and to demand that the "product" they purchase be to their satisfaction. It becomes all the more important, therefore, for universities to be able to demonstrate that students' classroom experience is worthwhile and will lead to the acquisition of knowledge and skills relevant to their occupational goals (Slaughter and Rhoades 2004). These new emphases in education have produced changes in the rewards offered to university teachers. Outlets for publishing the scholarship of teaching and learning have proliferated, major foundations (such as Sloan and Carnegie) have made resources available for research and other activities in these areas, efforts have been made within universities to reward good teaching (teaching awards, small grants for innovative teaching, etc.) and there have even been universities which have modified their tenure and promotion criteria to recognize academic achievements outside the realm of traditional published research. The new engineering curriculum undoubtedly is a product of this new academic context. It is possible that the new rewards for innovative pedagogy and the achievement of measurable learning outcomes will prove attractive to at least some engineering educators, especially since the new curriculum appeals to the value engineers place on practical problem-solving activities.

However, one must also acknowledge that the calls for improved pedagogy and accountability are not the only things going on in undergraduate education. In fact, many universities can be said to be engaged in a contradictory project: emphasizing teaching/assessment/accountability/retention on the one hand and increasing the pressure to cut costs on the other. Instructional costs, which represent a very large portion of most universities' budgets, are generally a key target. Faculty are asked simultaneously to care more about teaching and to spend less on it — it is hard to see how this can lead to the desired outcome of new pedagogical approaches.

Many observers have also commented on the growing emphasis in higher education on commercializing the educational product (Slaughter and Rhoades; Noble 2001). Part of this involves the focus on patents already discussed. However, it goes beyond this to the idea that pedagogy itself can be a source of income. Universities have become more and more interested in on-line learning opportunities and the development of courseware and other commercial educational products. Faculty are offered rewards offered for developing these products, rewards often as great as or greater than those provided for the development of effective new pedagogies. If engineers shift their attention from basic research to the development of on-line courses and "do-it-yourself" courseware, the goals of the new engineering curriculum (communication skills, group work, etc.) are unlikely to be realized.

CONCLUSION

Engineering values are not monolithic, and include both an emphasis on the importance of a scientific identity and a strong emphasis on service and practical problem-solving. The new engineering curriculum could sound a responsive chord among academic engineers, given the right set of circumstances, specifically a rewards system that sent clear signals to engineers about what activities were most important.

Unfortunately, at least from the point of view of the proponents of the new engineering curriculum, the academic reward system has shifted away from an exclusive emphasis on basic research, but in such a way as to send multiple, mixed messages to university faculty, including engineers. The various trends discussed above have created some rewards that appeal to the traditional engineer's orientation to scientific research, others that appeal to the more practical, problem-solving side of engineering values (and, thus, to the advocate of the new engineering curriculum); they have also created other rewards which appeal to other values altogether.

Under the circumstances, it shouldn't surprise us that efforts to encourage new curricula have encountered a complex, mixed professorial reaction. Robert Serow and his associates (1999; 2000), for example find that engineers reacted the new engineering curriculum in a variety of ways, depending on their situation:

a. some, especially those on the margins, embraced it as a way to bring in income, build a career.
b. others embraced it out of altruism – they retained a research orientation but sought to combine it with a focus on the new curriculum (inevitably likely to be a minority position)
c. still others were able effectively to ignore or reject the initiative because of the availability of alternative rewards: grant income, patents, etc. which are encouraged AT LEAST AS MUCH IF NOT MORE by their university employers.

The new engineering curriculum, thus, confronts a complex sociological context. It is clear that employers are supportive of many of its innovations (Lynn and Salzman 2002); it is hard to imagine that students would not welcome a stronger orientation to the skills demanded by engineering employers. Yet, as has been argued here, the engineering profession and the reward structure of universities are much more ambiguous and point to the possibility of many different outcomes for this effort to modify the curriculum.

This analysis points to a number of questions[7] important to an assessment of the prospects for the new engineering curriculum and to an estimation of the effectiveness of possible interventions in the process of curricular change. These include:

- With which sets of professional engineering values are the new curricular ideas compatible and how would we find out?
- Has the new engineering curriculum support found more support with particular sub-groups within engineering (gender, specialization, etc.) or within particular types of institution (public-private, different Carnegie classifications)?
- Has the shortage of traditional research funding eroded support for traditional curricula in any way? Has funding supportive of the new engineering curriculum increased support? What happens to the new

7 Thanks to Roberta Spalter-Roth for some of the ideas in this section.

curriculum when the funding runs out?

- Have the professional engineering associations (including SWE) played any role in fostering the new curriculum, as Slaughter's (2002) argument predicts? What kinds of effects have their efforts had on different groups of engineers?
- What effect does a shift to the new engineering curriculum have on engineers' research activities? Are the two compatible or incompatible? If the latter, in what ways?
- Some (e.g., Feldman 2001) have suggested that the creation of a "post-university," involving the elimination of traditional disciplinary boundaries and barriers between the university and the community, would help to foster positive change in both engineering curriculum and research. Is there evidence to support this claim?
- Do engineers trained in the new curriculum make different career choices than those trained in the traditional curriculum, with type of school held constant? What effort has there been to demonstrate the effectiveness of the new engineering curriculum? Has evidence like this increased (or decreased) support for the curriculum among various constituencies (students, employers, engineers, etc.) Could it? ❇

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Social Dynamics of Campus Change

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INTRODUCTION

In institutions that favor funded research, many academic departments have adopted a faculty workload model that may support but often ends up undermining the diffusion of innovation in engineering education. The practice of workload assignment, which I find quite common in many regional state universities that aspire to become a research institution, is to give a lighter teaching and service load to those faculty members who are usually newly hired and whose tenure and promotion depends heavily on externally-funded research, and to assign a heavier teaching and service load to other faculty members who either have explicitly expressed no desire to be engaged in research or are currently not involved in research.

This division of labor frees up those in the department who are interested in research to generate proposals, funded research, and scholarly publications – all indicators of productivity that are measured by central administration. Under this arrangement, there is an implicit but unspoken agreement that the teaching faculty would be left alone because they are responsible for generating the largest percent of student credit-hours in the department, another quantifiable indicator that central administration uses to scrutinize an academic unit's productivity. Depending upon the belief system of the teaching faculty, who most likely are the instructors of gatekeeper courses and serve on department committee that governs the engineering curriculum, there can be positive or negative influences on the diffusion of innovation in engineering education.

POSITIVE INFLUENCE ON THE DIFFUSION OF EDUCATION INNOVATION

If the teaching faculty members are searchers in the true sense of the word, i.e., they are open to new ideas and see themselves as co-learners in the classroom with a new generation of incoming students, they can have a direct positive influence on the diffusion of innovation in engineering education by adopting the new pedagogy or instructional method in the classes they teach. Indirectly, these teaching faculty members would allow a more flexible engineering curriculum as members of the curriculum committee, and would accept the scholarship of teaching and learning as legitimate research as members of the tenure and promotion committee. A department is lucky when such a workload arrangement leads to an opportunity for diffusion of innovation in engineering education.

The change agents may pull in one or two additional colleagues through the shear force of their enthusiasm, and evidence of student learning and satisfaction may be sufficient to win over another one or two more colleagues. However, to have a wider and lasting impact, these change agents will need to have the ability to identify the hidden forces that are often at work in academic departments that affect the faculty individually and the department collectively.

From personal experience, before I was ready to embrace a new approach to teaching and learning, I underwent changes in my attitude about students and motivation. What facilitated my involvement in integrating the service-learning pedagogy into engineering were my dissatisfaction with student performance and how the engineering curriculum is meeting the need of today's students. After I was sufficiently motivated, I was ready for change; literature on engineering education reform then widened my perspective on teaching and learning.

So when I suggest to colleagues to consider a new instructional method or to review multimedia resource materials that could improve their courses and they would answer "That seems a lot of work for what it's worth" or "I am not really interested," these comments tell me there might be other underlying factors for their resistance because faculty instructors are in general a hard working group and they are intellectually curious (or at least they once were, otherwise they would not have made it through tenure and promotion).

From a change agent's perspective, how can he/she identify the underlying personal and social forces at work that may facilitate or hinder a faculty to accept change? Is there a research protocol to assist the change agent (with step-by-step instructions) to inventory the attitude, motivation, and personality of a faculty which place that faculty in the continuum of the stages of readiness for change? What are the kinds of questions to ask or the traits/characteristics to observe that would allow the change agent to place the faculty in this continuum? Finally, is there a threshold on the continuum that serves as the tipping point, showing the faculty is now amenable to change, i.e., ready to accept a new approach to teaching and learning and ready to embrace innovation in engineering education? Such an investigation will increase the effectiveness of change agents to have a wider and lasting impact.

NEGATIVE INFLUENCE ON THE DIFFUSION OF EDUCATION INNOVATION

More often than not though, the department workload arrangement described on page one is a Faustian bargain because most teaching faculty has a belief system regarding the roles of teachers and students in learning that prevents them from searching for instructional strategies to match the diverse background and learning needs of today's students. In fact, they do not see the need to change the instructional strategies because they were successful in the way how they were taught. They are not troubled by the high withdrawn or failure rates in their classes; in fact, they consider it a badge of honor because they see their role in the department is to weed out the weak students, with tacit approval from the department colleagues. These teaching faculty members have appointed themselves as the guardian of "high" academic standard, and they stand in the way of the diffusion of instructional strategies that have been proven successful elsewhere by labeling any inclusion of new approaches to instruction as diluting the content of the disciplines or lowering the academic standard. A further irony is that while the teaching faculty is not involved in research (in fact, many of them were not involved in research when they were hired by the institutions because research was not then a primary mission of the institutions nor was their research records the reasons for their hiring), they have decided that disciplinary research is the only legitimate scholarly work and discount the scholarship of teaching and learning in tenure and promotion decisions.

From personal experiences, the above scenario describes a situation that is more common that we would like to acknowledge in engineering schools, including my own. There are gatekeeper courses which are subscribed by several undergraduate programs but have a high attrition rate. The mindset of this category of the teaching faculty is exemplified by one instructor that I know who proudly states that he is the most effective recruiter for the business college. While he is known as being a fair and effective lecturer, this instructor has nevertheless turned down an invitation to review an award-winning courseware that could help students in his class to assimilate visually the materials covered in his lecture. All that this instructor needed to do to assist his students who learn visually was to request that the free software be placed on the college computer network and to inform his students of its availability, even if his personal learning style is didactic. I want to add that this faculty is not averse to computer simulation; when I visited him in his office one time, I found him playing the game of Solitaire on his desktop computer.

As associate dean of undergraduate studies, I want to understand the social and political forces at work in the department that contributes to the emergence of this view of teaching and learning with quiet acquiescence from the rest of the faculty, and I want to identify the factors that influence a plurality of faculty to allow this view to become dominant in the faculty discussion on teaching and learning.

I also want to understand the socialization factors of faculty alliances so that a new alliance can be created to support a change agent and counter the existing view. I want to know what strategies are effective in shifting the current alliance from opposing to embracing innovation. Can we draw a parallel from historical examples of shifting social alliances and use that as a model to create faculty alliance in an academic department and institution to support the diffusion of innovation in engineering education? ❇

CASEE / ASA "Social Dynamics of Campus Change: Creating an Interdisciplinary Research Agenda" Workshop: Diffusion of Innovation Theme

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CHALLENGES FACED IN MY LOCAL ENVIRONMENT

Before launching into the kinds of challenges faced in my local environment, it would be useful to characterize my local environment. First and foremost it is important to understand that although I have been involved in engineering education for over 15 years, I am new to my current university (less than one year). Below I focus on the following important attributes of my institution:

Launching a Department of Engineering Education in a College of Engineering (2005-06). The focus of the department is research, although the department was built from a service-oriented program on the freshman engineering year. We will be launching a K-12 initiative this summer that involves research on engineering thinking at the K-12 level, with an ultimate goal of understanding and promoting pathways into engineering (a teaching certificate program is also scheduled). We anticipate launching a master's level certificate program to meet the needs of current engineering educators (e.g., engineering faculty or professional staff who seek an accelerated program to develop capabilities in conducting engineering education research).

Similarities and differences of institutional and college culture. In many ways our institutional culture is representative of most research intensive universities with a strong engineering program (Purdue is a large school that is ranked highly both nationally and internationally). Although educational innovations are now included in tenure and promotion reviews, the gold standard is still on research — faculty in the Department of Engineering Education will be reviewed on their research contributions to this field. Aspects of our institutional culture which facilitated the launch (top down and bottom up strategies): 1) alignment between the President's, Dean's and Chair's long term goals that created a pathway for creating the new department, 2) investment into research (in particularly interdisciplinary research) that created considerable resources for hiring faculty, 3) a freshman year program in which existing faculty had been building partnerships across campus around engineering education scholarship, and 4) existence of science and math education communities.

Key **challenges** that speak to understanding change pathways, how engineering education scholarship is perceived and encouraged, implementing and sustaining educational innovations, and how engineering education relates to the other engineering professions:

Narrow perceptions of engineering education. Although we have considerable support, the perceptions of what engineering education scholarship means to faculty and our new graduate students appear to be relatively narrow (a focus on the practice, not the research). Illustrating the breadth (and complexity) of engineering education scholarship appears to be an important hurdle, and an important aspect for creating multiple pathways to investigate, develop, and diffuse engineering education innovations. Similarly, little expertise exists for evaluating engineering education research contributions.

A continual perception of engineering education as service to the university. Most faculty who approach the department are seeking expertise in pedagogy or assessment, although there are some faculty who are interested in research collaborations. This can make collaborations challenging in that it supports a process of engaging engineering education faculty late in the collaborative process (sending a message that they are an "add-on" rather than having a central role).

Unclear conceptions on the nature of research (and perhaps the academic enterprise). My sense is that the nature of research in engineering is not a part of everyday thinking — that research philosophies in the more traditional fields of engineering (e.g., mechanical engineering, civil engineering, and even biomedical engineering) are often implicit, out of visible range, and not a frequent nor integral part of the engineering culture (in education there are courses on research methods, in engineering there are not). This makes it difficult to understand or imagine other modes of research, and may impact the breadth and depth of conceptions of research (e.g., a "silo" view of rigor in engineering education research as quantitative, a "scientized" view of research as following the scientific method).

Defining impact. The "impact" of our department is being seen (by many) as a measure of the impact of our department on the education system locally at Purdue. This is a large and somewhat unwieldy goal for any department (e.g., this kind of impact goes far beyond research to include the arts of negotiation, organizational leadership, and policy development). If impact is analyzed only locally, and not nationally — this may contribute to narrowing conceptions of engineering education (e.g., research contributions are evaluated by national colleagues).

Living the interdisciplinary challenge. While interdisciplinarity research is being promoted broadly at Purdue and processes exist to evaluate and acknowledge interdisciplinary work, the formation and functioning of interdisciplinary collaborations is a continual challenge. For those processes that do support interdisciplinary work, they are relatively new and are likely to require continual review and iteration.

There are also many opportunities (and testbeds) on this campus for understanding 1) the diffusion of innovation and how engineering education emerges as a area of scholarship, 2) how interdisciplinary research and partnerships grow and evolve, 3) pathways into engineering education, and 4) how a local model diffuses nationally and potentially internationally.

MY RELATED WORK AND EXPERIENCE

Over the past 5 years I've been working on projects that seek to engage people in engineering education research as one kind of diffusion pathway. Assumptions underlying these activities include a belief that 1) research should inform education practice, 2) the distance between research on learning and the practice of teaching should be minimized (to encourage stronger connections and interdisciplinary discourse), 3) efforts to promote diffusion should be based on a user-centered philosophy (e.g., understanding the needs of faculty and how they approach their academic work), 4) educators are crucial for sustainable and continual education improvement (as key decision makers within the academic system), and 5) community and social networks play a crucial role in constructing, diffusing, and enabling knowledge.

I have three projects around the question "how to build capacity in engineering education research":

(1) The Institute for Scholarship on Engineering Education - Center for the Advancement of Engineering Education (see Adams et al).
This is a year long program designed to build and sustain communities of engineering education scholars who can investigate student learning issues and transform findings into actionable improvements. Key attributes of the ISEE model include: 1) investigating engineering learning environments as education research laboratories (promoting reflective practice by encouraging the idea that all learning environments are laboratories for understanding learners and the learning process), 2) promoting a "scholarship of impact" by asking participants to develop impact studies (studies that included explicit plans for building impact networks and effectively communicating research findings) around potential zones of impact (classes, programs, etc.), 3) facilitating community building (locally and nationally) through a waterfall recruitment strategy and a high level of interactive community-centered and assessment-centered activities (e.g., interactive study posters, work-in-progress sessions, and sharing stories), and 4) adopting a user-centered approach on understanding the challenges of being an ISEE Scholar (via various evaluation activities).

Findings from evaluating our model (that appear useful for a discussion on the diffusion of innovation) are highlighted below.

- Openness and curiosity about qualitative research — Many Scholars were not familiar with more qualitative approaches to inquiry yet were very interested in learning more about them. Similarly, although Scholars feel comfortable with quantitative methods, they lack confidence and are confused about how to use them in educational research contexts.
- Engineering education fit their passion and their personal career goals but may not fit the values of their department - Many Scholars did not perceive their departments or Universities as particularly supportive of education or research on education, yet all the Scholars felt that their participation in ISEE fit their career goals (which make for an interesting question about how they saw their career goals aligning with the values of their respective campuses). Scholars spoke of a "passion" for engineering education and appear to choose to engage in activities that may be seen as flying in the face of adversity (and perhaps helps explains a driving need to find communities of like-minded folks).
- Learning and implementation challenges - 1) formulating research or impact questions (one Scholar noted that formulating a research question was its own form of research), 2) knowing when, why, and how to employ various research methods (and how to analyze the data once you get it), 3) navigating the human subjects process and recruiting participants, 4) learning how to narrow down the scope of a project so it is feasible, 5) navigating and finding (and understanding) relevant research (new disciplinary language), and 6) a preference for quantitative data yet a lack of knowledge around analyzing this kind of data.
- Organizational / structural challenges - 1) continuing community building (locally and distributed), 2) finding time and managing conflicting obligations, and 3) setting project milestones.
- Strategies Scholars employed to navigate challenges - 1) encouraging connections between existing engineering research knowledge and experience to help transition to a new form of research, 2) sharing work-in-progress, and 3) building community of like-minded colleagues and social networks.

(2) Exploratory research characterizing the process of becoming an interdisciplinary engineering education researcher (Allendoerfer and Adams, unpublished).
Five engineering education researchers (not ISEE scholars) at various stages in their interdisciplinary pathway were interviewed to illuminate stories around what it means to be an interdisciplinary researcher, pathways for entering and navigating interdisciplinary work spaces, and the construction of interdisciplinary identities.

- Pathways into and within engineering education research — Participants were driven by nagging questions about their current teaching and learning contexts, disenchanted with mainstream views and step across disciplinary boundaries to seek out alternative views, proactive and intentional about creating opportunities for increasing their participation in a new community of practice, and driven by personal motivation and persistence. Interestingly enough, pathways for doing this kind of work resembled the process by which participants did their disciplinary work (identify a problem, seek information from sources both within and outside of their current discipline, synthesize ideas from multiple fields, and apply what they find to the problem at hand).
- Constructing identities as interdisciplinary researchers — Each participant had different ways of describing their identity, yet all spoke to an interdisciplinary identity (e.g., a bridge, translator, and liaison). A sense of not quite fitting into traditional disciplines was apparent ("I'm this weird hybrid," "I was already considered 'fuzzy out there' by the engineering school"). The scholars' ways of talking about themselves acknowledged that the community which they have entered is inherently an "in between" space.
- Challenges consistently encountered and strategies employed — The participants spoke to the risks involved in stepping away beyond the boundaries of their home disciplines, and also about the difficulty of entering a new community of practice ("a culture shock"). Some lacked collegial support, and some were faced with questions of where to publish their work and how to make this work "count". New terminology had to be learned, new literature had to be navigated, and new approaches to research methods and "what counts" as evidence had to be learned and accepted. In discussing strategies for overcoming these challenges, the scholars repeatedly emphasized the importance of finding a supportive community (mentors, supportive colleagues or supervisors, and broader communities of like-minded people).

(3) <u>Descriptive research characterizing career trajectories in engineering</u> education (see Adams and Cummings-Bond).

This was a study to create a landscape view of engineering education career trajectories across three groups: 1) CAREER grant recipients (represented the least risky trajectory in that it more closely aligned with a traditional research focus), 2) recipients of "potential to impact engineering education" AWARDS, and 3) PHD dissertations in an engineering education topic (the most risky trajectory). Publicly available data was collected on current academic position and data on the nature of the institution (e.g., Carnegie class, geographic region, and the presence of a center for teaching or learning or an engineering education center). Findings illustrate that engineering educators (even those in the most risky groups) were finding careers in academia — particularly at research intensive institutions. A key finding was the influence of having a center for teaching and learning or an engineering education program (e.g., NSF funded Coalition) on career paths. In particular, a high percentage of PHD recipients and AWARD recipients were associated with schools that had these kinds of communities or networks. This suggests that the culture of these institutions may be different and that there may be were relatively thriving communities of engineering education scholars who could be mentors, provide professional development and research opportunities, and possibly strong social networks.

The other area of activity are 2 projects around the question "how to bridge research and practice" (see Turns et al).

(1) Research-to-Practice Workshops. The focus of these workshops was to engage engineering faculty in research that could have implications for addressing their individual teaching challenges. Many effective teaching workshops exist, and are successful. However, workshops attendees often experience failures (short and long term) with bringing these teaching practices into their classrooms. Although there may be many structural barriers, one barrier may be that such workshops often do the "work" of translating research implications — potentially limiting a deep understanding of the research (and an ability to relate research to specific educational settings). Research-to-Practice workshops were designed to reduce the distance between the research and the educator by engaging educators in actual research, and then discussing ways to use the research for a set of "teaching challenge" scenarios. We found that the leap involved in reading research was not a large barrier and that when given actual research, participants could identify a variety of implications for different situations. These beyond seeking an answer (e.g., follow a guideline) to experimenting with the ways research can be brought into classrooms (e.g., having students read the studies, having students solve the study task and compare themselves to the participants in the study, presenting some of the research as part of the lecture).

(2) A design expertise continuum. A goal of the design expertise continuum is to support educators in visualizing learners' growth toward acquiring engineering design expertise. Through iterative prototyping and building on adoption/adaptation research in K-12, some attributes of a successful continuum were identified. Attributes include 1) identifying appropriate courses of action (by illuminating learning targets and pathways), 2) promoting synthesis by linking to other research (including pedagogical content knowledge), 3) making learners' behaviors, thinking, and attitudes visible as well as using language that is recognizable and salient with users, and 4) organizing and representing

information to illustrate the complexity of learner trajectories (rather than watering down results).

MY VIEW ON FUTURE RESEARCH NEEDS

There are many opportunities for research (e.g., many unanswered questions on how to apply K-12 findings to engineering education). I can imagine research on individuals/collections of individuals, pathways/mediators, and cultures/contexts around the following topics:

Framing engineering education — What's the problem, what drives change, who gets involved, and for what purpose?

- How do different actors within engineering education frame "the problem" (and how do these framings relate – is there a common ground)? What are their intentions and motivations? How does this relate to what are perceived as effective approaches to addressing these problems? What catalyzes people to get involved even when they know they are taking risks?
- What are the dominant theories (or operating theories) that guide engineering education (e.g., is design a useful analogy that helps make visible intention and judgment)? What are conceptions of innovation in engineering education (and adaptation, diffusion, action), and how do these guide approaches to engineering education?
- What examples exist of confronting conceptions of engineering education and what can we learn from them? Is there a conceptual change model of engineering education (and if so what is the role of internal motivations)? Where does change get "bogged down"? What conceptions are being confronted (or need to be confronted)?

Interdisciplinarity and engineering education discourse — What are pathways/networks and what is the role of engineering education within engineering colleges?

- What are pathways into engineering education discourse? Who enters those pathways and why (and who needs to be there)? In what ways might graduate students be pathways for change (liaisons)? In what ways does an interdisciplinary approach support collaborations beyond "service"? What is the role of social networks in the change process? What are invisible networks?
- Where and how does engineering education fit within the broad engineering profession? Central? Fringe? Unconnected? How do conceptions of engineering education compare among engineering practitioners and engineering faculty / administrators? In what ways would bringing engineering education towards the "center" of the engineering profession (rather than some liminal space) influence approaches to improving engineering education?
- In what ways is engineering education similar / different from other engineering fields (e.g., design as a central theme, user-centered design as a philosophy)? In what ways might approaches to research be a thread

that links the various engineering professions? What are conceptions of research and how do they compare (are we more alike than we think)? Where are points of commonality?

A focus on educators — What do they find challenging / motivating, and how do they see themselves as actors within engineering education?

- What is the role of faculty in the engineering culture? In the change process? What are points of commonality for engaging faculty in change (e.g., reflective practice)? What are faculty epistemologies of teaching and learning? Adminstrators?
- What are assumptions about faculty (efficiency and time issues, motivations, etc.)? How and in what ways do engineering faculty construct their identities? How does this relate to their identity as engineering educators? How do engineering educators see themselves as decision makers? In what ways might their conceptions of power and agency influence their motivations and abilities to engage in curricular reform?
- What kinds of information about teaching and learning make it into classrooms? Into decisions about engineering education? How is information presented, translated (re-designed?) or brought to attention?

A focus on engineering education researchers— What is the role of research in engineering education and why should it be engineers (versus someone else) do it?

- How and why do people get involved in engineering education research programs? What makes them stay involved? How does work from these experiences diffuse into the local community? What challenges do they experience and in what ways are these indicative of those involved in engineering who do not engage in engineering education research?
- In what ways might these programs be intermediate steps towards diffusing education innovations? What could we do better? How could we speed up or scale up the rate of diffusion?
- How does new knowledge gain legitimacy and spread? What are we learning from our participants' experiences when they return to their local community (e.g., impediments, facilitators, resources and networks they use or create)?
- If faculty engage in classroom research or broader research, do they become more accepting of / proactive in seeking out research relevant to their situation? What contributes to seeking out other information (or not)?

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The following is provided as an "fyi" — for those who are curious about what ideas have guided my work and thinking:

Academic culture and organizational theory

- Faculty issues and the academic culture — e.g., reward systems and various barriers including the challenges of balancing external and internal motivations such as research / teaching and career / personal life (Huber & Morreale), challenges unique to interdisciplinary issues (e.g., Gidjunis, Stokols et al)
- Organizational theory, social networks, and design organizations (e.g, Van de Ven & Hargrave, Barley)
- Diffusion of innovations, trading zones, social life of information (e.g., Rogers, Galison, Brown & Duguid)

Theories of learning

- Communities of practice (and knowledge building communities of practice) — disciplinary and interdisciplinary communities (e.g., Lave & Wenger, Barretti, Cook et al)
- Adaptive expertise and cognitive flexibility
- Reflective practice, the scholarship of teaching and learning, and pedagogical content knowledge
- Identity development (as a driver for human behavior and social interactions)

Interdisciplinarity

- Interdisciplinary thinking (e.g., Kline, Klein, Lattuca, Weingart & Stehr), interdisciplinary environments (e.g., Newstetter), and interdisciplinary discourse (e.g., Frost & Jean, Spanner)

Design theory

- Use-inspired research (Pasteur's quadrant) and user-centered design (includes systems theory.)

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Challenges to Diffusing Engineering Education Innovations

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In participating in this workshop, there are two engineering faculty audiences for diffusion of engineering pedagogies that I want to serve. First are the classroom teachers—engineering faculty—the ultimate consumers of the pedagogies. Second are the innovators and opinion leaders who have the power to help disseminate pedagogies as informed insiders. Before we can discuss the research needed, there are important "cultural" aspects for reaching these audiences that need to be considered.

First, the roles of researcher and teacher are conflated for engineering faculty. The type of engineering education publications characteristic of the past several decades (written by engineering faculty) indicate a highly practical focus on the details of new pedagogies, often at the expense of evidence supporting their efficacy. However, as logical technical researchers, engineering faculty consider themselves analytical thinkers who are convinced by rigorous, quantitative evidence. Thus, there is a disconnect between the innovators, who focus on the mechanics of their new pedagogies, and the consumers, who desire rigorous evidence. It should be noted that these two groups are essentially the same; they simply act differently based on their roles with respect to a specific innovation. Recently, this has led to calls for increased rigor in engineering education work (Gabriele, 2005; Shulman, 2005).

But convincing teaching faculty is not as simple as appealing to their purported disciplinary modes of thinking. As potential users of new engineering pedagogies, engineering faculty are largely unconvinced by the same quantitative evidence they demand. Labaree argues that due to application and immediacy considerations, teachers value context-specific experience and use experience-based but subjective reasoning in making classroom decisions. As a result, they tend to devalue generalizations about what works in the classroom and reinvent the wheel, working alone, with little overall sense of what has been shown to work in most situations. They reject theory and generalizations as inconsistent with their copious teaching experience (2003).

Leaders within the engineering education coalitions have gone through the long and difficult process of discovering for themselves that compelling results alone do not convince engineering faculty (Clark, Froyd, Merton, & Richardson, 2004). Throughout the 1990s, the National Science Foundation invested millions of dollars in engineering education reform at over 40 institutions. I recently interviewed coalition faculty and was amazed by their stories of the painful uphill battles in trying to get their reforms institutionalized. (I imagine Jeff Froyd will elaborate on this in his whitepaper.) Thus, n*ot only is there a complex set of misconceptions to overcome in convincing faculty consumers of the value of a new pedagogy, but there are also misconceptions among innovators and opinion leaders as to diffusion processes and their proper applications, specifically the relevance of theory.*

Among this group of engineering education innovators and opinion leaders, there is the same reliance on practical experience and disregard for theory. This leads to misconceptions about specific aspects of diffusion of innovations theory. As in teaching, these faculty rely on their personal experiences, and a single experience can trump widely-tested theory. An example is identification of leaders, both leading institutions that should be emulated and the individual opinion leaders within an organization. Top-ranked ivy league schools are most commonly cited as the ones to emulate, but research has shown these schools are often less innovative than those seeking to move into the top of the rankings (Blau, 1994). In the case of individuals, there are many types of higher education opinion leaders, depending on the arena: research, administration, or teaching. Prior work in identifying teaching leaders a perceived by faculty within departments of chemistry, math and physics suggests that there are opinion leaders within the faculty ranks and that other than department chairs, administrators have little influence on faculty teaching decisions (Dearing, Casey, Larson, Singhal, & Rao). Likewise, much of the literature on institutional change advocates leadership from both administrative and faculty levels (Kuh & Whitt, 1988).

Take for example but one illustration of the way engineering faculty have undertaken diffusion studies. Published as a conference paper, a group of engineering education coalition members studied the diffusion of three software tools. The methods section states that they considered many different types of innovations, many less concrete, but in the end argued that the formal distribution systems for these three software tools overwhelmingly indicated that these were the most successful innovations (Serow & Zorowski, 1999). I think this study reflects the approach of engineers in two ways. First, the software tool is portable and requires no alteration to use. Engineers can be extremely utilitarian in this sense, not valuing a theory or philosophy but rather a student worksheet or software tool that can be applied with little thought. Second, the researchers chose something that was easily quantified. In each case, the software was distributed through a partner such as a textbook company or a national lab, which had tracked distribution of the software. Though Everett Rogers' book (1995, 2003)was cited, it merely provided context for a study focused on "the numbers," rather than guiding data collection or analysis.

Though these aspects of engineering faculty behavior are explained better by the applied aspects of engineering (with respect to other disciplines), engineers tend to identify much more with the "hard science" categorization of engineering (Biglan, 1973). Unfortunately, this leads to issues of status that can cause engineering faculty to further devalue the contributions of education research. The "hard" characterization arises from well-developed, agreed-upon and enforced standards of rigor in physical science and engineering disciplines. These articulated standards make it easier to evaluate and demonstrate success, which can draw the focus of institutional administrators and funding agencies to award a disproportionate amount of resources to these disciplines. Whether this is a cause or an effect is unclear, but it is definitely a roadblock. The National Academies report *Facilitating Interdisciplinary Research* cites numerous instances of resistance to collaboration within science and engineering research teams because certain members feel their disciplinary contribution is more important than the others (in these cases physics over other technology disciplines). The report actually cites this behavior as the single biggest roadblock to interdisciplinary collaboration, as perceived by leaders in industry, academia, and government research labs (Committee on Facilitating Interdisciplinary Research, 2005). While collaboration is not necessarily the goal in diffusing engineering pedagogies (but applying knowledge from social science research is), it is a more observable behavior arising from the same underlying attitude toward knowledge from other disciplines that prevents direct application by engineers.

The core problem is this: T*here is a huge body of research in education (how to teach) and sociology (how to disseminate) that engineering faculty are not using.*

I believe involving informed engineering faculty in sociology-grounded studies is the right next step. Two distinct types of research are needed to advance diffusion of engineering education innovations:

A. Ethnographic or socio-cultural research into specific higher education contexts for engineering education reform. This largely qualitative work would answer the questions: How do engineering faculty think they learn about and decide to use teaching innovations? What effects do work environment and culture have on the diffusion process for engineering teaching innovations, particularly since faculty often control their own classrooms?

B. Quantitative and/or applied work undertaken to widely educate engineering education innovators and opinion leaders. With engineering faculty as the audience, their own norms must be addressed: substantive, quantitative, and prescriptive research conducted with the participation of an "insider" engineering education leader. Examples include:

1. Research, mapping what is known about diffusion of innovations, particularly opinion leaders, to engineering education through a series of illustrative studies that can be used to educate engineering faculty. Case studies are a particularly effective means of reaching this audience, so they can serve as examples demonstrating the basic principles guiding an effective

dissemination plan and how to apply them.
2. Workshops focusing on dissemination plan design, conducted in cooperation with "insider" engineering education leaders with established audience credibility.

It is my understanding that too much diffusion of innovations (DoI) research is historical rather than experimental, or at least not forward-looking enough (Rogers, 1995, 2003). In a more proactive experimental approach, group A would receive a DoI-informed intervention and be compared to group B, a control group receiving the standard dissemination treatment. Though I am more interested in in-depth qualitative research, I fear that too much emphasis in this methodology might go the direction of education research, that is, to be largely ignored by engineering faculty because their interests as an audience are not directly addressed. The challenge is to advance the sociological knowledge base while providing research in the correct setting (engineering) that includes some research design characteristics that appeal to engineers. ❇

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Network Perspectives on the Diffusion of Innovation

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There is an extensive sociological literature on the diffusion of innovation that dates back many years. Among the classic works in the field are Ryan and Gross's (1943) study of the diffusion of hybrid corn seed in an Iowan farming community and Coleman et al.'s (1966) study of the diffusion of a new drug among physicians in four Midwestern cities. No attempt will be made here to survey this sprawling literature (see Rogers 1995). However, two general findings of this literature bear mentioning at the outset. First is the fact that the diffusion of an innovation typically follows an S-shaped curve in which the rate of adoption begins slowly, then accelerates as it spreads to a majority of the population, and finally tapers off again as the point of saturation is approached. Second is the fact that the diffusion of an innovation often occurs through what can be described as a two-stage process in which the innovation first must be accepted by a sufficient number of "opinion leaders," whose example then encourages adoption by other members of the population. Neither of these patterns should be construed as universal. Nevertheless, together they provide an orienting framework for much of the research on the success, failure, or timing of the diffusion of innovations.

The Network Perspective

The focus of this essay will be on the contribution of network theory and methods to the study of innovation diffusion. Network analysis is distinguished by the attention that it gives to the links or relations among social actors, the structure or pattern of such linkages, and the implications of those patterns for social behavior. In contrast to research that takes individuals and their attributes as the focus of study, network analysis focuses on the manner in which individuals interact with one another and how those interactions constitute a structure that can be studied and analyzed in its own right. As applied to the study of innovation diffusion, the network perspective argues that actors' decisions with respect to adopting or not adopting an innovation can be explained, at least in part, by the pattern of interconnections among them.

This thesis is by no means new to the study of innovation diffusion. Indeed, insofar as the diffusion of innovation is commonly conceived as a process of contagion or imitation, one could argue that actors' exposure to the influence or example of one another has always been, at least implicitly, a preoccupation of researchers in this field. Nevertheless, what network analysis brings that most prior research lacks is: (1) an explicit concern with collecting systematic data on the social relations among actors; (2) an extensive repertoire of mathematically tractable measures and models for describing the patterns revealed in such data; and (3) a body of theory for making sense of the social and behavioral consequences of different network topologies.

Proximity: Cohesion and Equivalence

At the heart of much network theorizing about innovation diffusion is the concept of proximity (Marsden and Friedkin 1994; Valente 1995). Stated in the broadest terms, the network perspective argues that "something about the social structural circumstances of ego and alter makes them proximate such that ego's evaluation of the innovation is sensitive to alter's adoption" (Burt 1987, p. 1288). Generally speaking, there are two main ideas about what that "something" is. The first is based on the concept of structural cohesion. The second is based on the concept of structural equivalence.

Structural cohesion is a measure of whether, how closely, or how strongly two actors are linked to one another. The most restrictive definition of structural cohesion is "adjacency" — the existence of a direct link between ego and alter. The concept can also be expanded beyond the dyad to encompass various measures of the extent to which ego and alter are connected, not only directly but indirectly, via chains of relatively short distance or within communities of relatively dense and strong ties. Structural equivalence defines proximity in terms of the similarity shown by ego and alter in the overall profile of their links to the larger network, whether or not they are directly or closely linked to one another or belong to a common, dense-knit community. Sometimes equivalence is measured not strictly in terms of the similarity of links to identical sets of third parties but to third parties who, themselves, occupy structurally analogous positions within the network. In the nomenclature of network analysis, this is referred to as "regular" equivalence. There is evidence to suggest that both cohesion and equivalence can play an important role in the diffusion of innovation. In the field of reproductive health, several studies have shown that the likelihood of adopting a new contraceptive technology by women in developing countries was enhanced by cohesive ties to women already using the technology (Entwisle et al., 1996; Valente et al., 1997). In the field of organization studies, Davis (1991) showed that adoption of the "poison pill" takeover defense by corporate managements was strongly influenced by the existence of direct board interlocks with previous adopters. The strongest evidence of the importance of structural equivalence for the diffusion of innovation comes from Burt (1987), who, in a reanalysis of Coleman et al.'s (1966) data on the adoption of a new drug by physicians, showed that similarity in the timing of adoption was better explained by structural equivalence than by direct interpersonal ties.

These two notions of proximity suggest different mechanisms by which ego's likelihood of adopting an innovation may be influenced by alter's prior adoption. In the case of structural cohesion, it is reasonable to invoke interpersonal mechanisms of trust, deference, persuasion, and conformity with community norms. In cases of structural equivalence that are not accompanied by direct interpersonal ties, we can reasonably exclude such mechanisms. Instead, any similarities in the timing or likelihood of innovation adoption must be attributed to more indirect processes of the enforcement of similar role expectations by disjoint sets of actors or to competitive efforts on the part of similarly situated actors to keep pace with others of their kind. Such causal mechanisms are not mutually exclusive. Moreover, it should be noted that, although cohesion and equivalence are conceptually distinct, empirically they are often aligned. Hence, it is possible that these two forms of proximity overlap in terms of their causal effects.

Structural Properties of Social Networks

Another important distinction in the networks literature on innovation diffusion is that between strong ties and weak ties. Here the terms "strong" and "weak" do not refer to the intensity of an individual relation (something that is encompassed within the concept of cohesion), but to the articulation between the multiple relations maintained by an individual actor or the structural position of a particular link within the network as a whole. Strong ties are links that are situated in dense clusters within a network, where any direct link between ego and alter is likely to reinforced by multiple indirect ties among members of a densely interconnected community. Weak ties are links that bridge between relatively segregated clusters or communities within a network and are seldom duplicated by alternative paths of comparably short length.

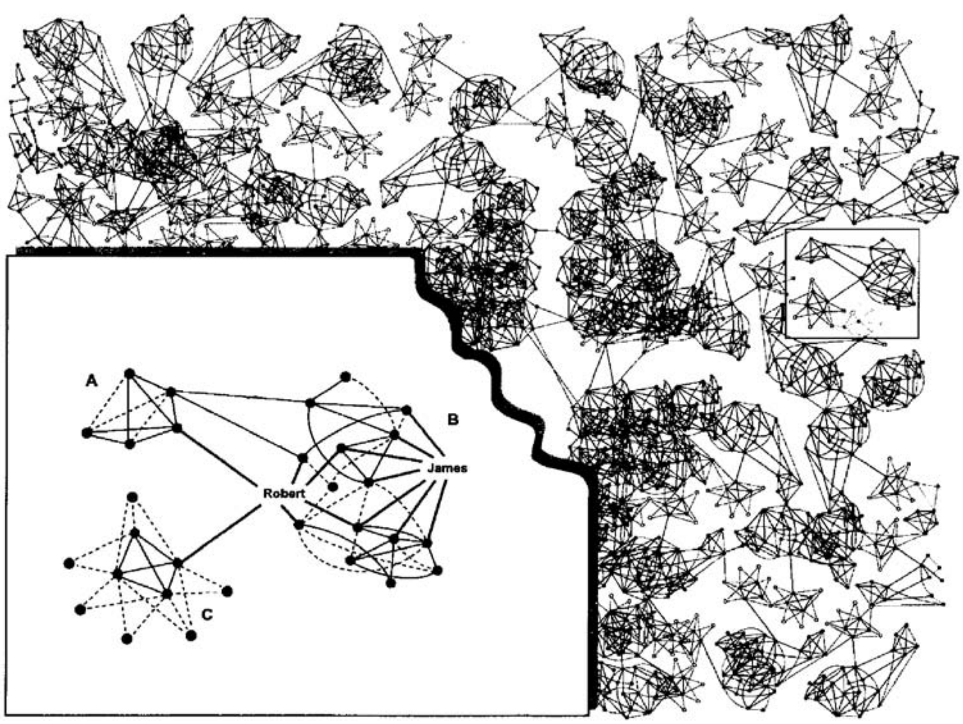
Most naturally occurring social networks display a distinctive mixture of strong and weak ties. Such networks typically exhibit a much higher than random degree of local clustering (strong ties) together with a sufficient number of bridging actors to create links between otherwise separate clusters (weak ties). The combination of these two properties yields what is known as the "small world" phenomenon in which path lengths between any two randomly chosen members of the network are surprisingly short — typically on the order of five or six links (Watts 2003).

An associated property of most social networks is a highly skewed distribution in the number of links maintained by actors. Actors who contribute most to the connectivity of the network, by either the large quantity or the strategic nature of their links, are called "central" actors. Some central actors have ties that connect them to a large proportion of the other members of their community, in which case they may be described as local hubs or stars of the network. Others have a substantial number of (weak) ties to clusters outside their own, in which case they may be said to function as bridges, brokers, or gatekeepers to the larger network. Some display a combination of these properties.

Figure 1 (adapted from Burt [2004]) illustrates the topology that is typical of many naturally occurring, small world networks. Note the pattern of relatively dense-knit clusters linked to one another by occasional bridges that span from one cluster to the next. In the insert at the lower left, the actor labeled "James" can be described as a local hub of cluster B insofar as he is linked directly to a high proportion of the other members of that cluster. James's links are mainly strong ties in the sense that many of those to whom he is linked are also linked to one another. Actor "Robert" has fewer links to other members of cluster B; however, he occupies a highly strategic position as the sole bridge between clusters B and C and one of only several bridges between clusters B and A. Robert is thus distinguished mainly by his weak ties that link him to actors or clusters that are not otherwise connected among themselves. Each in his own way, both James and Robert can be described as relatively central actors within the network. Together they illustrate the mix of hubs and bridges (strong and weak ties) that are crucial for the overall connectivity of small world networks.

These structural properties of social networks have important implications for the diffusion of innovation. In principle, local clusters provide ample pathways for diffusion to occur. However, so long as adoption is contained within a small number of relatively isolated clusters, diffusion across the larger network will be limited. Only when adoption begins to spread across the weak ties between clusters are we likely to witness a sharp increase in the rate of diffusion. Eventually, as most of the interconnected clusters become saturated, we are left with only a small number of relatively

Figure 1. A Small World Network



isolated actors or clusters whose adoption will be delayed or blocked. Network dynamics of this sort offer one explanation for the classic S-shaped curve that is observed in many studies of innovation diffusion.

Parallels can also be drawn between the concept of "opinion leaders" and the different types of central actors within a network. As noted earlier, relatively dense communities of strong ties offer ample pathways for diffusion; however such dense-knit communities also tend to exhibit resistance to change or innovation. The adoption of an innovation by locally central actors can be crucial to overcoming this resistance, both because of the large number of ties that they maintain and because of the prestige that typically accompanies their central role within their community. Strategically located actors with ties to other communities also play a pivotal role in the diffusion of innovation. Such actors are frequently the first ones to become exposed to new ideas (Burt 2004), and the fact that they bridge between multiple communities makes them less bound by the traditional norms and practices of any given community and more prone to be early innovators.

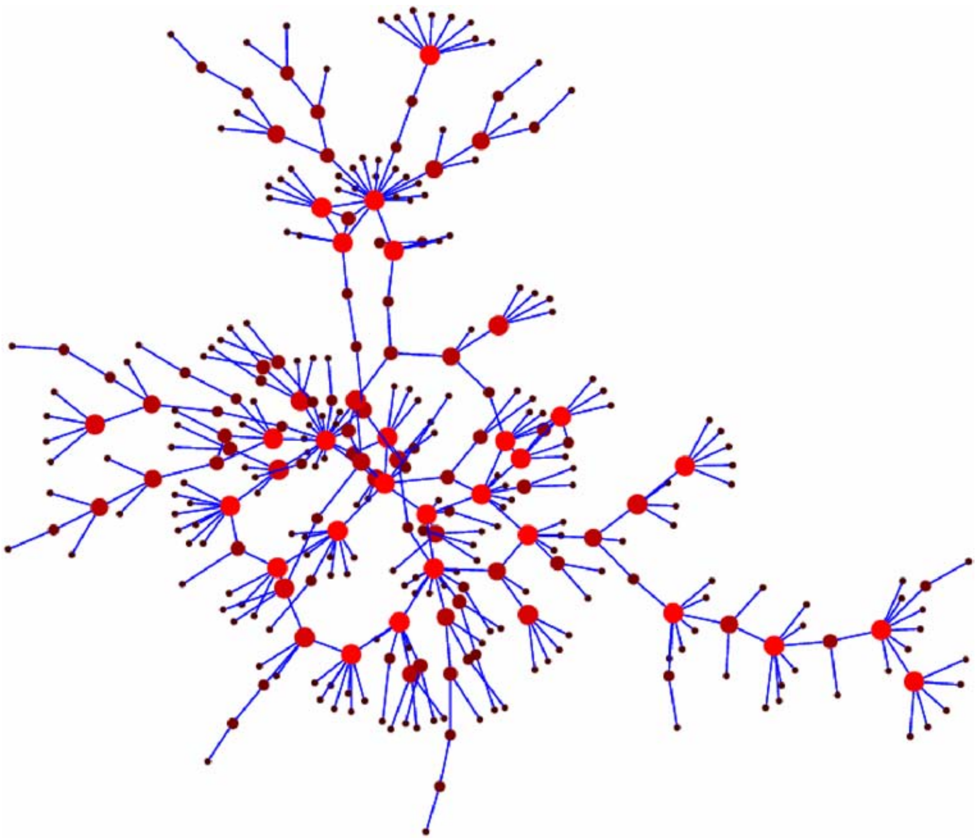
Variations in Network Topology: Examples from Epidemiology

Although most naturally occurring social networks exhibit certain structural uniformities, it is important not to ignore variations in network topology that exist between different social spheres. Instructive parallels can be made here to the field of epidemiology, which, like research on the diffusion of innovation, is concerned with modeling processes of contagion. In the research on sexually transmitted diseases (STDs) and the social networks through which those diseases are spread, important differences have been identified in patterns of clustering, the extent of bridging between clusters, and the degree of skewness in the number of sexual contacts. All of these have implications for the spread of disease and for public health efforts to limit that spread.

For example, within sexual networks that have highly skewed distributions in the number of sexual contacts (typical of the spread of HIV/AIDS among adult populations), or where the there exists a distinct category of structurally equivalent actors who function as bridges between clusters (e.g., long-distance truck drivers who regularly have sex with commercial sex workers), the most efficacious use of public health resources will be a targeted strategy aimed at influencing the behavior of those with the most sexual contacts or who function as vectors of transmission between otherwise isolated communities (Gopfert and Robert 2001). Less amenable to intervention, but also crucial to the success or failure of public health efforts is the extent of cyclic (loop-like) clustering, which tends to provide a fertile environment for the gestation of disease.

Figure 2 illustrates a disease transmission network with some of these properties, drawn from a community-wide study of HIV/AIDS contact tracing records in Colorado Springs (Potterat et al., 2002). In this network it is easy to identify certain actors who are likely to have disproportionate impact on the

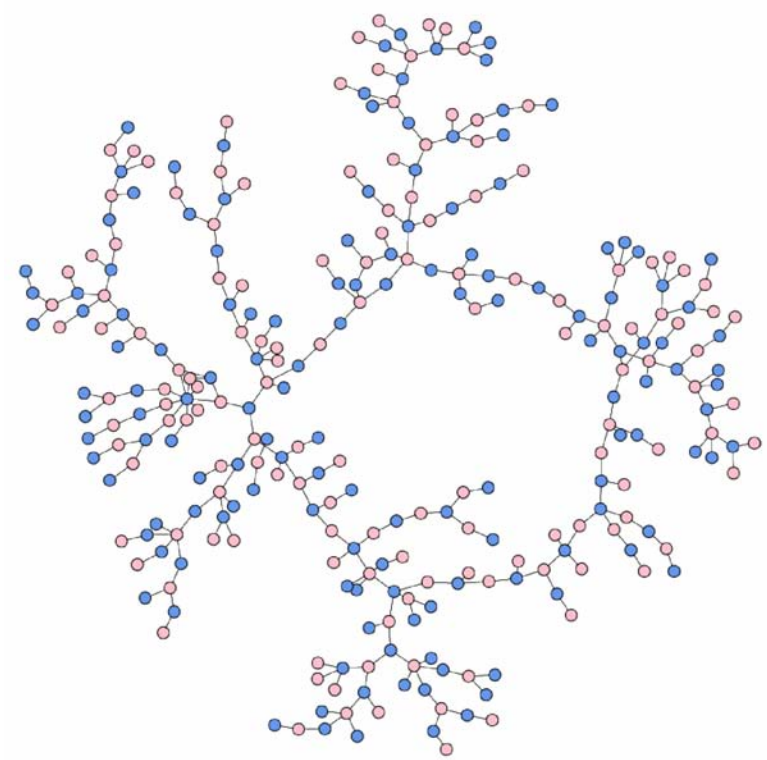
Figure 2. HIV/AIDS Disease Transmission Network



spread of disease, either because of the high number of their sexual (or needle-sharing) contacts or because of their strategic position as bridges between otherwise isolated segments of the network. The topology of this network is predominantly dendritic (branch-like), although it also exhibits a moderate level of cyclic clustering and can thus be characterized as intermediate in its susceptibility to the spread of disease.

Other STD transmission networks lack either a distinctive core of high-activity actors or an identifiable category of bridging actors. Figure 3 illustrates a network of this kind, drawn from a study of sexual relations among students in an American high school (Bearman, Moody, and Stovel 2004). Compared with the network shown in Figure 2, this network exhibits a much flatter distribution in the number of sexual contacts, and there is also a much wider and more equal distribution of weak, bridging ties. The extent of cyclic clustering is also less pronounced, which ceteris paribus makes for a less fertile environment for disease transmission. In a network of this kind, there is little basis upon which to design a targeted disease containment strategy, and a more broadly directed educational campaign will likely be most effective in slowing the spread of disease.

Figure 3. High-School Sexual Network



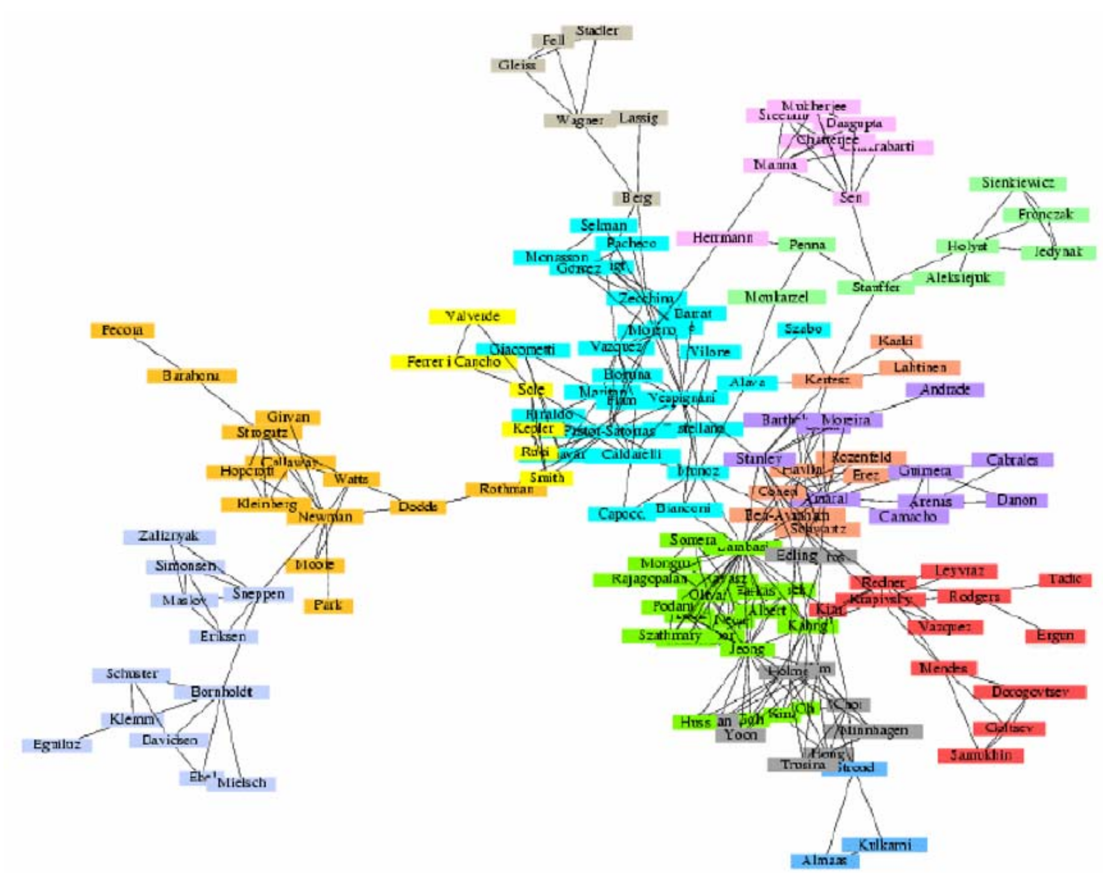
Of course, where the diffusion of innovation is concerned, we are more likely to be interested in how contagion might be encouraged rather than prevented, but the same variations in network topology are relevant in either case. Knowledge of network topology is essential to designing an effective strategy to promote the diffusion of innovation. Where they exist, actors with disproportionately high numbers of social ties and/or actors who create bridges between otherwise separate segments of the network must be identified if resources are to be targeted in an effective manner. In more homogeneous networks, the most effective diffusion strategy may be one that eschews targeting and relies mainly on broadly focused efforts at communication and persuasion.

Networks and Innovation Diffusion in Higher Education

The network perspective has made important contributions to the study of innovation diffusion. Nevertheless, further advances in this area confront significant challenges. Perhaps the most pressing is the relative paucity of data on social networks of sufficient completeness and detail to allow us to model the diffusion of different types of innovations across different populations. As a consequence, the data from a small number of classic studies (such as those mentioned at the beginning of this essay) continue to be used and reused by researchers in the field. This is a serious limitation insofar as different types of innovations will likely encounter different obstacles to adoption, and different target populations may exhibit variations in network topology that have important consequences for the dynamics of diffusion.

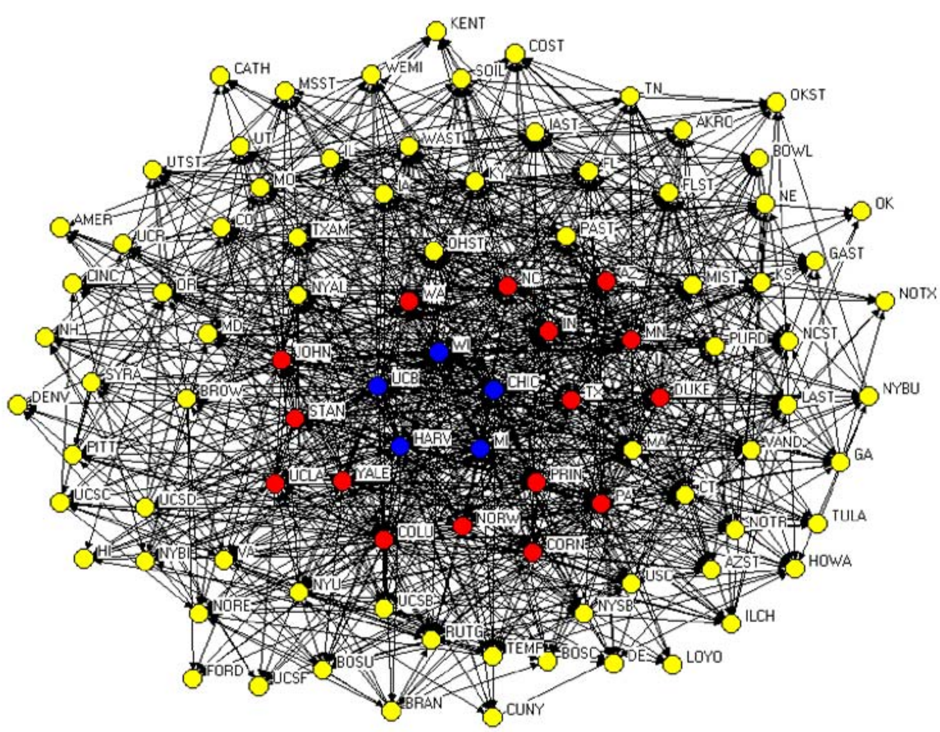
With regard to the field higher education, there are (to my knowledge) no systematic network studies of the diffusion of innovations, either in teaching or in research. There is some related research on the structure and functioning of academic networks from which one might hazard some hypotheses about processes of innovation diffusion within higher education. Two specific areas that have been studied are coauthorship networks (Newman 2001; Moody 2004) and networks created through the exchange of Ph.D.'s (Hanneman 2001; Han 2003; Burris 2004). The image that emerges from these studies is one of academic disciplines as "small worlds" in which randomly chosen pairs of scholars, departments, or universities are typically separated by only a short path of intermediate ties. Figure 4, which is drawn from a study of coauthorship links among physicists (Newman and Girvan 2004), illustrates this pattern. Note here the commonly observed topology of relatively distinct and moderately dense clusters linked by occasional bridges between clusters.

Figure 4. Coauthorship Network among Physicists



Judging from the available research, academic disciplines also tend to be highly stratified networks with relatively skewed distributions of social connections and strong correlations between the number of social ties maintained by actors (either as individuals or as departments) and subjective perceptions of their prestige. This pattern is illustrated in Figure 5, which is based on a study of the exchange of graduates among Ph.D.-granting departments in sociology (Burris 2004). The density of this network is much higher than the coauthorship network shown in Figure 4, and clustering is much weaker. Average path distances between departments are quite small, but this is mainly because of the extraordinarily high number of links maintained by the most central actors within the network. The five departments shown in blue are among the historically most prestigious in the discipline. These have an average of roughly 120 links apiece to other Ph.D.-granting departments created through the placement or hiring of graduates. Arrayed around them in red are fifteen moderately prestigious departments that have an average of roughly 50 links apiece to other departments in the network. The remaining 75 Ph.D.-granting departments (in yellow) have an average of roughly 18 links apiece. With respect to proximity, the most central departments in the network tend to be both cohesive among themselves (i.e., they recruit Ph.D.'s heavily from one another) and struc-

Figure 5. PhD Exchange Network in Sociology



turally equivalent with respect to the larger network (i.e., they frequently place Ph.D.'s in less prestigious departments but rarely hire from those same departments).

In each of these respects, academic disciplines would appear to be structured in such a way that the acceptance of an innovation is likely to depend crucially on its adoption by the most central actors of the network, but which poses few barriers to diffusion (at least from a network standpoint) once the innovation has been accepted by a critical number of these opinion leaders. Of course, these are only hypotheses based on analogies with the flow of other types of influence, resources, and information within academic networks. It should also be noted that, even among the relatively limited number of disciplines studied in network research, moderate differences in the patterns enumerated above are evident. Only by collecting the additional data needed to study the role of social networks in the diffusion of specific innovations within specific disciplines can we hope to ascertain the validity of these hypotheses and their consistency (or variability) across academic fields.

Collecting the data necessary for a network study of innovation diffusion within higher education would require considerable effort and ingenuity, but is not beyond the realm of feasibility. As the focus of such a study, it would be important to select an educational innovation that is relatively discrete and for which adoption or non-adoption can be unambiguously ascertained at multiple points in time. The most likely candidates would be innovations in curriculum or degree requirements that are formally instituted at either the department or college/university level. Presumably, data on the adoption or non-adoption of such innovations could be acquired through a combination of archival and survey methods. Pedagogical innovations of a more informal nature or that are made at the discretion of individual faculty are likely to be impossible to track with sufficient accuracy unless one is dealing with a very small sample.

The bigger challenge is posed by the need to collect data from which one can construct a model of the network of social connections within the relevant population of actors that is reasonably accurate, even if it is inevitably less than comprehensive. The most feasible strategy here is to seek out archival data, ideally of a sort that is available in machine-readable format. As noted above, previous researchers have mined data on coauthorship ties to model networks of association, influence, and information exchange among individual scholars and, indirectly, among the departments and universities of which they are members. Others have drawn upon archival data on the flow of Ph.D.'s among departments and universities as another way of modeling such networks. Data on the joint participation of departments or universities in common organizations, initiatives, or events might be used for a similar purpose. Where direct data on social ties among actors are lacking, rough proxies for network positions or relations might be employed. Judging from the existing research on academic networks, prestige rankings of academic departments or universities are likely to provide reasonable proxies for centrality within inter-organizational networks. Similarity of prestige rankings might also be used as a rough proxy for structural equivalence within networks. Geographic proximity is likely to be moderately correlated with cohesion within networks. Exclusive reliance on proxies of this sort is not recommended, but they might be useful as supplements to more directly measured indicators of network positions and relations.

Despite the formidable challenges posed by data collection, there is potentially much to be gained from applying the tools and methods of network analysis to innovation diffusion within higher education. Previous research demonstrates the importance of network topology for the process of innovation diffusion. Knowledge of the underlying structure of social networks can be invaluable in the design of strategies to promote the diffusion of innovation. More detailed information on the structure of social networks within particular academic disciplines and the role that those networks play in the diffusion of innovation would be of great use to those interested in educational reform. ❇

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Creating a Plan to Promote Broader Adaptation of Education Innovations

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ABSTRACT

Creating plans that promote broader adaptation of innovative educational practices is an essential part of efforts to improve engineering education. However, the intellectual foundations for developing an adaptation plan are spread across many different research areas and may not have reached the stage where they can adequately guide decisions required in creating such plans. The present paper explores how expanded knowledge bases might support development of action plans to promote broader adaptation of innovative educational practices. Specifically, questions that address development of (1) plans to contact potential adapters, (2) plans to initiate, sustain, and grow support networks, and (3) plans to produce materials that will enhance broad adaptation, are offered.

Introduction

Many different perspectives might be adopted to explore questions of how innovative practices that enhance instructional effectiveness and student learning within undergraduate engineering education start from an individual or small group that originally creates an innovative practice and are adapted by a large number of faculty members across the engineering education community. Some perspectives focus on explanations of how diffusion of innovative practices occurs. Other perspectives emphasize factors than enhance or hinder diffusion of innovative practices. Drawing upon work in decision-based design (Chen, Lewis, & Schmidt, 2000; Hazelrigg, 1998), the current paper chooses the perspective of a small team that has created and tested an innovative practice, found evidence of effectiveness, and seeks to promote wider adaptation. The team proposes to create a plan of action to promote adaptation and wants to base its decisions in creating the plan upon solid intellectual foundations. Other perspectives might be extremely valuable in developing the necessary intellectual foundations, but in this paper, the focus will be on the nature of the intellectual foundations that support decisions related to development of the adaptation plan.

Several considerations motivate selection of the perspective. First, note that the team has not chosen to focus on creating awareness of its work; instead, it has chosen to focus its energy on adaptation of its practice. Greater awareness of their project might promote adaptation, but awareness would be a means, not an end. Broader adaptation is emphasized by funding agencies that support development of innovative practices and the team seeks to address priorities established by the program that helped support initial development of the innovative practice. Second, the team has not chosen to focus its energy on satisfying promotion and/or tenure (P&T) criteria for individual members of the team at their home institutions. Meeting P&T criteria might be a very high priority for individual members and might be another goal that the team has formulated. However, the selected goal is broader adaptation, not tenure and/or promotion. Third, the nature of the innovative practice is fixed. Considerable research has investigated characteristics of an innovation, such as relative advantage, compatibility, complexity, trialability, and observability (Rodgers, 2003). However, the team has created an innovation, so it cannot alter the characteristics of the innovation. Other perspectives might explore selection of innovative practices for student learning and institutional effectiveness that result in practices that will diffuse more easily. With the chosen perspective, explorations of the intellectual foundations that support decisions in development of an adaptation action plan might begin.

To aid in reflection on the nature of intellectual foundations, a list of potential decisions that the team might consider in developing its adaptation action plan will be offered first. The decisions might be broadly grouped in the following categories, but not necessarily in the following order.

- Contact Plan
- Sustaining Network Plan
- Supporting Materials Plan

Contact Plan

In a contact plan, the team must decide between passively promoting broader awareness of its innovative practice and waiting for individuals and/or institutions to contact the team for further interaction and actively contacting selected individuals with details about the innovative practice and seeing if individuals desire further information. The team may also select a combination of the two strategies. The following questions would need to be addressed in the formation of a contact plan:

- What factors should be considered when deciding whether to initiate contact, wait to be contact, or combine the two activities? How might the intellectual foundations support construction of a contact plan and aid analysis of investment of resources in such as plan?
- If the team elects to actively initiate contact, what factors should be considered in deciding whom to contact and how to make contact? What types of individuals might be more prepared to accept the innovative practice? What types of individuals might be more effective in promoting the innovative practice at their institution? This raises questions of differences between innovators and early adopters in Rodgers' model (Rodgers, 2003). Innovators may be more willing to consider adaptation of an innovative practice, but they also tend to be individuals who have less influence in promoting adaptation by other individuals in their organization or community. Early adopters are

more influential in promotion innovations, but initiatives to encourage participation by early adopters may have to be fashioned differently. Additional research in identifying and reaching early adopters would be helpful to construction of the team's strategies. In considering whom to contact, should characteristics of institutions be considered? What types of institutions might be more supportive of the innovation? How would these types of institutions be characterized? This element might consider socio-cultural structures of "receiving" institutions that facilitate or impede the acceptance and institutionalization of an innovation, For example, studies have shown relationships between culture and educational change (Kezar & Eckel, 2002; Merton et al, 2004). However, multiple frameworks have been offered for culture (Schein, 1992; Tierney, 1988; Bergquist, 1992), and further work is necessary to develop culture audits that might identify specific factors that may aid selection of institutions, in terms of their readiness for change.

- If the team elects to begin a plan in which they wait to be contacted, different questions need to be considered. What types of materials might promote/enhance likelihood of contacts in a passive contact plan? The importance of developing materials and events for a range of individuals who are willing to invest different amounts of time and energy in finding out more about a particular innovation has been suggested elsewhere (Froyd, 2001). Different materials and events may be needed to address different audiences, but less work is available to guide choices of events and materials with respect to audiences.
- Does specialized, contextual knowledge play a much larger role in development of a contact plan than general research?

Sustaining Network Plan

The value of networks of relationships in sustaining learning and innovative practice have been demonstrated through a variety of theoretical perspectives including social capital (Maskell, 2000; Etcheverry, Clifton, & Roberts, 2001; The World Ban, 2002; Kilpatrick, Bell, & Falk, 1999), communities of practice (Lave & Wenger, 1991; Wenger, 1998; Wenger, McDermott, & Snyder, 2002), emphasis on community-centered learning (Bransford, Brown, & Cocking, 1999), and faculty learning communities (Cox, 2001; Layne et al., 2002). Although the preceding work emphasizes the value of supportive networks, the team that developed the innovative practice might find little on which to base decisions about how to initiate, nurture, grow, and sustain communities that provide scaffolding for members who choose to study the innovative practice more deeply and possibly adapt it.

There are various types of groups that the team might decide to foster: local user groups, regional networks, and national networks. Each might require different efforts to create and support. The team might seek answers to the following questions:

- What is the knowledge base that improves understanding of how faculty members decide whether to participate in supportive learning communities, user groups, regional networks, or national networks? What factors promote participation? What factors hinder participation? Work exploring faculty participation in learning communities intended to promote greater understanding of the pervasiveness and complexity of gender inequity provides small clues (Covington & Froyd, 2004), but more research is needed.
- What roles might prior knowledge play in decisions regarding participation? Cognitive learning theories have demonstrated the enormous importance of prior knowledge in learning (Bransford, Brown, & Cocking, 1999), and prior knowledge would be expected to be an important factor participation decisions. However, more knowledge of the roles of prior knowledge would be helpful. Further, it would be helpful it the team knew how it might capture information about prior knowledge with minimal expenditures of resources. Sosa, Eppinger, and Rowles (2004) have shown how organizations might benefit from aligning interrelationships among their teams with the interrelationships of the interfaces within complex designs. Similar alignments between structural interrelationships of support networks and interrelationships among prior knowledge of potential network participants may be possible.
- What roles might workshops play in initiating, growing, and sustaining supportive learning networks? Workshops frequently appear in plans to promote broader adaptation of innovative educational practices. Pimmel (2003) has evaluated effectiveness of workshops in promoting innovative educational practices. However, there has been little research on how workshops might support development of networks. More generally, what roles might expertise on innovative educational practices play in the growth of networks?
- What might be learned from the experiences of POGIL (The POGIL Project; Hanson & Wolfskill, 2000), EPICS (EPICS at Purdue University; Oakes & Spencer, 2004) and SENCER (SENCER) in forming and sustaining networks that support innovative educational practices?
- What can be learned from the study of networks through random graph theory (Strogatz, 2001; Barabási & Albert, 1999)? Research in random graph theory has shown the importance of hubs; however, can factors that might characterize a hub early in the evolution of a network be identified?
- What roles might communications technology play in promoting development of networks around innovative educational practices (Sherer, Shea, & Kristensen, 2003; Courter, Freitag, & McEniry, 2004)?

Supporting Materials Plan

Materials including textbooks, assessment and evaluation data, modules, projects, laboratory experiment manuals, and problem sets can reduce the amount of time and energy that potential users must invest in order to adapt an innovative practice. Given that the team might develop a large array of different materials, the team is interested in what types of materials promote adaptation effectively in relation to the effort expended in developing the resources. Hutchinson and Huberman (1994) stress the importance of building relationships between developers and users of the instructional materials. From their synthesis of the literature, they offered the following factors that will affect potential adaptation: accessibility, availability, and adaptability; relevance and compatibility; quality, redundancy of messages; linkages among users; engagement; and sustained interactivity (Hutchinson and Huberman, 1994). For the last factor, they noted that

Overall, the best single predictor of knowledge use and gain is intensity of contact(s) between disseminators and receivers. "The process that succeeds best...involves frequent contact, some face-to-face interaction, and an exchange between dissemination specialists and participants that lasts more than a few months over time (Louis, Dentler, Kell, 1984, p. 17)." Sustained interactivity was also illustrated by the RDU [Research, Development, and Utilization] experience. The reviewers of that experience found that the amount of time that field agents spent with staff at the local schools, both before and after initial implementation, was one of the most important predictors of success in the effort (Louis, et al., 1981). (Hutchinson and Huberman, 1994)

Emphasis on sustained interactivity is consistent with strategies intended to develop sustained support networks.

Development of materials that are focused on an audience that will implement an innovative practice, e.g., textbooks, ignores audiences that are unwilling, at their present level of interest, to invest sufficient time and energy to engage an extended body of material. Consideration might also be given to audiences that will invest limited time and energy to explore an innovative practice (Froyd, 2001). The usefulness of a staged model of adaptation (Froyd, 2001); pre-awareness, awareness, interest, search, decision, and action could be studied. Given the importance of the potential audience in development of materials, the team might also want to consider collaborative development of materials from the beginning. Involving users in materials development is supported by collaborative technologies (Cunningham; Hendricks, 2001). Collaborative materials development raises at least two questions:

- How might the team locate potential users who are willing to invest energy and time in contributing to development of materials?
- How does collaborative materials development interact with strategies for development of sustained support networks?

Conclusions

Although the existing knowledge base on promoting broader adaptation needs to be expanded to address types of questions raised by the hypothetical project team, at least one message echoes throughout: focus on increasing the capabilities of potential adapters to use the innovative practice rather than developing materials that explain and justify the innovative practice. The latter perspective should not be ignored, but sole emphasis on explaining and justifying is unlikely, given the present research, to promote broader adaptation. Broader adaptation depends more significantly on the quality of relationships and the interconnectedness of the participants in support networks than the quality of a single set of materials. More research that addresses effective strategies for initiating, sustaining, and growing supportive networks is needed to allow the hypothetical team to select strategies that will promote broader adaptation while requiring quantities of resources that are likely to be available to the team. ✻

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Network Foundations for the Diffusions of Innovations

James Moody and Erin Leahey

INTRODUCTION

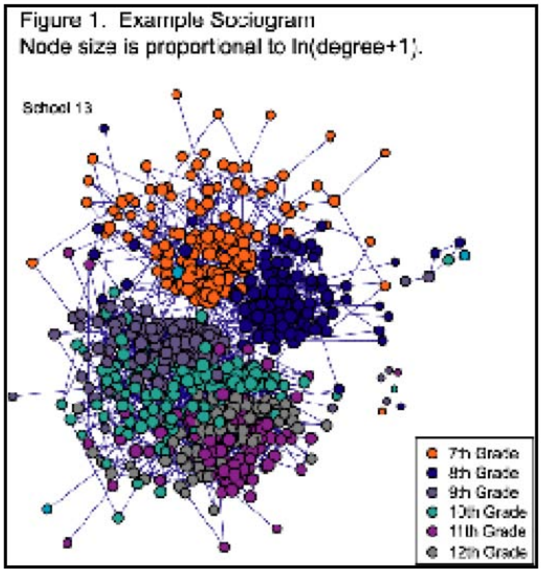
This paper concerns the network foundations for the diffusion of innovations. Our primary concern is howthe pattern of connections among individuals in a departmental or disciplinary network can help facilitate the spread of new curricular developments across that network. We approach this question at multiple levels. We ask how the pattern of ties in a network affects diffusion. We then move on to discuss the types of positions in networks that facilitate diffusion at the individual level and highlight factors that might encourage influence, or inter-personal agreement, between dyads that are connected within a network. The success of an innovation depends both on individuals who are aware of the innovation accepting it, and the process of spreading this acceptance to others. Importantly, research on social networks cannot help determine which individual (or department) is most likely to adopt first, but it can assess how diffusion might be affected depending on the network position of this initial adopter, thereby informing decisions about where to begin efforts to introduce a new curriculum. We take up such issues toward the end of the paper.

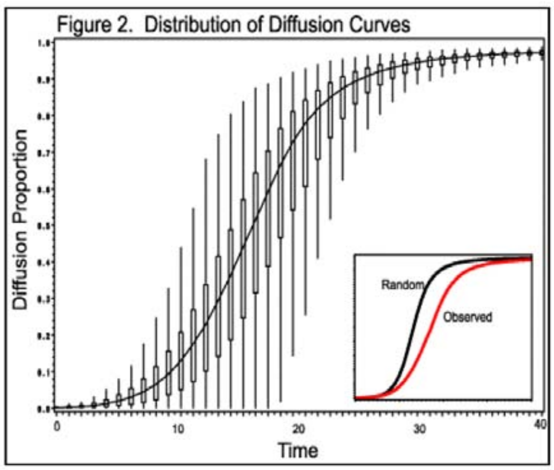
HISTORY

Those interested in the history of social network approaches to diffusion have a rich tradition to draw on. For a general overview, see Valente 1995. Classic works on innovation diffusion include: Coleman, Katz, and Menzel 1966; Crane 1972; Katz, Levin, and Hamilton 1963; Kerkchoff and Back 1968; Morris 1993; Myers 2000; Rogers 1962. Early work focused on describing the diffusion curves and relating network position to adoption. While most work (including ours below) focuses on the diffusion of goods through direct contact, a strong argument can be made for adoption based on similar interests represented by position in network (Burt 1987; Friedkin 1984; Mizruchi 1993). Unlike contagion models, this argument suggests that those with similar patterns of ties have similar interests, similar levels of access to the new practice (e.g., curriculum), and similar motivations for adopting it. How individuals become exposed to the innovation is overlooked; to understand this, we turn to the literature on diffusion through direct contact with others.

GLOBAL NETWORK DIFFUSION PROCESSES

Paths through networks: a simple example. Consider figure 1, which is a graphical representation of school social network, with points (nodes) representing students and lines (ties) representing friendship relations. For now we consider the ties to be symmetrical. Imagine that a new innovation in, say, free music





downloading was discovered by one of the students. We would expect the student to share this information with his or her friends, who would likely pass it on to their friends and so forth. This is the basic diffusion process we are trying to describe with network models: given that a small number of initial adopters communicate an innovation to their contacts, how does the pattern of contacts affect the ultimate diffusion of the innovation?

To answer this question, we assume that everyone has an equal probability of adopting given each opportunity for exposure.[1] If we randomly selected an individual to be the initial adopter and examined the resulting pattern of diffusion, and repeated this process many times, we could capture the overall pattern of diffusion with a set of diffusion curves, where the horizontal axis measures time and the vertical axis the proportion of the population who adopt. Figure 2 shows a summary of just such a simulation applied to the network depicted in Figure 1. The inset shows the mean curve relative to a network with randomly distributed ties (but identical volume). Why is the rate of diffusion slower in the observed network than in the randomone? Why is the curve lower? There are four features of network that affect diffusion rates throughout a network, relative to other networks with a similar contact volume (i.e., number of ties): network distance, clustering, multiple paths, and timing.

Network Distance

The primary requirement for a contagion diffusion model is that non-adopters come into contact with adopters, this means that the network must be connected. In figure 1, the small number of isolated

[1] That is, at each point in time, every "adopter to non-adopter" contact represents an opportunity for the non-adopter to adopt. If a non-adopter has many adopting friends, then he or she will have many more opportunities to adopt. This is a simplifying assumption that removes much of the internal decision making process in order to highlight the effect of network structure.

nodes in the middle-right of the plot cannot be exposed (through the network) to adopters, and thus no network-contagion effects are possible (though they might adopt through some other source). Given simple connectivity, the probability that *i* will pass the innovation to *j* is typically less than 1. As such, the probability of passing an innovation down any single long chain of contacts (iց jց kց l) decreases as a power function of the length of the path. Thus, all else equal, *innovations diffuse over a network in inverse relation to the average distance between nodes*.

Network Clustering
If diffusion were certain, then the most efficient network would be one where every linkfrom an adopter leads to a non-adopter, which would be represented by a spanning tree. In real world networks, relations tend to clump around substantive features (Feld 1981), especially geographic bounds (Leahey& Cabrera 2006). These clusters tend to make diffusion patterns "lumpy," as diffusion will be facilitated within clusters, but then get stuck there waiting to move out through a local bridge: a person or node that serves to connect two clusters. If we focus solely on the recursion feature of clustering (the extent to which ties coming fromnode k reconnect to the people k received the innovation from), then both theory and simulation suggest that *as network clustering increases, diffusion rates decrease* (Pool and Kochen 1978; Skvoretz 1985; Watts and Strogatz 1998).

Multiple Paths
While path length decreases the likelihood of transmission, multiple paths provide alternative routes and thus increase the probability of transmission. Thus while each step in a chain represents an "and" condition for the probability, each alternative route provides an "or" condition. Figure 3 illustrates this relation with the diffusion of a low-probability good over long distances. Thus, all else equal, the more paths connecting two nodes, the higher the likelihood of diffusion transmission.

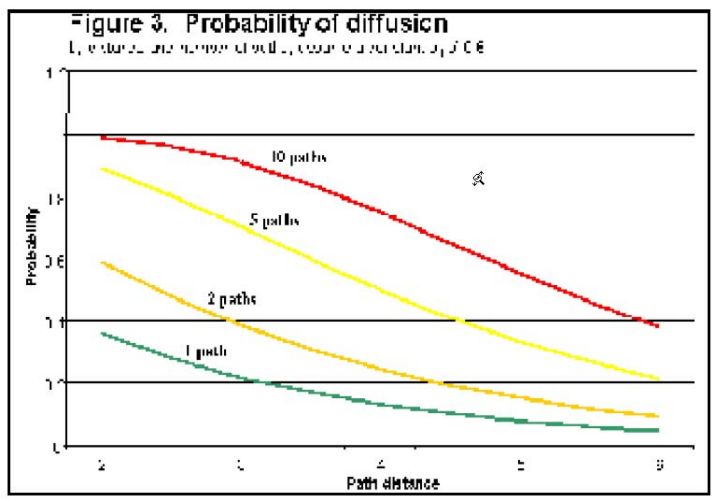


Figure 3. Probability of diffusion

Timing
Finally, the results from above all assume a network where the edges are constant and diffusion occurs across an otherwise stable network. In reality, any real-world social network will be continually changing, and changes in the edges affect the likelihood that an innovation can pass from one person to another. In essence, if node *j* leaves the network before mode *i* adopts the innovation, then *j* cannot learn of the innovation from i. Such timing issues can have a dramatic effect on

opportunities for contact and thus influence (Moody 2000). The lowest possible diffusion occurs when relations are of short duration and nodes have only one relation at a time, creating short time-ordered paths through the network. In contrast, when relations overlap significantly in time (they are temporally concurrent), information can potentially travel through all edges, magnifying the likelihood of diffusion (Morris and Kretzschmar 1997).

POSITIONS IN NETWORKS: STARS & STRUCTURAL HOLES

The features described above relate to differences across networks. A glance at figure 2, however, reveals significant variation within networks. If we were to contrast the fastest diffusion curve (the top of the box-plot tails) with the slowest (the bottomtails), time to reaching 50%of the population is nearly double in the slowest diffusions. This internal variation rests on the position of the initial adopters. When initial adopters are central players in star-shaped networks and/or "brokers who carry information across the social boundaries between groups" (Burt 1999, p37) they are likely to be opinion leaders whose ideas spread easily, quickly, and widely.

If the initial adopter is a central node in a star-shaped network, then their contacts' contacts' reach the entire network quickly and widespread diffusion is likely. This is the individual level correlate of the distance feature described above. Since central nodes are closer to everyone, the average path distance between adopters and non-adopters is comparatively low. *All else equal, diffusion will be faster when initial adopters are central to the network* (Friedkin and Johnsen 1997; Valente and Davis 1999).

If the initial adopter serves as a bridge that spans clusters within the network, then the rate of diffusion will also increase. This individual position correlate of clustering rests on Burt's notion of structural holes (Burt 1992; Burt 1999; Burt 2005): essentially the gaps between clusters. A node bridges a structural hole if their contacts are not in contact with each other. If ideas run a risk of becoming sequestered in clusters, then promoting diffusion rests heavily on individuals who connect otherwise disconnected people. When clustering is evident, individuals serving as bridges are critical to spreading an innovation between clusters.

FACILITATING NETWORK DIFFUSION

The above summary of work on the structural features of diffusion in networks suggests a few broad features. Diffusion will be most rapid and complete when short average distances, relatively low clustering, multiple paths and comparably stable relations characterize the networks. Within such networks, diffusion will proceed most rapidly if central actors can be convinced to initially adopt and if cluster-brokers can be convinced to share the information with others. How do we build such networks?

The simplest heuristic for building rapid diffusion networks is random mixing, particularly given the comparative search costs for attempting to engineer such networks. That is, recent work (Watts and Strogatz 1998) shows that a relatively small number of random connections between otherwise disconnected clusters in networks can rapidly decrease average distance and increase the number of unique paths (Moody and White 2003). As such, perhaps a very simple yet structurally effective curricular development model will focus attention on creating new links between individuals or groups that are likely to adopt and the wider body of engineering instructors. While random mixing has the advantage of making the most with the least effort, *any mixing strategy that does not simply reinforce current clustering patterns* will rewire a network to facilitate diffusion.

Some consideration might also be given to the type of network tie that could best foster discussion and adoption of an innovative curriculum. One could imagine, for example, some sort of workshop or short-term exchange program that brings innovators into contact with other faculty members. But would this be enough? Investigations into the kinds of relationships that best foster discussion of pedagogy and related implementation strategies would be useful in this regard. Previous research suggests that weak, advice-seeking relationships tend to foster attitudinal agreement, whereas longer, stronger, close working relationships tend to foster behavioral agreement, or shared practices, between individuals (Leahey and Cabrera 2006).

We note that a variety of other features can influence diffusion of an innovation, regardless of network structure and relationship type, and we assume such considerations will be taken up by other panels in this workshop. For example, previous researchers have found that the rationality (Strang and Soule 1998), compatability, and portability (Abbott 1999) of an innovative practice are positively related to diffusion, and complexity (Rogers 1962) is negatively related to diffusion. How an innovation is presented, and the means by which it is encouraged may also affect diffusion rates. Institutional theorists DiMaggio and Powell (1983) stress the importance of both mimetic processes (when people simply copy others) and coercive isomorphic pressures,which can emanate from either formal policies or informal pressures or invitations to adopt the innovation.

Edge Effects of Status Distinctions

Finally, we want to make one clear point of caution. The summary above works on the assumption of bi-directional flow in the networks across edges. However, academic disciplines and departments are formally structured around status, with lower-prestige departments and assistant professors in a subordinate position relative to prestigious departments and full professors. As such, it is likely that innovation flows more readily fromtop departments to less prestigious departments (Leahey 2005) and from senior faculty to junior faculty or faculty-intraining (Leahey, *in press*). That is, an otherwise simple “contact” tie between a full professor and a new assistant professor is really likely to be a *directed* tie fromthe full to the assistant, and diffusion is likely to follow in that direction. This suggests that there may be greater diffusion returns by convincing senior faculty (especially those in top departments) to adopt the innovation initially. There is, of course, an obvious trade-off here. On the one hand, senior faculty have well-developed courses and little incentive to change them. On the other hand, they may have the least to loose if the implementation of a new curriculum represents time lost to other activity favored by promotion and tenure committees. Our goal here is to highlight this asymmetry in network relations between individuals and departments and suggest how it informs efforts to implement a new curriculum widely within a discipline. Exactly how important players (central nodes, bridges, prestigious departments, and full professors) are convinced to adopt the new curriculum is an important subject ideally addressed by other panels in this workshop. ❇

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Pedagogical Change in Schools as Diffusion of Innovation: Some Sociological Guidelines for Research

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INTRODUCTION

Everett Rogers, in his widely cited book, defines diffusion as the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003). Several aspects of this definition are noteworthy and can productively guide research into whether and how decision-makers within schools of engineering will be receptive to pedagogical reforms. First, the definition does not assume adoption (implementation) by even one member of the social system in question. As soon as information about the innovation has reached just one person (or decision-making entity), a diffusion process can be said to have begun. Information may eventually reach all members of the social system, or only some. The spreading of that information — plus other accompanying forces, such as perceived social pressure and the consensus or harmony within the broader institutional environment (Frank, Zhao, & Borman, 2004; Rowan, 1982; Wejnert, 2002) — may lead all, some, or none of the system's actors to adopt the innovation.

Secondly, the words *process* and *time* are key to Rogers's conceptualization (and to the most satisfying and informative empirical research on the topic of innovation and organizational change). The often-observed S-shaped cumulative adoption curve can only be discerned if one studies actions over time (Mahajan & Peterson, 1985; Rogers, 2003). At least as importantly, an understanding of how various potential influences (e.g., types of information, types of change agents, patterns of communication among colleagues) have differential effects as time elapses will only be gained if diffusion is recognized and analyzed as a multifaceted, unfolding process.

Consistent with Rogers's conceptualization, Strang and Soule identify diffusion at the most general level as "the spread of something new within a social system" (Strang and Soule, 1998, p.266). Those authors describe the flow or movement of a behavior, strategy, belief, technology, or structure from a source to a potential adopter (or adopters), typically via communication and influence. Strang and Soule make a strong case for not simply equating diffusion with increased incidence; they urge us not to treat diffusion as simply an observed outcome of "use versus non-use."

In order to acknowledge diffusion of innovation as a process (as opposed to simply an outcome observed if and when adoption of a practice occurs), I organize my discussion around nine distinct aspects of the spread of something new within a social system. For the purposes of this paper, the something new should be assumed to be a set of pedagogical practices and accompanying philosophies that some change agents would like to see implemented within post-secondary schools of engineering. Depending on the context or particular example under discussion, the members of a social system might best be imagined as one or another of the following:

- All faculty and instructors employed by one school of engineering,
- All faculty and instructors nested within a set of schools of engineering,
- All departments nested within one or more schools of engineering, or
- A set of schools of engineering.

Listing these four different operationalizations of the members of a social system serves to remind us that innovations are marketed to, and sometimes implemented by, actors and decision-making bodies at various levels of aggregation.

As I briefly discuss each of the nine aspects of diffusion, I give particular attention to (1) findings and perspectives coming from the sociology of education subfield, (2) observations or principles I draw from my involvement with middle school and high school educational reform, and (3) sociological studies of diffusion processes more generally.

NINE OUTCOMES OF INTEREST

Table 1 presents the nine areas of attention, including suggestions about appropriate units of analysis (which may change depending on the area under consideration) and interesting or important questions that may be asked.

1. Timing of awareness.

If one is going to stay true to the conceptualizations of Rogers (2003) and Strang and Soule (1998) — authors who are very thoughtful and thorough in their treatment of diffusion of innovation — then one will begin by studying the spread of awareness or information before studying changes in individuals' behaviors (e.g., adoption or rejection). It is illuminating to document, describe, and/or formally model:

- The proportion of actors within the social system who have a working understanding of the proposed reform by *Time t*.
- The paths by which information comes to *Person i* (e.g., directly from an external change agent, from an internal colleague to whom i is only weakly connected, or from an internal colleague with whom i is closely connected).
- Various factors that may predict whether *Person i* will have a working understanding of the reform by *Time t* (examples listed in Table 1).

2. Adoption rates and interrelationships of multiple innovations.

In conjunction with studying the diffusion of information and the spread of awareness, clearly we will be interested in studying actual behavioral change — the adoption of an innovation. As we pursue this task, it is important to consider the existence of multiple innovations, and the interrelationships that may exist among them.

Researchers who study the successes and failures of educational reform initiatives quickly realize that they do not have the luxury of comparing intervention sites with pure control sites that are receiving "the absence of any intervention or treatment." Furthermore, educational organizations are constantly subject to (or generative of) multiple proposed reforms and paths to improvement. In light of these facts, the diffusion of, or resistance to, any one initiative should be analyzed and understood within the context of other new ideas or reforms that are circulating through the social system simultaneously.

Rogers (2003) directs our attention to technology clusters, which consist of multiple distinguishable elements of a technology (or innovation, more generally) that are perceived as being closely interrelated. It may be the case that change agents will be most successful in promoting a given innovation if it is "bundled" or "packaged" with other closely related innovations. For example, one can imagine that engineering professors who teach freshmen would be most enthusiastic about expanding the opportunities for group projects and hands-on experimentation if they knew that senior capstone projects featuring these same skills and activity structures were being promoted within their schools.

Rogers advises that we avoid the dubious assumption that the trajectory of a given innovation (i.e., its spread or stalling) is independent from other innovations. Furthermore, as we think about the interdependencies of multiple innovations, it becomes clear that mutually reinforcing (complementary) bundles of innovations are not the only interrelationships that we need to consider. Mahajan and Peterson (1978, 1985) identify four categories of innovation interrelationships that can affect the adoption rate as well as the cumulative number of adoptions of an innovation. These four are:

- *Independence*, whereby innovations are independent of each other in a functional sense, but adoption of one may enhance adoption of others;
- *Complementarity*, whereby increased adoptions of one innovation result in increased adoptions of other innovations (e.g., washing machines and dryers);
- *Contingency*, whereby adoption of one innovation (e.g., computer software) is conditional on adoption of other innovations (e.g., computer hardware); and
- *Substitution*, whereby increased adoption of one innovation results in decreased adoption of other innovations (e.g., Coke and Pepsi).

Extensions and refinements of the standard (quantitative, parameterized) diffusion models have been developed to incorporate these possible interrelationships. Similarly, extensions of the standard models have been made to recognize that outcomes of the diffusion processes for individual actors (i.e., one's receipt of information or one's decision about adoption or resistance) might not be simply binary.

Cynthia Coburn is one sociologist of education who has been thoughtful about moving beyond a binary conceptualization. Her study of teachers' reactions to competing ideas about reading instruction in California schools between

1983 and 1999 is informative (Coburn, 2004). This study is mostly qualitative, but the typology Coburn develops for teachers' possible responses to institutional pressures to alter their instructional styles could certainly be incorporated into quantitative modeling of diffusion. Coburn moves beyond a simple dichotomy of acceptance versus rejection. She develops the following range of reactions a teacher might have to proposed reforms:

- *Accommodation*. Engaging the reforms in ways that represent fundamental revision of one's pedagogical views and practices.
- *Assimilation*. Making an attempt to accept and implement the reforms, but only after transforming the tenets or interpretations of them to fit one's preexisting pedagogical beliefs and ways of doing things. When assimilation occurs, an actor will often come to understand the reform, its goals, and practices, in ways that differ substantially from what was intended by its developers or the change agents.
- *Parallel structures*. Taking the reform seriously and adopting its practices but only some of the time or in some contexts, thereby leaving intact and unchanged other (possibly conflicting or antithetical) practices at other times and in other contexts.
- *Decoupling/symbolic response*. Giving lip service, or making superficial changes to give the appearance of compliance, without changing previous practices in any serious way.
- *Rejection*. Outright refusal to engage or adopt the reform; outright dismissal of a mandate.

3. Innovativeness of individuals or organizations.

We are likely to gain a more complete understanding of individuals' or organizations' receptivity to a particular innovation if we consider the actors' past experiences with other innovations and generalized openness to change. Table 1 offers questions to be asked along these lines, and a guiding principle derived from prior research.

4. Opinion leadership.

Early innovators and opinion leaders are often (perhaps usually) two distinct subgroups within a social system. More than forty years ago, Carlson (1965) studied the diffusion of modern math in the public schools of Allegheny County, Pennsylvania, as an educational innovation. He focused on the decisions and sociometric positions of thirty-eight school superintendents. These superintendents were key decision-makers whose awareness and enthusiasm were necessary if principles of modern math (e.g., newly conceptualized textbooks featuring set theory, Venn diagrams, and probability; audiovisual aides; and summer institutes to retrain school teachers) were to become established in the schools they oversaw.

Carlson demonstrated how the earliest innovator among these thirty-eight was a sociometric isolate with no interpersonal network connections with any of the other superintendents. The fact that this early innovator embraced the modern math approach in 1958 apparently did little or nothing to encourage other superintendents and school districts to do the same. Only when the members of a clique of centrally connected and influential opinion leaders embraced modern math a year or two later (after apparently being prompted by other channels of communication and encouragement) did a rapid sequence of adoptions occur — culminating in all thirty-eight superintendents embracing modern math by 1963.

One general lesson suggested by Allegheny County's somewhat-distant past is that change agents would be wise to identify key opinion leaders in a social system and to focus dissemination of information and initial training opportunities on these individuals. This may be easier said than done, however, as key opinion leaders generally hold that designation precisely because they are very much in conformity with the norms and standard operating procedures of their organizations. If the change agents who are urging reforms in the pedagogy of engineering schools are perceived as (A) outsiders to the social system and (B) advocates of something that is antithetical to the norms and priorities of the social system then overtures to key opinion leaders within a school might fall onto unreceptive ears. The most productive research (and, for that matter, strategizing by change agents) will direct attention to how successfully external change agents can minimize the extent to which they are perceived as (A) and (B), above.

5. Structure and content of diffusion networks.

See Table 1 for summarized points.

6. Adoption rates contingent on organizational traits.

Strang and Soule (1998) state that the most common design in diffusion research has examined variability in the timing of adoption of a single practice across a single community (a relationally and culturally connected population, to use their phrasing). They assert that our understanding of diffusion processes — and the factors accelerating them or stalling them — will grow more quickly and comprehensively if we consider (a) the spread of a given practice within multiple communities or (b) the spread of different practices within a single community. Clearly the most ambitious comparative effort would entail multiple practices studied within multiple communities. As one considers pedagogical change in post-secondary engineering education, it is important to consider what defines a fairly closed community of practice. If one were to study ten schools of engineering as they encountered a proposed pedagogical change, could we justify calling these ten distinct communities? Or is the reality that collegial relations, channels of communication and influence, and cultural understandings of "how we do business" span multiple institutions such that no one institution should be called a (relatively) bounded community of practice?

If we can agree on where the true (empirically existing) boundaries of community or social system lie, we can then engage in the exciting exercise of conceptualizing analyses of individuals nested within communities of practice as they receive or fail to receive information, and subsequently make decisions about embracing or rejecting pedagogical reforms.

7. Use of communication channels.
Information about an innovation will generally reach different potential adopters from different sources or via different network paths. Furthermore, the most active and effective disseminators of information will often change over time (e.g., from external change agents to internal converts or, alternatively, obstructionists). See Table 1 for additional summarized points.

8. Consequences of an innovation.
In addition to studying the spread of information and the actual adoption or rejection of an innovation, we will probably want to study potential effects on various outcomes or subsequent processes. Table 1 lists some outcomes of interest for the particular case of pedagogical change in post-secondary schools.

9. Desistence rates.
Desistence rates and processes are an area of inquiry that can be considered secondary — most likely a topic for later consideration. The idea is that we should not be satisfied by understanding just the timing of, and processes driving, (1) actors' initial receipt of information (if any is received) and (2) actors' initial adoption an innovation (if this occurs). If learning about an innovation, and adopting that innovation, can be conceptualized as two potential "birth" processes, then one might want to study desistence of the innovation as a "death" process.

Researchers likely will develop event-history models of the likelihood of adopting the innovation by *time t* for those who had not adopted it by *time t-1*. It would then be informative to also develop models of the likelihood of ceasing to use the innovation by *time t'* among those who had begun using it at some earlier time and had not yet abandoned it by *t-1'*. It seems likely that the rate of abandonment among previous adopters will affect the rate of new adoption among potential adopters. It also seems likely that abandonment processes would be characterized by points of rapid acceleration, probably triggered by the actions of an organization's key opinion leaders, just as adoption processes are generally characterized by the S-shaped curve with a point of rapid acceleration as the so-called *early adopters* inspire the so-called *early majority*.

CONCLUDING COMMENTS

I am writing this final section after having attended the ASA/CASEE workshop. The workshop was a valuable opportunity for engineers and sociologists to talk about the research interests and perspectives each group brings to the study of innovation diffusion, and also to talk about the sorts of curriculum and instruction that can be imagined for post-secondary education.

The workshop confirmed for me the importance of heeding the caution voiced by Rogers (2003) and others to guard against the pro-innovation bias. I certainly do not object to educational and professional leaders conceptualizing pedagogical reforms that might benefit post-secondary students and the professions into which they are entering. And I do not object to change agents actively strategizing about how to increase the speed and/or fidelity with which proposed reforms are, first, communicated and, secondly, adopted. I do not object to using past and future research as a resource for advising change agents.

We should, though, strive to give attention to the false-starts and failed attempts at widespread diffusion just as energetically as we study the processes that take off and get sustained. And, if we are to be good sociologists, as we attempt to study diffusion processes we will need to try to get inside the hearts and minds of the potential adopters. We will need to understand the pressures, incentives, perceptions of mission, and perceptions of professional identity that guide their actions. We cannot let ourselves jump to the conclusion that individuals who are not receptive to a reform — even in the face of detailed information about it — are naive or misguided. When we find individuals who are not receptive to a reform, I think we will generally find all or some of the following accompanying that situation:

- Change agents who have not invested enough time in, or developed effective strategies for, the interpretative work and cultural framing of the reform (i.e., convincing the potential adopters — one hopes in a very genuine way — that the reform is not inconsistent with their goals and worldviews).
- Potential adopters who simply have not received organized or thorough information about the reforms.
- Potential adopters who have considered the reform but have concluded that it is not consistent with their goals or worldview.

At the ASA/CASEE workshop, we made valuable first steps toward defining particular innovations that have been developed (or are currently being developed) in engineering education. The working group of three engineers and three sociologists of which I was a member discussed various innovations that have been attempted (or might be attempted) in the realm of teaching and learning (particular task and reward structures, or methods of instruction). We also discussed innovations that have occurred in the curricular or organizational realms (the sorts of courses offered and/or required; new types of departments or interdisciplinary centers that have been established). Our working group began to conceptualize research designs to investigate innovation diffusion either from archival sources or via prospective studies involving original data collection. We discussed formal quantitative models (and the data structures needed to estimate them) that can be utilized in studying diffusion of innovation. Some of these modeling strategies are used at the aggregate level (considering proportions of potential adopters who have tried an innovation by a given time). Additionally, to study the actions or situations of individual potential adopters, there are available a variety of event-history or hazards formulations (Strang & Tuma, 1993; Strang, 1995) and models that incorporate sociometric measures and nested data structures (e.g., Frank, Zhao, & Borman, 2004). ❇

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**Table 1. Nine Areas of Attention for Diffusion Research:
Guided by Rogers's Table 2.2 (Rogers, 2003, pp.96-98).**

DEPENDENT VARIABLE	APPROPRIATE UNITS OF ANALYSIS	INTERESTING/IMPORTANT QUESTIONS TO BE ASKED
1. Timing of knowing about an innovation by members of a social system	Members of a social system (usually individual people)	• What do we learn if we keep awareness of the practice analytically distinct from use of the practice? (Short answer: Potentially very much.) • What predicts Person i having a working understanding of the practice by Time t? – Type of institution of employment (by Carnegie classification or other criteria)? – Type of institution attended for graduate school? – Years since degree completion? – Number and type of professional conferences attended in past five years? – Frequency and content of communication with others inside and beyond one's current institution?
2. Rate of adoption of different innovations in a social system	Innovations	• As we track multiple innovations within one social system, do we see evidence that pairs or bundles of these innovations are independent, complementary, contingent, or substitutes? • How much information about each innovation has reached the potential adopters by Time t? • Has any such information come directly from change agents external to a potential adopter's institution, or has it been communicated by/through others within a potential adopter's institution? • How much normative or regulative pressure exists to consider each innovation? • How complex do potential adopters perceive each innovation to be? • How congruent with, or divergent from, preexisting worldviews and practices do potential adopters consider each innovation to be? • What sort of cultural framing, interpretative work, or "sales work" has been done by change agents or key opinion leaders around each innovation? • What do we learn if we expand our conceptualization from a binary "adoption or not" to (1) a scale measuring intensity of use or (2) a typology such as (a) rejection, (b) decoupling/symbolic response, (c) parallel structures, (d) assimilation, and (e) accommodation? (Short answer: Potentially very much.)

Table 1. Nine Areas of Attention for Diffusion Research: Guided by Rogers's Table 2.2 (Rogers, 2003, pp.96-98) (continued)

DEPENDENT VARIABLE	APPROPRIATE UNITS OF ANALYSIS	INTERESTING/IMPORTANT QUESTIONS TO BE ASKED
3. Innovativeness of members of a social system	Members of a social system (may be individual people or departments within a university or universities within a population of universities)	• Do past histories of experimentation and openness to change suggest that some people or institutions within the population have a high "baseline" willingness to innovate while others have a low "baseline" willingness to innovate? • Past research suggests that the most innovative members of a system are very often perceived as deviant from the social system and are accorded a status of low credibility by the average members of the system. Is this generalization upheld in the case of pedagogical innovativeness within and among engineering schools?
4. Strength of opinion leadership	Members of a social system (usually individual people)	• Who are the opinion leaders in a given institution? (Research and theory tell us that opinion leadership is an informal position that is earned or established through technical competence, social accessibility, and conformity to the system's norms. It does not necessarily reside – perhaps resides only very infrequently – with those who are official or formal leaders.) • When it is discovered which individuals function as opinion leaders, it is then interesting to ask whether they have been recruited by external change agents or institutional administrators (formal leaders) as internal change agents. There are reasons to expect the success of such recruitment/co-opting to be variable or conditional.
5. Diffusion networks	Dyadic network ties connecting pairs of individuals (or organizations) in a system, but also structural locations (as related to structural equivalence)	• Within the social system(s) under study, what is the network structure of affiliations, connections, and/or structural equivalence? • See papers by Burris, and by Moody and Leahey, in this volume for further discussion.
6. Rate of adoption of innovations in different institutions or organizations	Ideally, a nested structure of individuals within institutions or organizations	• Each school of engineering, or department within a school, is likely to have a unique combination of professional norms, reward and incentive systems, concentration of opinion leadership, relationships with change agents, and network attributes (structure and content of flows of information and influence). How do these attributes affect the rate of adoption of an innovation?