AC 2007-220: EXPERIENCES AND EXPECTATIONS OF DOCTORAL INSTITUTION FACULTY COLLABORATING ACROSS DISCIPLINES

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Experiences and Expectations of Doctoral Institution Faculty Collaborating Across Disciplines

Abstract—Engineer-social scientist collaborations are an important strategy for advancing engineering education research. To understand the nature of disciplinary differences that might complicate cross-disciplinary collaborations, a survey of 200 NSF-funded faculty from Carnegie doctoral institutions was conducted. Faculty rated and described their attitudes and experiences with research and collaboration, which the literature predicts would vary by disciplinary background. However, few statistically significant differences were found between science/engineering faculty and social science/humanities faculty. The entire sample reported a strong perception that their institutions (61% "encourages it quite a bit") and other faculty at their institutions (43% "very open to it") are supportive of cross-disciplinary collaboration. Most respondents have located collaborators via prior work interactions like committees (89% have done this), but many are also willing to ask other colleagues for recommendations (49% have done this). This paper also reports on the wide range of difficulties experienced collaborating and participants' expectations for the process of collaboration. These results are discussed in the context of existing theories of disciplinary differences, and recommendations for fostering cross-disciplinary collaboration are offered.

I. Introduction and Literature Review

Interdisciplinary research is increasingly cited as an important research approach[1-4]. Within the traditional higher education system organized into disciplinary departments, interdisciplinary work often means collaboration among individuals representing multiple disciplines. Though recent theories (e.g., Communities of Practice[5]) advocate transcending disciplinary boundaries, the actual processes and challenges of cross-disciplinary collaboration remain largely unaddressed by these theoretical orientations. This paper argues that greater awareness of the factors that support and hinder productive collaboration can facilitate more widespread cross-disciplinary collaboration.

A number of related theories might serve to explain the difficulties researchers encounter when attempting cross-disciplinary collaboration. Sociological theories that emerged during the 1970s describe physical sciences and engineering as fields with high levels of consensus with respect to terminology, methods and important questions, in contrast with social sciences and humanities disciplines which feature less consensus[6]. A wide range of differences between these broad categories of disciplines has subsequently been explained using disciplinary consensus as the independent variable, including: publication length[7], numbers of coauthors[8], and journal rejection rates[9]. Some of this work has been extended to claim that collaboration in fields with a high degree of consensus is enabled by these standardized methods and terminologies[10]. As a result, collaboration—measured by multi-author publications—occurs more frequently in these technical fields[8, 11, 12]. However, the work has been criticized in the interdisciplinary research literature as being too separate and lacking in integration to be truly interdisciplinary[13, 14]. Applied to cross-disciplinary collaboration, these findings raise a number of questions about disciplinary styles of collaboration, which disciplines collaborate "better," and whether different styles can be linked to the challenges of cross-disciplinary collaboration.

The purpose of this survey research was to better understand cross-disciplinary collaboration across a wide range of disciplines with respect to disciplinary differences, common strategies, and reported difficulties. The research questions addressed are:

1. What, if any, are the correlations between disciplinary background and expectations for collaboration?
2. What strategies do successful researchers employ in cross-disciplinary collaboration?
3. What difficulties do successful researchers report from their experiences in cross-disciplinary collaboration?
4. What recommendations can be made to help facilitate more widespread cross-disciplinary research collaboration among faculty?

The study focuses on National Science Foundation-funded faculty at Carnegie doctoral institutions as a sample with a high level of credibility, representative of a wide distribution of disciplines and institutions. The participants represent physical and mathematical sciences, engineering, social sciences and some humanities.

II. Method

A. Sample

Survey participants were selected from among primary investigators listed in the public awards database on the National Science Foundation's web site (www.nsf.gov/awardsearch) under one particular directorate (unnamed to protect confidentiality) that funds a variety of projects in STEM education settings. All PIs currently funded under this directorate who were faculty or university-level administrators at Carnegie Doctoral Intensive or Doctoral Extensive institutions were included in the pool. The result was a systematic sample of experienced, successful research faculty distributed across a range of technical and social science disciplines who are likely to have collaborated across disciplines for NSF projects. When contacted for the survey, participants were told only that they were selected using the NSF awards database, and were instructed to answer the questions based on their general research experience rather than just their NSF-funded work.

The sample comprised 347 faculty and administrators from 144 different U.S. institutions. Only 15% of the potential participants were from Doctoral Intensive institutions; the rest were from Doctoral Extensive institutions. Ninety-seven percent of the 347 subjects in the sample could be contacted with a valid email or regular mail address. Ultimately, 202 responses were collected, for a return rate of 60%. Among respondents who entered the incentive drawing, 18% were from Doctoral Intensive institutions.

B. Data Collection

The survey included 16 multi-part questions related to institutional support and participant demographics, attitudes, and experiences related to research and collaboration. Many of the items were developed from participant responses in a prior interview study by the author[15]. The survey was posted online, and potential participants were emailed the link. As an incentive, an Apple iPod was raffled off. Raffle entries were collected via email, independently of the survey data, to preserve confidentiality. Participants not entering the raffle were sent multiple email reminders. To increase the response rate, a paper version of the survey was mailed to participants who had not yet entered the raffle. Several more responses were obtained using this strategy.

C. Analysis

This conference paper reports descriptive statistics and in a few cases preliminary analysis of correlations between response items. Microsoft Excel was used to generate percentages. SPSS statistical software was used for other analyses, including chi square, independent samples t-tests and linear regression.

III. Results

A. Demographics of Respondents

A range of disciplines was sought to uncover collaboration differences which correlate to disciplinary training. Fifty-four percent of respondents (n=106) listed a technical engineering, science or math discipline including chemistry, physics, other physical sciences, biology, engineering, mathematics, and computer science. Twenty-seven percent of respondents (n=53) listed a social science or humanities discipline including education disciplines, psychology, cognitive sciences, economics, philosophy, and science and technology studies. Another 20% (n=39) listed STEM education disciplines like math education, science education, physics education, and engineering education. This survey oversamples technical disciplines; nationally, technical faculty account for 24% of all faculty, while social science, education, and humanities faculty are 29%[16].

Respondents ranged in rank from assistant professor to university-level administrator. Fourteen percent held positions of department head or higher level administrator (n=28); 40% were full professors (n=80); 31% were associate professors (n=61); 11% listed assistant or untenured professor (n=11%); and 5% were non-tenure track research scientists or instructors (n=10). There were slight differences in representation within the disciplinary categories. Full professors were 66% of all technical scientists, but only 54% of respondents overall. Social scientists were overrepresented (29-36% vs. 27% overall) at levels below full professor. STEM education disciplines (e.g. engineering education) were distributed evenly throughout all the levels.

Women are represented in all categories, but at higher levels among administrators, untenured faculty, and social science/humanities participants. Overall, the respondents were 37% female (n=74) and 62% male (n=124). Nationally, women accounted for 34% of full-time faculty at doctoral institutions in 2005-06[17]. Among untenured faculty respondents, women range from 44-57% across the disciplinary categories. At the full professor level, they account for only 24% of respondents, but are 39% of administrative respondents. Nationally, 26% of tenured faculty and 41% of tenure track faculty at doctoral institutions are women[17]. Women also account for 26% of technical science respondents, 35% of STEM education respondents and 40% of social science/humanities respondents, as compared to 22% of technical faculty and 48% of humanities, social science and education faculty nationally[16].

B. Institutional Setting for Collaboration

To provide context for their other responses, participants were asked about their perceptions of their institutional setting for cross-disciplinary collaboration. Two separate items rated administration’s support and faculty openness to interdisciplinary collaboration. The results are summarized in Table 1. The results were overwhelmingly positive, with no more than 11% responding neutrally or negatively to each question. Although the sample was selected for a high probability of cross-disciplinary collaboration experience, not all respondents had collaborated with other disciplines.

Table 1. Administration and Faculty Attitudes toward Collaboration.

What is the attitude of your institution's administration toward interdisciplinary research collaboration?			**What is the attitude of other faculty at your institution toward interdisciplinary research collaboration? (no answer n=1)**		
Encourages it quite a bit	61%	n=122	Very open to it	43%	n=86
Encourages it somewhat	31%	62	Somewhat open to it	46%	92
Neutral opinion	6%	12	Neutral opinion	4%	8
Discourages it somewhat	2%	3	Somewhat resistant to it	6%	11
Discourages it quite a bit	0%	0	Very resistant to it	1%	1

One of the Likert-scale items later in the survey dealt with satisfaction: "I am satisfied with my current and past interdisciplinary research collaborations." An attempt was made to model satisfaction using linear regression. A statistically significant model (p value of .000) was developed with an R-square value of 0.134, meaning that 13% of the variance in satisfaction is explained. Although 6 items were included in the model, only one, institutional support, was significant (p value of .000). There were no other correlations between administrative or faculty attitudes toward collaboration and any of the other survey items, including demographics.

Just below the questions on administrative and faculty support for interdisciplinary efforts, there was an open response item for participants to qualify their responses. Seventeen of these responses were positive, either citing specific on-campus initiatives or restating that the institution was very supportive of interdisciplinary efforts in general. However, there were nearly twice as many negative comments stating that while faculty and administrators pay lip service to interdisciplinary research, the values, understanding, policies and infrastructure do not exist to truly support it. One respondent explained, "[Administrators] and [faculty] at all levels talk about this a lot (say it is a high priority) but have not developed the infrastructure and reward system to [facilitate] true collaborative interdisciplinary work." (Brackets are used to indicate spelling corrections.) The most often specifically cited policies that inhibit interdisciplinary work were budget-related (returned overhead, proposal writing) or promotion and tenure-related (credit for bringing in external funding and single vs. multi-author publications). Multiple participants explained that administration is "more encouraging to interdisciplinary research collaboration among tenured faculty" than untenured faculty and that funding agencies often drive multidisciplinary collaborations.

C. Finding Collaborators

Participants were asked how they located cross-disciplinary collaborators. A number of checkbox items were offered, as well as an "other" open response option. These responses are summarized in Table 2. Almost 90% of respondents had located a collaborator they had met or worked with before. The second most popular response was cited just over half as often. This difference attests to the importance of networking across departmental and disciplinary lines. Apparently the personal connection of having spoken with someone before helps greatly in overcoming some of the barriers to cross-disciplinary collaboration.

Other items can be categorized as either a specific case of knowing someone prior to initiating collaboration, or working from a more formal listing or recommendation.

Table 2. Finding Cross-disciplinary Collaborators.

How did you find your recent interdisciplinary research collaborators? (Check all that apply.)		
I met them through work or worked with them before	89%	n=177
Recommendation of a colleague	49%	98
I knew them socially (from non-work activities)	19%	37
A directory, web site, or other publication	12%	24
Other: professional meetings, literature, former students, NSF research center (most were "does not apply")	11%	21

An open response item asked respondents who checked "recommendation of a colleague" to list the disciplines involved in the recommendation. 80 useable responses were coded. Though the question focused on the disciplines of those involved in the referral, nine participants listed department chairs or deans of research, graduate studies, or specific colleges. Five mentioned staff at funding agencies or the National Academies. As one participant put it, "I ask for suggestions from people who are at 'node net' points, e.g., from the NSF or IES, NICHD." These responses reveal an important option that should be made available to respondents if this survey is repeated or replicated in the future.

D. Difficulty Collaborating

Participants were asked which difficulties they had actually experienced in cross-disciplinary collaboration. Eleven checkbox items were offered, as well as an "other" open response option. These responses are summarized in Table 3. Nearly three-quarters of participants had experienced lack of time on the part of at least one collaborator, by far the most popular response. Other top responses include two related to terminology problems.

Table 3. Difficulties Experienced in Cross-disciplinary Collaboration.

Which obstacles have you or your collaborators experienced in your interdisciplinary research collaborations? (Check all that apply.)		
Lack of time on the part of at least one collaborator	73%	n=146
Different definitions of the same terms	46%	91
Loss of interest or motivation by at least one collaborator	45%	89
Different terms for the same concepts	38%	75
Lack of common interest in the same type or aspect of the problem	34%	68
Differences of opinion regarding research methods or approaches	33%	66
Institutional or departmental pressure for at least one collaborator to focus effort elsewhere	28%	55
Disagreement over deadlines, scheduling, or priorities	27%	54
Power struggle among collaborators	19%	37
Disagreement over relative workload	16%	32
Disagreement over first authorship or PI/Co-PI status	13%	26
Other: lack of institutional support/rewards, budgets/financial disagreements, publication outlets, lack of trust, "really different worldview"	10%	21

The open response "other" option in this question repeated many of the institutional support mechanisms mentioned in the institutional setting section above. Most common were budgeting policies and reward systems that discourage or appear to discourage interdisciplinary collaboration.

Preliminary chi-square statistical analysis suggests that respondents with more experience collaborating are more likely to report a greater number of difficulties collaborating. However, this analysis is ongoing, since there are multiple definitions for degree of collaboration experience. It is suspected that some difficulties can be traced to the combinations of disciplines involved (e.g., terminology issues), while others are an inherent effect of collaborating with other individuals (e.g., disagreement over project deadlines and scheduling).

E. Expectations for Cross-Disciplinary Collaboration

Finally, participants were asked about their expectations for collaboration. Responses to the 13 items are summarized in Table 4. An independent samples t-test was used to identify differences in responses by discipline. Social scientists and humanists were more likely to agree "The first author of a publication does all the work writing up the results…" (mean 3.38 vs. 2.90, $p = .018$) and "I learn from my collaborators by just sitting in research meetings with them" (mean 4.06 vs. 3.70, $p = .004$) than engineering and physical or biological scientist respondents.

Table 4. Expectations for Cross-disciplinary Collaboration.

	"Strongly Agree" or "Agree"	"Neither agree nor disagree"	"Disagree" or "Strongly disagree"
I look forward to learning from my research collaborators.	98%	2%	1%
I expect that my collaborators will value my contributions and take my suggestions seriously.	96%	2%	2%
When organizing a new research project, I try to find collaborators to handle each aspect of the project in which I do not have expertise.	90%	7%	3%
I expect my collaborators to make in-depth comments on drafts I share with them, often reorganizing the information or presenting different viewpoints.	84%	13%	3%
I am satisfied with my current and past interdisciplinary research collaborations.	77%	15%	7%
I learn from my collaborators by just sitting in research meetings with them.	76%	15%	7%
Because I am not an expert, I have to trust my collaborators to do their part well.	72%	15%	13%
I try to select collaborators who will add prestige and credibility to my research.	66%	23%	12%
New projects usually start with initial meetings to brainstorm ideas, then everyone takes care of their assigned part of the work.	62%	23%	15%
Time pressures limit the attention I give to my collaborators.	59%	19%	21%
I select collaborators that I know I will get along with philosophically and socially.	54%	28%	18%
I learn more from collaborating with people in disciplines that are very different from my own, as opposed to those in similar disciplines.	50%	39%	10%
The first author of a publication does all the work writing up the results, or if necessary, soliciting and ultimately combining sections written by different coauthors.	41%	19%	40%

F. Note on Inquiry Paradigms

One additional theory that might serve to describe some of the challenges of cross-disciplinary collaboration was also included in the survey: inquiry paradigms. According to the most often-cited authors on the topic, inquiry paradigms are a deeply ingrained way of thinking about the world that guides the practical issues related to the conduct of research, including relevant research questions and appropriate methods of study[18]. Guba and Lincoln posit four inquiry paradigms: positivism, post-positivism, critical theory, and constructivism. For each, they describe the ontology (nature of reality), epistemology (relationship of the knower to what is to be known), and research methodology (process of discovering). These are summarized in Table 5.

Table 5. Inquiry Paradigms Presented by Guba and Lincoln[18].

	Ontology (Nature of Reality)	Epistemology (Relationship between Knower and Knowledge)	Research Methodology (Process of Discovering)
Positivism	A single reality exists, governed by immutable natural laws, which can be discovered	Researchers can and should be completely objective; replicated findings are true	Situations are manipulated to test hypotheses with strict control of variables
Post-positivism	A single reality exists, but it can only be approximated due to the complexity and flaws of humans	Complete objectivity is impossible, but worth striving for; replicated findings are probably true	Research in natural settings to determine meanings and purposes of human action; multiple sources to triangulate findings; qualitative methods
Critical Theory	History is shaped by social, political, cultural, economic, ethnic and gender values; reality crystallizes over time	Values of investigator, respondents, and other inevitably influence the inquiry	Dialog transforms ignorance and misapprehensions into more informed consciousness
Constructivism	Realities are local and specific, constructed by individuals and cultures	Findings are created through transactions between investigator and respondents	Findings are elicited and refined through further interaction

The authors believe that paradigms reflect such fundamental beliefs that it is often difficult for a person to evaluate research from another paradigm[18]. As Elizabeth St. Pierre states the issue, “Unfortunately, it is often the case that those who work within one theoretical framework find others unintelligible”[19]. Kuhn’s theory of scientific revolutions cites numerous historical instances and one contemporary psychological experiment to illustrate that one’s own paradigm doesn’t become obvious until one is *repeatedly* confronted with situations that do not align with the paradigm[20].

Positivism, as the traditional inquiry paradigm, has been said to characterize physical science and engineering research. It might be expected that researchers working within these disciplines may never have been exposed to the three alternative inquiry paradigms. Among social science and humanities disciplines, all four inquiry paradigms are expected to be more evenly distributed. If alignment of inquiry paradigms is one explanation for compatibility in collaborative research, then hypotheses to be tested include whether (1) science and engineering researchers report fewer difficulties collaborating with related disciplines than with unrelated disciplines and (2) social scientists and humanists report fewer difficulties collaborating across diverse disciplines than do scientists and engineers.

Three questions addressing the ontology, epistemology, and research methodology of the four paradigms were included at the end of the survey. Participants were asked to select the statement (from among four corresponding to the four paradigms) with which they most strongly agreed. The statements were generated from a previous study by Creamer, who used case studies to illustrate how inquiry paradigm can serve as common ground for collaborating pairs with different ages, genders, and disciplinary backgrounds[21].

These questions were by far the most controversial on the survey. Though an open response item was not associated with this section of the web survey, respondents found places to comment either in previous questions or in the email informed consent raffle entry. Participants who were unfamiliar with the underlying theory dismissed the questions as confusing, poorly-written and unfounded. One wrote: “What on earth are those about? Sounds like psycho-babble that is so poorly defined as to be meaningless in the answer! I think the last time I tried to respond to your request I read those and gave up as this being a project of delusional folks with some kind of agenda!” Participants who were familiar with the underlying theory objected to having to choose from among the paradigms, as several viewed themselves as crossing paradigms. The decision to combine the items into three multiple choice rather than 12 additional Likert-scale items was made to minimize frustration for participants unfamiliar with this theory; however, the rigidity and confusion of these items was not alleviated enough to provide reliable or valid data on the inquiry paradigms of the participants. In summary, classifying a diverse group of researchers by inquiry paradigm via multiple-choice questions, particularly when the participants are not familiar with the underlying theory, presents a difficult challenge.

IV. Conclusion and Implications

Theory suggests that differences between level of consensus in various disciplines affects expectations for collaboration, and that differing expectations can create difficulties in cross-disciplinary collaboration. A broad sample of NSF investigators who are faculty at doctoral institutions was surveyed for evidence of these differing disciplinary expectations for collaboration. Simple statistical analysis reveals few correlations between survey items or significant differences between various groups. The survey questions and responses were generated from qualitative interview data and theory. The strength of this quantitative survey data set lies in the diversity of disciplines and collaboration experience levels. Future hypotheses emerging from interview data can be tested using these survey results to elucidate the questions surrounding the challenges of cross-disciplinary collaboration.

Perhaps the most important finding is that perception of institutional support was the only statistically significant predictor of satisfaction with cross-disciplinary collaboration. Through open responses, participants offered many examples of ways institutions can support cross-disciplinary collaboration:

- Sponsor opportunities for people to meet and network across departmental and disciplinary lines
- Publicize recommendations by “hub” personnel as a method of identifying collaborators.
- Simplify mechanisms for budgeting and assigning credit across departments, schools, and colleges
- Offer resources for cross-disciplinary efforts (e.g. seed money, space)
- Institutionalize reward systems that recognize cross-disciplinary efforts and value systems, particularly for untenured faculty
- Present explicit instruction in the most common pitfalls of cross-disciplinary research, from credible (experienced) researchers

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Appendix: Paper Version of Survey

Research and Collaboration Survey

Thank you for participating in this survey. The 15 questions should take approximately 20 minutes to complete. Please answer based on your general research attitudes and experiences, not specifically your NSF work. If you wish to be included in the drawing for a free iPod Nano, be sure to follow the instructions on the enclosed informed consent sheet.

Research Context

1. What is the primary academic discipline of your current research
(e.g. your current department or your degree)?

2. What is your position title and academic rank?

3. What is your gender?
____female
____male

4. What is the attitude of your institution's administration toward interdisciplinary research collaboration?
____Encourages it quite a bit
____Encourages it somewhat
____Neutral opinion
____Discourages it somewhat
____Discourages it quite a bit

5. What is the attitude of other faculty at your institution toward interdisciplinary research collaboration?
____Very open to it
____Somewhat open to it
____Neutral opinion
____Somewhat resistant to it
____Very resistant to it

6. Use this space to qualify your responses to the questions above, if necessary:

Collaboration Style

7. For the following 13 statements, please indicate your agreement or disagreement with each.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
7a. When organizing a new research project, I try to find collaborators to handle each aspect of the project in which I do not have expertise.					
7b. New projects usually start with initial meetings to brainstorm ideas, then everyone takes care of their assigned part of the work.					
7c. I expect that my collaborators will value my contributions and take my suggestions seriously.					
7d. I try to select collaborators who will add prestige and credibility to my research.					
7e. I learn more from collaborating with people in disciplines that are very different from my own, as opposed to those in similar disciplines.					
7f. I expect my collaborators to make in-depth comments on drafts I share with them, often reorganizing the information or presenting different viewpoints.					
7g. Because I am not an expert, I have to trust my collaborators to do their part well.					
7h. I am satisfied with my current and past interdisciplinary research collaborations.					
7i. I look forward to learning from my research collaborators.					
7j. Time pressures limit the attention I give to my collaborators.					
7k. The first author of a publication does all the work writing up the results, or if necessary, soliciting and ultimately combining sections written by different coauthors.					
7l. I select collaborators that I know I will get along with philosophically and socially.					
7m. I learn from my collaborators by just sitting in research meetings with them.					

8. In what ways would your responses to the previous 13 items change depending on the disciplinary backgrounds of your collaborators?

Collaboration Experience

9. What are the disciplinary backgrounds of your recent research collaborators, other than those from your own discipline?

10. How did you find your recent interdisciplinary research collaborators? (Check all that apply.)
____I knew them socially (from non-work activities)
____I met them through work or worked with them before
____Recommendation of a colleague
____A directory, web site, or other publication
____Other:

11. If you have ever collaborated with someone based upon the recommendation of another colleague, please list the disciplines of those involved (e.g. “someone from chemistry recommended the person I currently work with in biochemistry”):

12. Which obstacles have you or your collaborators experienced in your interdisciplinary research collaborations? (Check all that apply.)
____Disagreement over deadlines, scheduling, or priorities
____Disagreement over relative workload
____Disagreement over first authorship or PI/Co-PI status
____Different definitions of the same terms
____Different terms for the same concepts
____Lack of common interest in the same type or aspect of the problem
____Differences of opinion regarding research methods or approaches
____Power struggle among collaborators
____Loss of interest or motivation by at least one collaborator
____Lack of time on the part of at least one collaborator
____Institutional or departmental pressure for at least one collaborator to focus effort elsewhere
____Other:

Research Style

13. With which of the following statements do you most strongly agree?
    ____The aim of research is prediction and control.
    ____There are multiple realities, all of which can only be imperfectly understood.
    ____Knowledge construction requires a dialog between researchers and participants.
    ____Participants should be involved as co-researchers so their voices can be heard.

14. With which of the following statements do you most strongly agree?
    ____Research can make the world a better place, particularly for the disenfranchised.
    ____The knowledge, beliefs and customs of a group shape or are directly linked to their behavior.
    ____The aim of research is to objectively discover reality.
    ____Knowledge is created, not discovered.

15. With which of the following statements do you most strongly agree?
    ____Knowledge is relative or local to a specific context.
    ____Reality can only be imperfectly understood because of the inevitable subjectivity of the researcher.
    ____Differences of opinion are not really possible among collaborators. Knowledge accumulates and you work until you get it right.
    ____Knowledge is socially constructed and reality is shaped by historical, social, political and cultural factors.

Thank you for completing the survey.

Please fax to (540) 231-5974 or mail to Maura Borrego, Department of Engineering Education, College of Engineering (0218), Blacksburg, VA, 24061. A return envelope is provided.