Engineering Pathways Study: The College-Career Transition Informing Educational Practice

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A. Proposed work

Research in engineering education has shown that academic programs are often designed based on a projected image of engineering practice, which may be outdated or misaligned with today's professional practice (Duderstadt, 2008; Good *et al.*, 2007; National Academy of Engineering, 2004; Sheppard *et al.*, 2008; Vest, 2009).[1] In the proposed research, we look at the preparation of engineers retrospectively and longitudinally, examining actual experiences of early-career professionals. The overarching goal of the proposed Engineering Pathways Study is

> *To make timely improvements in colleges and universities, as well as in professional workplaces, to facilitate the transition from an engineering undergraduate to a successful engineering career professional.*

To achieve this goal, we pursue two research questions aimed at first understanding the experiences of early-career professionals (ECPs) to enable subsequent changes:

RQ1. What factors or combinations of factors facilitate ECPs' transition into a professional culture, and their conceptions of and preparation for their specific professional careers?
RQ2. How and to what extent do the factors that influence ECPs' professional development contribute to their future careers?

Using both qualitative and quantitative research methods, we anticipate outcomes that are both rich in description and grounded in statistical measures. Specifically we will identify and factors from ECPs' educational preparation and current work environments that influence early career pathways. We also anticipate being well positioned with piloted instruments and an experienced, multi-institutional research team to develop a revised full proposal and pursue a larger-scale study in 2012.

The proposed two-year Engineering Pathways Study extends findings from the NSF-funded Center for the Advancement of Engineering Education (CAEE), and in particular findings from CAEE's Academic Pathways Study (APS) research project. Building on the detailed knowledge of specific students' experiences learning engineering and the generalized experiences across students developed through APS, we are uniquely positioned to explore transitions to the workforce and the needs/experiences of ECPs. The following section summarizes key, relevant APS findings and describes how they inform our proposed work.

B. Summary of Academic Pathways Findings

The primary goal of the Academic Pathways Study (APS) was to create a rich and wide-ranging portrait of undergraduate engineering learning experiences, using a variety of research methods and relying on the students' own words for much of the data.[2] APS research questions focused on how students develop engineering-relevant skills and understanding of engineering practice, how they develop identity as engineers, and how they transition from school to the workplace. APS was based on a series of longitudinal and cross-sectional studies of engineering undergraduates' learning experiences and

[1] Complete reference list in original CCLI Proposal 1022644
[2] During the course of the APS, over 130 faculty, research scientists, graduate and undergraduate research assistants, and staff representing 12 universities and six national organizations were involved in the research. Detailed research design began in early 2003, and data were collected during the 2003–04 through 2007–08 academic years. The original funding was from 2003 to 2007, and NSF provided supplemental funds to enable two additional years of work. Data analyses continued into 2010.

transition to work that used qualitative and quantitative research methods. Details on the design and implementation of the study are documented in the report *An Overview of the Academic Pathways Study: Research Processes and Procedures, CAEE Technical Report #CAEE-TR-09-03*, available on the CAEE web site (http://www.engr.washington.edu/caee/). The CAEE final report, *Enabling engineering student success: The final report for the Center for the Advancement of Engineering Education*, was submitted on June 29, 2010, and includes a 76-page description of APS findings, as well as a complete list of the over 130 papers and presentations that resulted from this research (Appendix A). In addition, research briefs on a large number of these papers are posted on the CAEE web site. Six key topics emerged from analysis across the APS longitudinal and cross-sectional studies. The following three topics are the most relevant to our proposed study of ECPs.

B.1 Positioning Students for Professional Success
About 30% of the engineering students we studied had post-graduation plans focused exclusively on engineering (work and/or graduate school). These students were strongly intrinsically motivated to study engineering and were likely to have had co-op and/or internship experiences. In general, these same students were among those who were less confident in their professional and interpersonal skills than those considering non-engineering professional endeavors after graduation.

Most other students conceived of their careers as combining engineering and non-engineering components. Faculty, staff, and programmatic structures may do little to acknowledge (much less support and advise) students looking at combining engineering and non-engineering endeavors in their career plans.

Connection of this finding to the proposed study: Having had the opportunity to see how students' career plans and expectations develop through APS, the proposed study enables us to study the actual transition to the workforce, seeing how early-career experiences unfold for these ECPs. We expand our scope further to examine how ECPs are conceiving of and planning for "a career," what skills they see as critical for this career, and how their educational background has prepared them for this career. By studying graduates from varied institutions, we can probe how institution influences ECPs' pathways.

B.2 Helping Students Become Engineers
Students develop an engineering identity and learn about engineering from a variety of sources: from co-op and internship experiences, from their coursework and instructors, from extracurricular activities, and from personal contacts. APS data show that these sources vary little by gender or underrepresented minority status. Through the APS, we found that seniors are indeed developing skills and knowledge necessary for engineering practice. However, we also found room for improvement with respect to engineering design and conceptions of engineering practice. When approaching open-ended engineering design problems, seniors, as compared to first-year students, did *not* exhibit greater attentiveness to the problems' broad context. In addition, seniors did *not* perceive professional and interpersonal skills—leadership, public speaking, and business abilities, as well as communications, teamwork, and social skills—as being any more important than did their first-year counterparts, even having had project-based learning, design experiences, and, possibly, co-op or internship experiences.

These gaps suggest that some students fail to integrate the knowledge they are gaining about engineering from the various sources and across their years of schooling into a more complex, complete understanding of what it means to be an engineer. Furthermore, students are not always successful at transferring specific course knowledge and skills to real-world problems and settings.

Connection of this finding to the proposed study: Through APS, we understand how students conceive of engineering (*e.g.*, what skills it requires), as well as how students approach design. Through the proposed study of ECPs, we can extend this understanding to identify what key skills are utilized in a variety of workplaces and career trajectories, and observe whether ECPs see these skills as being connected to their school experience.

B.3 Welcoming Students into the Work World
During the APS study, in addition to examining the experiences of students, we began to explore the experiences of ECPs through a smaller sampling. We found that students who enter the work world after graduating face multiple challenges. They find that the problems that they are solving are more complex and ambiguous than the problems that they solved in school. The structures of their new work environments are unfamiliar and multi-faceted, and it can be difficult for newly hired engineers to find the information they need. Sometimes, they feel that they are not allowed sufficient exposure to the "big picture" of where they and their work activities fit into the goals of the work group or company. These new hires also find that they are working with larger, more diverse teams than they experienced in school—teams that are composed of engineers and non-engineers, coworkers, and customers or clients. They must often learn new terminology and new communication skills.

Connection of this finding to the proposed study: Building on our current understanding of the challenges faced by ECPs, the proposed study will illuminate the ways in which ECPs respond to specific challenges. We will also examine the extent to which their undergraduate experiences, curricular and otherwise, equip them to respond to these challenges and, more generally, engage in life-long learning.

C. Summary of Proposed Engineering Pathways Study

C.1 Research Questions and Study Outcomes
Our project is framed around the goal of improving engineering education, based on a comprehensive understanding of the needs/experiences of *early-career professionals* (ECPs). We define an "early-career professional" as someone who has graduated from an engineering program within five years. It has been well established in studies of adult development that the five-year period after graduation is a highly formative one for the acquisition of work attitudes, understanding, and motivation across all the professions, including engineering (Gardner, Csikszentmihaly & Damon, 2001; Seering, 2009; Yeager, Bernecker, Andrews & Bundick, 2008). However, we know little about ECPs in engineering. Therefore, our research, focused around the two previously posed questions, will help us understand the experiences of ECPs and identify gaps, leading to better design of engineering learning experiences.

We propose to ground our research in *social cognitive career theory* (SCCT). Described in great detail in our full proposal, we provide only a highlight here. SCCT (Lent, Brown and Hackett, 1994) defines relationships among self-efficacy, outcome expectations, interests, choice goals, choice actions, and contextual influences that affect a student's career development process. SCCT has shown promising results for understanding career choices of engineering students, and particularly underrepresented populations, (*e.g.*, Trenor *et al.*, 2008; Lent *et al.*, 2005) demonstrating that SCCT is a useful framework for exploring engineering career persistence.

C.2 Project Design and Research Methods
Our study uses a qualitative-to-quantitative research design (Creswell & Plano Clark, 2006). We will use interviews to explore in rich detail the experiences of a subset of study participants. We will then use the outcomes from the interviews to inform our quantitative survey instrument, the Pathways of Engineering Alumni Research Survey (PEARS), thereby enabling generalization across a larger group.

Participants: The nested samples of ECPs participating in the proposed Engineering Pathways Study are summarized in Table 1. The larger Survey Sample consists of ECPs who graduated from Stanford, Colorado School of Mines (CSM), University of Washington (UW), and Purdue in 2007. This sample includes three schools from the original APS longitudinal study (Stanford, CSM, and UW). In addition, all four schools participated in the APS cross-sectional survey work, the Academic Pathways of People Learning Engineering Survey (APPLES) in 2007 and 2008. Data will be gathered from the Survey Sample using the PEAR Survey instrument in Year 2 of the proposed study.

The Interview Subsample is a subset of the main Survey Sample and consists of individuals who graduated in 2007 and who were studied longitudinally in APS (2003–2007). In the Engineering Pathways Study, they will participate in interviews in Year 1. Our interview protocol and subsequent analysis will draw heavily on APS findings and raw data. Our potential pool of 104 interview participants

includes 40 Stanford graduates, 40 CSM graduates, and 24 UW graduates. We aim to interview 10-12 graduates from each of the three APS sites (30-36 total). We will use purposive sampling (Patton, 2002b) based on richness of stories in the APS data. Participants will include those who graduated with a degree in engineering, regardless of their post-graduation career choice. Moreover, since women and underrepresented minorities were oversampled in the original APS study (Sheppard *et al.*, 2004), our sample will represent a diverse group of participants and experiences.

Table 1: Engineering Pathways Study participants

Sample	Description	Estimated no. of participants	Data collection	Research Questions
Survey Sample	ECPs who graduated in 2007 from four schools	500*	quantitative survey (PEARS)	RQ1, RQ2
Interview Subsample	ECPs who participated in the APS Longitudinal Cohort	30**	semi-structured interviews and PEARS	RQ1, RQ2

Notes: *based on the response rate of APPLES in 2007 & 2008, **based on anticipated response rates and purposive sampling

Data Collection and Analysis: The project timeline is shown in Table 2. As described below, we organized our research teams and data analysis plans to encourage collaboration across all schools (rather than analyze data within each institution) and to use findings/themes from the semi-structured interviews of Interview Subsample (Year 1) to form the conceptual framework for PEARS for the main Survey Sample (Year 2).

Table 2: Project timeline

		Fall Yr 1	Spr Yr 1	Su Yr 1	Fall Yr 2	Spr Yr 2	Su Yr 2
Qualitative Data	Interview Protocol Development						
	Subsample Interviews (30)						
	Interview Analysis/Reporting						
Quantitative Data	PEARS Instrument Development						
	PEARS Deployment to Survey Sample						
	PEARS Analysis/Reporting						
Mixed Data	Comparative Analysis of Qualitative and Quantitative Data						

Interviews: The interviews with Early-Career Professionals (Interview Subsample) will be in-depth and semi-structured (Patton, 2002a), providing an opportunity for these individuals to describe in their own words and from their own perspectives their experiences transitioning to the work world. Grounded in SCCT, interviews will address both RQ1 and RQ2 and will include follow-up questions based on each participant's prior APS interviews, as well as additional questions soliciting their perceptions of career preparedness and career plans. All interviews will be audio recorded and transcribed verbatim. Transcript analysis will include common thematic analysis approaches (Miles & Huberman, 1994; Strauss & Corbin, 1998) using a combination of open, inductive codes and *a priori* codes (Patton, 2002b). Findings from the interviews will feed directly into development of PEARS.

PEAR Survey: The Pathways of Engineering Alumni Research Survey (PEARS) instrument will be created and used to look at issues of career fit with a broader and larger population that is too large to interview individually. PEARS aims to address both RQ1 and RQ2, and respondents will be engineering alumni from the four schools who graduated in 2007. The survey instrument will be informed by the outcomes from the interviews with the subsample, other alumni surveys (*e.g.*, Courter, 2009; Fouad, 2008), and the APS APPLE Survey and its analysis. Our timeline (Table 2) allows for this sequential process. We are also committed to regular conference calls and web-facilitated (using CLEERhub.org) and in-person meetings among the interview analysis team and the survey development team to facilitate connectivity of the project parts.

Data Reporting: Taken together, the combination of interviews and surveys of today's early-career professionals will result in a rich and robust picture of what it is to conceive of and enter, build, and sustain an engineering career, based on a small sampling of schools. Moreover, based on the outcomes from this proposed work, we will be well positioned to deploy our instruments at a larger cross-section of schools, disseminate findings through papers, presentations, and CLEERhub.org, and contribute to building a community of practice (researchers and practitioners, the CoRE2-Practice Community of Practice from our original proposal).

Evaluation: Dr. Gary Lichtenstein, Quality Evaluation Designs (www.QualityEvaluationDesigns.com), will be the external evaluator. In addition to monitoring progress on the project timeline, the external evaluation focuses on two evaluation research questions (ERQs):

ERQ 1: Is the proposed project integrating findings from the prior APS study in the design of instruments and reporting of data? Through surveys distributed during Spring 1 and Spring 2 (during PEARS survey development and quantitative and qualitative data analysis) and semi-structured interviews with graduate students and staff during Years 1 and 2, Dr. Lichtenstein will ascertain project personnel's familiarity with key CAEE reports and papers on the APS on senior career decision-making and transition of post-grads into professional work settings. Specifically, QED will determine the extent to which APS findings have informed development of the interview protocol and PEARS survey.

ERQ 2: To what extent are project deliverables created through engaged, interactive collaboration of team members across institutions? Project Leads seek to create a model of engaged, interactive collaboration by assigning responsibility for deliverables to work teams distributed across institutions, rather than to staff within specific institutions. The effort will be facilitated by CLEERhub.org, a web-based tool that supports online learning communities. QED will interview project members and monitor activity on CLEERhub.org to assess the nature and extent of cross-institutional collaboration. Critical focus will be paid to development of the PEARS instrument (Spring/Summer Year 1, Fall Year 2), the conceptual framework for which must be based largely on analyses of qualitative interviews.

Comprehensive evaluation reports will be delivered in Summers of Year 1 and Year 2, which will also review the extent of adherence to the project timeline.

C.3 Project Management

Project Timeline: The project timeline has been shown previously as Table 2. In two years, we will have completed data collection, analysis, and reporting for a sample of students at four institutions. We will also be well positioned to resubmit a more extensive proposal in 2012, grounded in our pilot data,

Team Responsibilities: Sheri Sheppard will be the PI for the project and will oversee all of its elements, and with Cindy Atman will facilitate quantitative/qualitative research integration. All co-PIs (Sheppard, Atman, Matusovich, Miller, Streveler) will be part of the project leadership team and will participate in monthly conference calls and communications via CLEERhub.org. Leadership responsibilities of the various project activities are detailed in Table 3.

Table 3: Team responsibilities

Project Elements	**Led by**	**Other Team Members**
Interviews	Holly Matusovich	Graduate students, Ron Miller, Deborah Kilgore, Helen Chen, Cindy Atman, Sheri Sheppard
PEARS (survey)	Shannon Gilmartin	Helen Chen, Ken Yasuhara, Sheri Sheppard, Ron Miller, Ruth Streveler, Graduate students
Evaluation	Gary Lichtenstein, Quality Evaluation Designs	