Research Design Becomes Research Reality: Colorado School of Mines Implements Research Methodology for the Center for the Advancement of Engineering Education

Heidi G. Loshbaugh, Ruth A. Streveler, Kimberley R. Breaux
Colorado School of Mines/Regis University

abstract

In 2003, NSF funded development of the Center for the Advancement of Engineering Education (CAEE) at University of Washington, Colorado School of Mines (CSM), Howard University, University of Minnesota, and Stanford University [1] (ESI-0227558). Any research requires adapting design into practice, as reality impinges on the researchers' free-ranging ideals. A multi-institutional, multi-year grant multiplies opportunities for reality to interfere with design. As engineering education evolves, many more researchers must become familiar with methodologies outside traditional technical disciplines. Mixed-methods research calls for documentation of processes of research so subsequent projects can benefit from the learning curve of prior research activities [2]. This paper examines CSM's implementing research design into practice, describing both successes and stumbling blocks.

introduction

Founded in January 2003, the Center for the Advancement of Engineering Education (CAEE) is a higher-education Center for Learning and Teaching, funded by both the Directorate for Education and Human Resources and the Directorate for Engineering (ESI-0227558). The goal is to improve knowledge about and practice of engineering teaching and learning. This five-year grant brings together a team of scholars with diverse backgrounds and disciplines from five campuses: Colorado School of Mines (CSM), Howard University (HU), Stanford University (SU), the University of Minnesota (UM), and the University of Washington (UW), the lead institution [1].

This paper focuses on one of CAEE's research goals: understanding and enhancing the engineering student's learning experience. The Academic Pathways Study (APS) component of CAEE involves data gathering and analysis, interpretation and dissemination of the research data and findings. The mixed-methods study uses three primary investigative tools: surveys, in-depth interviews, and ethnographic observations. Participants also complete an open-ended performance task. Surveys and interviews provide data on a large set of participants, while ethnography provides a deeper level of information on a small number of subjects. Each tool provides insights to inform the others, allowing generalization of specific findings to a broader population. Companion data is collected through participants' academic records.

We discuss implementing CAEE research design at CSM. In keeping with mixed-methods research practices, this paper documents our path through the research process. In this first year of integrating the study, our activities are the data. We provide considerations for other

researchers in engineering education using mixed-methods practices. "[T]he development of such accounts relies on methods that can document and connect processes of enactment to outcomes of interest" [3]. Design research depends on iterative events and discussion and evaluation of events within the process. Our hope is that this discussion can play a role in assisting other researchers to "systematically create, test, and disseminate teaching and learning interventions that will have maximum impact on practice and…contribute…to theory" [4]. In particular, this paper describes a campus-specific implementation of a collaborative study and how research design in a collaborative study must conform to the reality of a specific target campus and its representative population.

the drawing board

In the first year of APS, primary tasks were selecting the participant pool and collecting data through ethnographic observations, on-line surveys, and interviews. Critical factors were time, staff, and coordination between campuses. Most CAEE communication takes place by email and telephone conferences, given the great distances between campuses and large numbers of researchers involved. Among the activities in the first year were conference calls to clarify, refine, and implement the research. Important opportunities for the researchers to make decisions about research design and policy face-to-face occurred in meetings at UW in January and July of 2003 for all members of the CAEE team, and at Stanford in April 2003, which APS researchers attended.

In academic year 2003-2004, CSM had 2,667 undergraduates. The 623 women equaled 23.4 percent. The 378 ethnic minority students equaled 14.17 percent. The incoming first-year class was 750 students. To be eligible for APS, CSM participants had to be May/June 2003 high-school graduates, eighteen or older by October 1, 2003, and U.S. citizens/permanent residents. We also required that students have enrolled in or have the intention to enroll in an ABET-accredited engineering major. On CSM's campus, that excludes three majors: Chemistry, Math and Computer Science, and Economics and Business.

Our sample design was fifty percent female, fifty percent male; the Study group and Control group would mirror each other. Fifteen participants would be white (or possibly Asian American, because of the high representation of Asian Americans in engineering, nationwide), and five would be Latino/a, Native American, or African American. Among the latter, we hoped to observe two who had participated in a CSM summer bridge program, Challenge, run through the Minorities in Engineering Program (MEP) and three who had not attended Challenge.

CSM's total APS population was to be eighty students: forty Control/Comparison, thirty-two Study participants, and eight Ethnographic participants. The Control/Comparison group was designed to verify whether or not participation in APS would affect the success of Study/Ethnography participants. (In year two, the four campuses have disbanded the Control/Comparison groups, recognizing the impossibility that participation has no effect, given the frequent contact participants have with the researchers.) Control/Comparison participants agreed to allow APS to track their academic and admission records. Study participants agreed to have their records tracked, as well as take part in two online surveys per academic year and one

interview per academic year. Ethnographic participants also agreed to allow a researcher observe them in classrooms and activities related to their lives at CSM.

it takes a village

At CSM, the CAEE was integrated into the relatively new and quite small Center for Engineering Education (CEE); our CAEE Co-Principal Investigator (PI) and CEE Director are one and the same. As with other campuses, the CSM PI does not participate in active data collection to avoid data contamination. In the first year, the primary researcher was employed at 80 percent of full-time and became pregnant with a due date halfway through Spring semester 2004, the first active year of APS. Two temporary researchers were hired to conduct research activities during the maternity leave, one to conduct formal interviews, one to conduct ethnographic interviews and observations.

Table 1: Designed Sample, CSM APS Participants

Sex/Ethnicity	Study	Control/ Comparison	Total
White and Possibly Asian Men	15	15	30
White and Possibly Asian Women	15	15	30
African-American, Hispanic, Native-American Men, Challenge	2	2	4
African-American, Hispanic, Native-American Women, Challenge	2	2	4
African-American, Hispanic, Native-American Men, Non-Challenge	3	3	6
African-American, Hispanic, Native-American Women, Non-Challenge	3	3	6
	40	40	80

As CAEE researchers have found, it "can be difficult for a single researcher to carry out both qualitative and quantitative research, especially if two or more approaches are expected to be used concurrently; [the methodology] requires a research team" [2].

Part of this team has been undergraduate employees. Funding for undergraduate researchers became available in late 2003, but at CSM, hiring Research Experience for Undergraduate (REU) employees to conduct CAEE research poses certain complications. Because this is a small campus in which students are tightly scheduled into common classes, share residence halls with one common cafeteria, and have few opportunities for activities external to the campus, odds are good that students know each other or at least know of each other. Protecting confidence of participants involved in this research is critical, so we had to make careful accommodations to ensure that the REU's would not be privy to information about research participants. Because this campus has no social sciences, students potentially interested in mixed-methods or human-subjects research of any kind are hard to come by. Finally, as with any tasks to be performed by students, semester schedules and class deadlines can interfere with a student employee's ability to meet employment deadlines.

calling all engineers

We recruited participants at nine events early in academic year 2003-2004. From summer campus visits, to the MEP retreat in the mountains outside Denver, to the industry-sponsored Society of Women Engineers' "SWE-nie Weenie" barbeque, to the Chemistry I class, which nearly every first-year student at CSM takes, we took sign-up sheets and information describing the study, as well as Hershey's kisses and miniature bottles of bubbles as incentives. We received 342 signatures and email addresses; ninety-eight were women, 244 were men. Forty-four were signatures from ethnic minorities. We invited these students to informational sessions, which included pizza, soda, candy, and APS basics. Interested and eligible students signed informed consent documents and completed questionnaires, which we used in placing them into either the Study group, Ethnographic group, or Control/Comparison group (Appendix 1). Participants in the Study and Ethnographic groups receive $175 per academic year; those in the Control/Comparison group received $25.

After these sessions, we still lacked enough females to complete our sampling plan and had had no African-American attendees. Of the six incoming first-year African-American students, five were in majors eligible to participate in APS. We scheduled two more recruiting sessions for female students and attended a lunch meeting of National Society of Black Engineers (NSBE) to describe the study. We discussed ways to further recruit women and African Americans, including arranging for direct contact from upper-class students and the Assistant Director of MEP. Ultimately, we decided not to risk discomfiting these students and stopped recruiting. Thus, we were unable to include any African-American students in our study sample and had to adjust downward the number of women included in the study.

As described earlier, we initially considered categorizing Asian-American students as white because Asian Americans have a high representation in engineering, nationally. However, at CSM, Asian Americans are poorly represented in engineering majors, and we have few ethnic minorities overall; thus, we decided to include that ethnic group in the category, "underrepresented." Finally, we did not separate out participants from Challenge, the summer bridge program, again, because of the few ethnic minority candidates available to us.

rubber meets the road

At the end of the recruiting sessions and prior to our placing students into the three study groups, we received consent signatures from 112 students. Forty of these were women, one from an ineligible major. We did not have enough non-Caucasian females to meet our designed sample and instead over-sampled for ethnic-minority males (Latinos and Asian Americans/Pacific-Islanders).

As a university with about seventy-percent in-state enrollment, seventy-seven percent males, and eighty-six percent whites, broad representation is a relative term. We placed participants considering their majors, hometowns, ethnicity, sex, and the answers to questions on a recruiting questionnaire (Appendix 1). We divided candidates geographically by out of state, Denver metropolitan, other areas of Colorado. Then, based on their responses, we eliminated students who identified "money" as their primary motivation and students who selected "records only"

(Control group) as their principal level of interest (Appendix 1). Because they were the best-represented minority groups, we sought balance in numbers between Latino/as and Asian Americans/Pacific Islanders. Finally, we looked at the students' interests for participating in the study.

time marches on

Recruitment and ethical-compliance issues devoured time, as did shepherding participants through the expected research activities. Scheduling proved to be a significant challenge, and the resolution of time conflicts required flexibility from the participants and creativity from the research team. CSM's semesters run from about August 20, to December 15, and January 5 to May 5.

Table 2: Sex & Ethnic Breakdown of APS Participants, Fall 2003

Sex/Ethnicity	Study	Control	Ethno-graphic	Total
White Male	12	15	3	30
White Female	12	15	3	30
Hispanic Male	3	3	0	6
Hispanic Female	1	3	1	5
Asian Male	1	3	1	5
Asian Female	2	1	1	3
Native American Male	1	0	0	1
Native American Female	0	0	0	0
African American Male	0	0	0	0
African American Female	0	0	0	0
	32	40	8	80

HU's calendar is similar to CSM's, but UW and Stanford operate on quarters. Coordination and time pressures, given the different needs of the different campuses have proven to be an ongoing challenge.

CSM has no Institutional Review Board (IRB) for research with human subjects, yet APS's focus on human subjects requires informed-consent protections. (HU) sponsored CSM's informed consent protocols, which was a significant cost-savings. As the study got underway, the APS methodology continued to be refined; thus, informed-consent needs kept changing. Audio-taping, photography, and issues such as duration of surveys and interviews were among the concerns fine-tuned as APS evolved. Internal Review Boards operate slowly and deliberatively, making for some months the signed consent status out of sync with hoped-for data collection methods. This also meant that students needed to sign several different versions of the human-consent forms, which led to staff/resource concerns. Each iteration of the informed

consent required tracking down all eighty participants and scheduling individual appointments for them to sign new documentation. Asynchronous academic calendars also posed challenges for CSM in administration of the online surveys and one-on-one interviews, in particular because elongating the schedule meant hiring additional staff to conduct the interviews because the primary researcher was on maternity leave.

Variations among institutional academic calendars can hinder the effectiveness of cross-institutional research. Anticipating and planning for this complication could make such multiple-institution research projects run more smoothly.

research is a contact sport

Researchers need dedication and diligence to obtain meaningful data. In truth, sometimes, the researcher must be a bloodhound to track down participants to obtain any data at all. The necessary activities are time consuming and not seemingly data collection.

Although email is quick, it is flawed. First, it is easily ignored. Second, to conduct even a simple task such as scheduling and confirming an appointment requires a minimum of two actions. Given overscheduled days, forgetfulness, and the different priorities of participants and researchers, scheduling by email has meant lots of time for the research staff.

Because of the need to have protocols in place before data collection could begin and the relative need to have chronological parallels in data acquisition, CSM could not begin data collection before research subjects were in place at the collaborating institutions. Thus, students at CSM agreed to participate but then waited for several weeks before the study actually began. The delay resulted in one male student choosing not to participate in APS and several others contacting the study coordinator to see why they had not been involved in a study activity. Four students in the Control group voted with their feet: they disappeared and were never heard from again.

After the initial recruiting sessions, to maintain participant confidentiality, each interaction between participant and researcher has had to take place one-on-one. The researcher needed to make contact for and schedule eighty different appointments for updating informed consent. At first, the APS research team had not decided whether or not a listserv would fall into appropriate use under informed consent. So, the CSM researcher sent eighty emails and then scheduled the appointments one by one, sending reminders and rescheduling as students forgot or ran into conflicts. This task took five weeks of continued and ongoing effort.

Scheduling for one-on-one interviews was also cumbersome. Initially, all four universities were to schedule with an on-line software program. However, the software was not available to CSM in time, so we contacted participants individually. Furthermore, interview protocols were still being refined as CSM's academic year drew to a close. When protocols were complete, CSM had only four weeks between Spring Break and Final Exams to schedule forty-eight interviews one-and-one-half hours, each. When a student had to reschedule or missed an appointment, the entire schedule was under even greater pressure.

Researchers must be mindful of the participant's value, remaining accommodating and tactful, even when participants require multiple prompts to complete assigned tasks. One subject in the CSM Study group is particularly resistant to reminders. To complete each of the online surveys, this participant has required multiple emails and telephone calls. For the most recent iteration of the survey, a phone call and fortuitous (for the researcher) chance campus meeting were needed to get the questionnaire completed. Even getting students in to pick up their checks for participation has required repeated correspondence.

moving targets: in process

Year Two has continued some of the challenges in contacting students for participation. Several subjects have left CSM, and we have replaced Study participants with Control/Comparison group participants, taking care to maintain as many underrepresented minorities as possible. We have replaced four Study group students in Fall 2004: one Anglo male, and two Latinos left and were replaced by one Anglo male and two Latinos. One Anglo female left the Study group and was replaced by one Latina. We made this replacement because CSM has such a low percentage of ethnic minorities enrolled that we did not want to lose a Latina from the Control group. One Anglo male is on leave from CSM.

Despite our engineering focus, CSM has two APS participants with non-engineering majors. One is an Anglo male who declared Computer Science early in his first year, yet somehow enrolled in APS despite various screening practices. The other is a Latino whom we moved from the Control group to the Study group to replace a Latino who transferred from CSM to another university; this second Computer Science major declared early in his sophomore year.

what's it all about, e.e. (engineering education)?

To enact fundamental change in engineering education, projects like CAEE will be ever more common. Managing the transition from research design into practice is critical for success. Future researchers must know that post-design activities required to establish conditions for research are time consuming and personnel intensive. Anticipating calendar challenges is critical, as is maintaining team-oriented communications alongside task-based functions.

Our recommendations? Be flexible. Research design will change as you meet the pragmatic realities of your campus. At CSM, we altered our sampling scheme due to the limited number of women and minority students on our campus. Our time schedule also needed to be modified to parallel the schedules of our partner campuses. Consider the culture of your campus. The small and highly homogenous nature of CSM had its advantages (recruitment was much easier than on the other campuses of this project) but also its disadvantages (students tend to know each other, which requires special measures to maintain confidentiality.) Finally, enjoy the groundbreaking work you are undertaking. Design may be the stuff dreams are made of, but research in practice is the stuff discovery depends on.

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Biographies

HEIDI G. LOSHBAUGH is an Assistant Research Professor for the Center for the Advancement of Engineering Education at Colorado School of Mines. She holds a Doctorate, Master's Degree, and Bachelor's Degree from the University of Denver. She taught in CSM's Engineering Design program, for which she developed extensive course and faculty-support materials, and implemented a leadership course. She also has experience in international education, corporate training and coaching, and academic editing.

RUTH A. STREVELER is the Director of the Center for Engineering Education at the Colorado School of Mines and Associate Research Professor in Academic Affairs. Dr. Streveler holds a Ph.D. in Educational Psychology from the University of Hawaii at Manoa, Master of Science in Zoology from the Ohio State University, and a Bachelor of Arts in Biology from Indiana University at Bloomington. She is co-principle investigator of three NSF-sponsored projects: *Developing an Outcomes Assessment Instrument for Identifying Engineering Student Misconceptions in*

Thermal and Transport Sciences (DUE - 0127806), *Center for the Advancement of Engineering Education* (ESI-0227558), and *Rigorous Research in Engineering Education: Creating a Community of Practice* (DUE-0341127).

KIMBERLEY R. BREAUX has collaborated with CSM in the Academic Pathways Study as an ethnographer and interviewer. She holds a Master's in Business Administration in Accounting, Finance, and International Business from Regis University, Denver, a Bachelor of Arts in Science and Psychology from University of Missouri-Columbia, and is completing a Master's in Counseling Psychology, from Regis. She has extensive corporate experience in finance and human services.

Appendix A

Participant Questionnaire

To help us distribute participants evenly across the study groups, please answer the following questions:

Name _____

Home town _____ State _____ Country_____

Major/dream job _____

3 hobbies _____ _____ _____

3 adjectives to describe yourself _____ _____ _____

What is your greatest strength? _____

What is your greatest weakness?_____

Why do you want to be an engineer?

What interests you about the study?

***Rank your interest in the 3 levels of participation (1 = high, 3 = low)**

_____ academic records only
_____ surveys & interviews
_____ the whole show

*Note: by signing the consent form, you agree to participate at any level in the study