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Social Science Research in Engineering Education: Lessons Learned

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Introduction

The *Journal of Engineering Education* recently published an article about difficulties experienced by trained engineers embarking on educational research [1]. The last hurdle in Borrego's assessment (a very engineer-like construct) was to integrate social scientists into engineering education research teams. Essentially, her description of this process implies that the social scientists will be consultants supporting the efforts of the engineering educators. However, what we found was that our scholarship was improved and our experience more satisfying when we moved beyond an engineer-consultant relationship to an integrated partnership. Our research process is similar to those strategies espoused in recent forums and reports on qualitative research in engineering education and the work of social scientists studying engineering education. (Ref. such as [2-21]) We will share the challenges and lessons we, the STEM professionals on the team, learned in our struggle to build a mutually respectful, trust-based, and symbiotic relationship with our social science partners. In the spirit of an authentic partnership, our anthropology colleague also faced challenges and grew intellectually through the experiences of this collaboration, but that story is for a different audience. Hopefully our story will inspire other engineering education researchers to not just use social science techniques and theories when expedient to do so, but to open their minds to new ways of thinking, investigating, and reporting.

The Research Institute for STEM Education (RISE) [22] grew from conversations in fall 2001 around ideas for a proposal to submit to the NSF Program in Gender Equity (now Research on Gender in Science and Engineering, Grant No. 0225228). The original group built a multi-disciplinary team with faculty from education, engineering, mathematics, women's studies, and chemistry. The team decided to go beyond quantifying enrollments, graduation rates, etc. to developing a broad and deep understanding of the diverse range of factors and of the complex interrelationships between factors which were contributing to successful students and engineering programs. To accomplish our goals of identifying these factors and their interplay in the lives of students, we decided against administering a survey comprised of our preconceptions of what the factors would be, but instead chose to use an open-ended interview protocol to allow students to tell us their stories in their own words. An optimal team for accomplishing this research would need to include a cultural anthropologist who would be familiar with ethnographic interview-based research and socio-cultural theoretical frameworks. We expect that other kinds of social scientists would provide similar benefits to research projects with other goals, as has been suggested by others [1, 20].

When the STEM practitioners that dominated the initial group integrated social scientists into RISE, we blithely assumed that the social scientists would be assimilated into the existing STEM research culture. We'd all share calendars using Outlook, track changes in Word documents, and use email for our primary mode of communication. We'd collect data, count the number of students whose comments fell into well-defined categories, draw the one and only correct

conclusion, and publish our results in the best journals and conference proceedings. What we failed to realize was that this integration would be more like a volcanic upheaval that would challenge not only the social scientists, but the STEM practitioners as well. As engineering education opens to embrace non-statistical methodologies, this article is intended to provide a travelogue for other STEM practitioners who want to take on the challenge of building a research team that includes social scientists as full collaborators instead of service providers.

This work builds upon results presented in the Annals of Research in Engineering Education [23-25]. The personal reflections that were solicited for AREE, were specific to the production of the JEE paper that the invitation was based on. This paper provides a broader perspective that focuses on the development of the entire research team instead of just the process of developing a single paper. We'll present the description of the evolution of the research team as a series of lessons learned.

Lesson 1 – Embrace new ways of thinking about the world – paradigms, methodologies, and theoretical frameworks

Like many engineers (and other non-social scientists), we were trained and previously practiced in a positivist paradigm, the underlying basis of the scientific method. Like most engineers we wanted a world that can be explained applying principles steeped in mathematical models. Given sufficient time and resources, every variable could be controlled and all valid results would be fully reproducible. We liked to think that science and engineering stood objectively independent of human actions, intentions and motivations. Given this epistemological standpoint, we were most comfortable operating within frameworks that were both "obvious "and "right" [1]. If there was a single right answer, then there must be a single, correct framework for finding or interpreting that answer. We've had to let go of that way of thinking. Social life, and research on the human condition, is much messier than positivism allows. Individuals can exercise free will: they can't be meaningfully isolated and mathematically modeled. The range of forces and constraints that individuals encounter, claim or resist are complex, situational, and ever changing. One of the first, but ongoing, challenges for the social scientist collaborators has been to remind us that there is not a single answer to the questions surrounding academic success waiting to be discovered. There are multiple, contextual, and textured explanations that may or may not be connected to one another. While changing worldviews is conceptually simple, rather like changing the postulates in mathematics, in practice it takes years of careful thought and practice, missteps, and encouragement from colleagues trained in other ways of considering the world.

In order to achieve our goal of mapping the dynamic processes individuals use to overcome inequality and to construct nuanced explanations of those behaviors, we needed to use a qualitative approach. We chose ethnographic interviews [21, 26, 27]. Our gaze was not on particular programs at the institution but how individuals experience those programs. We wanted to focus on student's intentions, the options they believed they had, the decisions they made, the consequent actions they took, and the resultant actions of others. Through these semi-structured interviews, we built an understanding of the affects of social structure and institutions on the individual's opportunities for success. Though we faced other difficulties, the selection and

acceptance of the ethnographic interview for our methodology was not a stumbling block for the engineers on the team.

Grounding our interpretations in the data and not in pre-determined theoretical framework proved difficult for us and even more difficult for reviewers of submitted publications. Unlike with the scientific method where an experiment is designed to confirm or refute a hypothesis, discourse analysis rarely begins from a defined theoretical framework. An accepted practice in ethnographic based research is for interpretation of discourse to be grounded in the data not the theoretical framework [28]. The danger of grounding interpretation in the framework lies in forcing the interpretations of the data into a finite set of predefined categories supporting the framework. In contrast, data-grounded inquiry develops the categories as a function of the data analysis. From these emergent categories, a theoretical framework is selected to take the specific and local experiences and offer them in broader contexts, in other words, to provide generalizability and transferability of local experiences. The use of different theoretical frameworks allows multiple interpretations from different perspectives to be constructed from the same data. This accepted practice is quite different from that in engineering, where two engineers working from the same data set would be expected to come up with a similar analysis.

An example of a framework that the social scientists introduced to the scientists and engineers through this collaboration is that of constructionism [29]. A constructionist maintains that power and therefore inequality is interwoven into all aspects of social life. A constructionist approach questions the naturalness of the social order and seeks the underlying social motivations and mechanisms that shape human social relations and institutions; furthermore, this approach considers the individual as an active agent in the process. More specifically, we have applied Bourdieu's cultural capital theory [30] as a framework to analyze part of our local data [31] and to demonstrate how differences are produced and reproduced within the global setting of engineering education, how power is acquired, enacted and maintained and yet, how people resist and negotiate life within that setting. One of the obstacles for scientists and engineers doing social science research is learning a new suite of theoretical frameworks, instead of being limited by positivism.

Lesson 2: Understand the timeline for accomplishing qualitative research

The timeline for qualitative research is different than that in well defined engineering projects. This difference comes from having to deal with the complexity of human participants in research at every step of the process, from institutional review board clearance through scheduling interviews, up to transcription and analysis.

As engineers embarking on a research question of interest to engineers with the intent of disseminating to an engineering audience, we felt compelled to design a study with as large a participant population as we believed we could recruit. For our results to be heard and respected by engineers, we believed that we needed a large "N" similar to broad-based survey research. While this decision appealed to the engineers and undoubtedly makes the research easier to publish in engineering venues, data saturation could have been achieved with fewer participants. There is a point in time when additional interviews do not provide new or different experiences; at this time data saturation is said to have occurred. Recognizing that continuing to interview

participants beyond data saturation is not fruitful; social scientists are more comfortable with data saturation than engineers.

The consequences of the decision to interview hundreds of participants are many and varied. The first set of issues with building a qualitative study with so many participants revolves around the participants themselves. The use of the university wide email system seemed ideal for reaching the electronic-generation of students. Unfortunately every other office on campus thinks so too – students ignore email messages from campus offices that they are not expecting to hear from. We found that employing fellow engineering students as recruiters was essential for getting the students' attention. A typical NSF funding cycle is three years, so a study with this large N should complete interview data collection within one and a half years to allow adequate time for data analysis. We discovered that with the schedule intensity of engineering students only one or two students would take time after mid-semester to be interviewed – i.e. give up 2 hours of their time – even with generous monetary incentives. Since participants were only available for about six weeks twice a year, our data collection period extended beyond the ideal eighteen months, compressing the time available for data analysis and publication.

The short period of time that we had to interview students was sometimes impacted by the requirements of the Institutional Review Board (IRB). Most engineers are not accustomed to having their research delayed by this type of administrative requirement. For human subjects' research, everything -- every recruiting email, poster for the halls, incentive, interview protocol, informed consent form, questionnaires, data storage, etc. -- must be pre-approved by IRB. When adjustments were needed or legally reportable events were revealed, interviewing ceased until either approval of new documents or resolution of the events came through IRB. Since the board meets monthly, the delay in interviewing further compressed the time for analysis.

Transcription is also a time-consuming process, particularly when dealing with large Ns. Early in the project, we used graduate assistants to transcribe interviews. The graduate assistants found the process to be tedious, and we found their work to be unreliable and impossibly expensive given the low productivity. Eight months into the project, we switched to using an internal university transcription service. While this service was more reliable and cost effective than the graduate students in one sense, the transcriptionists that our institution provides know little about standard engineering college culture and terminology. For example "MoHeat", our participants' abbreviation for a much discussed Momentum and Heat Transfer class, was transcribed as a variety of things such as "mohe," "mohene," "mohawk." Imagine the humorous transformations of "AICHE", the name for the American Institute of Chemical Engineers. Using a transcription service required creating and implementing a confidentiality agreement approved by the IRB. It also added another layer of administrative minutiae. Transcription time varied wildly, from three weeks to four months. We could have used an external service, but the cost and confidentiality concerns (such as having a secure FTP site) were prohibitive.

Transcription requires verification (listening to the interview audio while proof-reading the transcription), particularly given the limitations of our transcription service. Initially Co-PIs and interviewers verified the transcriptions. We found this to be an inefficient use of Co-PI time, and the backlog of transcribed but not verified data was preventing analysis. Our next solution was to assign verification to interviewers and other undergraduate and graduate assistants. We found

their work to be uneven. We were then recommended to hire a music major (who would have high levels of auditory acuity) to verify transcription; however, the one we hired didn't have the proof-reading or editing skills to produce high quality data. Finally, we hired a professional editor for transcription verification.

There is a tradeoff between accelerating the research timeline by hiring professionals and having team members do the transcription and verification. Hiring professionals for those data processing tasks carries the disadvantage that we aren't as intimately connected to the data as we were when we were doing the data processing tasks ourselves. Hiring professionals is a very engineer-like solution to this problem, particularly given not only funding agency deadlines but the necessity of producing an acceptable volume of publications to be considered professionally productive.

After transcription, the interviews were coded using NVivo qualitative data analysis software [32]. This software allows users to tag passages with identified themes and categories for future analysis. A typical one hour interview takes four to five hours to code, with an additional couple of hours for coding review. The more than 16,000 pages of data in our two projects have been coded with between 200 and 1000 categories, depending on the project. In our first major research project, all members of the team shared a single set of categories that were derived from the literature base and interview protocol. This systematic approach is rather like the process used in creating a survey, something engineers are more familiar with. Disadvantages of this approach include the possibility of projecting preconceived ideas onto the data and the need of keeping all people coding the data aligned in their use of each category. In our second project, teams organized by the race/ethnicity of the participants independently created a grounded set of categories as needed from the data. Since these categories were built organically, they provide a better fit to the data. However, with this process making comparisons of data across groups requires iterative consensus building. The change in approach reflects our growing comfort level with social science methodology, but further contributes to the extended timeline of this type of research.

Qualitative research, particularly methods like ethnographic interviews, can require long periods of data collection and analysis before the first publications appear. This timeline needs to be understood not only by the engineers, but by people evaluating the engineers' productivity, including program officers at funding agencies and departmental evaluation committees.

Lesson 3: Qualitative research results reflect the complexity of the human experience and must be strategically framed for engineering audiences

Borrego has encouraged qualitative researchers to frame questions with broad appeal, and this advice is generally good [1]. Indeed, a broadly appealing, generalizable research question is necessary for obtaining funding and launching a research project. However, we have found that including the broad research question in resulting papers confuses reviewers, and sometimes even editors, who then look for the one single correct answer to that research question in the conclusion. This confusion is understandable for people trained in the positivist tradition of science. Often in qualitative research, the research questions are progressively focused over the course of data collection and analysis. The full gamut of questions does not necessarily arrive at

the beginning and get neatly and succinctly answered by the end. More specific research questions emerge, are refined, and are then investigated, possibly producing even more questions along the way. Progressive focusing leads away from merely describing events and processes toward testing explanations and theories.

For example, as we investigate factors influencing differential success rates among under-represented minority populations, the importance of our Multicultural Engineering Program (MEP) leadership is emerging as influential. An ethnographer might be comfortable submitting a paper talking about the impact of MEP on engineering students as *a partial* answer to the research question of what helps students be successful in engineering. The engineering audience expects *a wholly answerable* research question to frame a publication around. Therefore, the pattern of differential impact on different student groups by changes in MEP leadership would need to be framed as its own research question to be acceptable to an engineering audience instead of presenting the broadly appealing, funded research question.

If we were to delay publication of our partial answers to the funded research question until the analysis is complete, the result would be a lengthy book (such as Seymour and Hewitt [27]), not a journal article. While in social science disciplines publication of a single book that summarizes many years of research is an expectation for tenure, publication of several journal articles every year is a more typical expectation in engineering disciplines. Selecting the type of publication venues (e.g. books, journal articles, conference papers) has been an ongoing challenge for the research team. When we started this research, our team contained two assistant professors seeking tenure and two associate professors seeking eventual promotion. The timeline for writing a book fit neither with the tenure clock, nor with the productivity expectations of the departments involved. A book would be only one publication in a portfolio that would typically be expected to contain dozens of publications. Likewise, a typical federal granting agency time period of three years does not allow sufficient time for data collection, processing, and the comprehensive analysis to publish a book without multiple no-cost extensions.

Another challenge to publication of this work is disciplinary differences in the treatment of conference publications. In disciplines like computer science, full-paper peer reviewed publications at the best conferences are of similar stature to journal publications. In social science disciplines, conferences have less stature and full proceedings often aren't published. Without rigorous full-paper peer review, the engineers on our team are unable to get academic credit for this work. This practice has inhibited the team from publishing in social science venues, and has limited our ability to attend social science conferences where we could network with a broader range of social scientists, especially those who are not focused on engineering.

Our research team has chosen to use the expedient conference and journal venues, like this one, for our work. We find ourselves constantly walking a fine line between giving the partial answers that fit the page limitations of these venues and ultimately responding to the broadly generalizable research question expected by funding agency program directors, reviewers and editors.

Lesson 4: Recognize that these disciplines have different conceptions and practices for written expression

In engineering, the writing of research papers and publications is considered an objective report of the researchers' understanding of data; whereas with ethnographic interview based research, writing is an analytic tool used to construct an understanding of data in a particular theoretical framework for a particular audience. As a result of the fundamental difference in the conception of written work, each discipline has its own form of written expression. Engineers tend to be concise and direct. Engineers take the complexity of the physical world and summarize it in mathematical formulas. While engineers rightly think of the physical world as complex, the physical world can usually be modeled by mathematics. The world of human experience, however, is not only complex but includes human free will that is not necessarily well modeled by mathematics. Practitioners in fields such as cultural anthropology have a different way of looking at the world. They recognize the complexity of human experience and are not comfortable with a simple mathematical explanation. Rich, textured, layered explanations including caveats that recognize this inherent complexity and subjectivity are expected and desired [33]. Thus, our partnered social scientists tend to want to include every detail, even if that makes an explanation long and complex. We (the engineers on the team) want to remove the texture and layering that the social scientists are working hard to add.

Social scientists often write in the first person and reflect on their personal involvement in constructing interpretation, as we are doing here. Engineers see this as overly personal and even unprofessional. There may be readers who are uncomfortable with this right now. Engineers want to create the appearance of complete objectivity. Social scientists acknowledge that the production of knowledge includes the producer, and that complete objectivity is impossible.

A team that contains members from these disparate disciplines has a major challenge producing written documents [23-25]. When we were learning to work together, we used to have individuals write part of the document, we'd circulate it through email and offer critiques and suggestions with change tracking and electronic comments, which the original author would integrate (or not) into the document. We found that this process was unsatisfactory because it didn't allow the authors to negotiate and construct understanding together. While the process is efficient in terms of time, it didn't allow for good scholarship.

Our next attempt to develop a collaborative writing process was to have one person produce a draft and then meet together to critique and change it. There is a vulnerability to having your work immediately critiqued face to face, rather like having a dissertation defense once a week. This painful process allowed for better scholarship, and eventually resulted in building of mutual trust and respect. The process was used in the development of our most acknowledged work to date [31]; an example is offered below.

Our anthropologist originally wrote the following sentence for an early version of that paper:

> According to LeCompte [34], the silenced offer a perspective that is counter-hegemonic; that is, their narratives offer a critique of the canon of existing social and institutional structures and hierarchies of power embedded there in.

After substantial explanation and negotiation with the scientists and engineers, the sentence became:

> According to LeCompte [34], the words of the silenced shine a sometimes unflattering light on existing social and institutional structures and hierarchies of power that are invisible to those in the mainstream.

Building on that mutual trust and respect, our current writing process involves writing each sentence together, one at a time, starting from a blank piece of paper. It is a very time-consuming process. For example, the production of this submission took more than three months of weekly meetings. The advantages include spending more time building shared meaning and understanding, which has greatly improved our mutual respect for each others' discipline, scholarship, and perspective. It isn't a time-efficient process, but it is a satisfying and productive one.

The collaborative creative process has enriched each of our intellectual abilities by allowing us to integrate values from different disciplines and see the strengths and weaknesses of our thought processes more fully. Engineering education research using social science methodologies that can be understood and accepted by engineers is well worth the effort.

Conclusion

Many engineers who study engineering education have, understandably, applied their engineering research skill set. As a result, obtaining statistically significant proof that interventions produce results that meet well-defined objectives is an accepted research paradigm. Studying education is not a typical engineering task. We shouldn't be surprised that tools for mathematically modeling physical properties of inanimate objects aren't as effective when studying humans who negotiate, resist and conform to social structures and hierarchies of power.

The most basic assumptions about how the world works are different in social science than they are in engineering, e.g. whether there is one universal knowable truth or not (positivism vs. naturalism). Building a symbiotic collaboration with social scientists required that we think about the world in an entirely different and new way. Intellectual growth of this magnitude is not something that could be accomplished quickly. To increase the excellence of our engineering education scholarship and effectively partner in the collaboration, we had to take the time and invest the energy to augment our engineering skill set with social science skills. We learned to:

a) think about the world in a different way; and
b) embrace textured, reflective written expression of research findings.

Furthermore, we had to learn to build bridges between the social science world we are adopting and the engineering world in which we live by:

c) preparing for the timeline of qualitative research; and
d) strategically framing qualitative research questions for engineering audiences.

One way to add the social science skill set to engineering education is to use social scientists as consultants. While this would undoubtedly improve the quality of engineering education research to some degree, we would predict that the process will be more satisfying, the product will be more meaningful, and the transformations more encompassing if the engineers are willing to

expand their intellectual repertoire to embrace, endorse, and incorporate the way that social scientists think about the world.

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