Exploring What Engineering Doctoral Students, Aspiring to Faculty Careers Learn About Research From Faculty Mentors

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Abstract - **This qualitative study explored the socialization process of doctoral students aspiring faculty careers. Using qualitative methods, 20 engineering doctoral students from four Predominately White Research Institutions were interviewed to understand what knowledge and skills students learned about research while working collaboratively with faculty mentors. Findings suggest that by conducting "problem solving" research during the research collaborative experience with faculty mentors, engineering doctoral students discovered their capabilities to contribute innovative research to the field that is highly competitive in addition to gaining perseverance during the research process.**

Index Terms – graduate education, socialization, mentoring

INTRODUCTION AND PURPOSE

Graduate research training should produce scholars who are able to conduct independent, original, and ethical research [1]. These skills, in particular, are essential for doctoral students pursing faculty careers because research is an essential aspect of faculty life. Maintaining an active research agenda is necessary for the success of faculty members. So, it is reasonable to assume that doctoral students, aspiring to faculty careers, need to be socialized to the research role of faculty careers.

This qualitative study explored the socialization process of doctoral students in engineering fields committed to a career as a faculty member. Specifically, this study attempted to understand what knowledge and skills [2]-[3] are acquired during research collaborations some doctoral students have with their faculty members. Core elements of the Graduate and Professional Student Socialization model (knowledge and skills acquisition, investment, and involvement) were used to explore doctoral student socialization [2]. Semi-structured telephone interviews with twenty (N=20) engineering doctoral students from four predominately White research institutions (PWRIs) were conducted. For purposes of this study, faculty mentor was defined as the person who collaborated with the doctoral student on a research project and who the doctoral student identified as the person having the most significant role in helping to prepare the doctoral student for a faculty role. Doctoral students were defined as graduate students at four research universities, located in the Northeast, Midwest, and Southwestern regions of the United States, who were enrolled full time and who had finished their course work. Research collaborative activities included a range of activities (e.g., conducting research, writing for scholarly publication, presenting at professional meetings) that the doctoral student engaged in with a faculty member. This research was guided by the question: What do engineering doctoral students, aspiring to faculty careers, perceive they learn about research through their research collaborative experiences with faculty members?

THEORETICAL FRAMEWORK

The Graduate and Professional Student Socialization Model [2] was used to explore how engineering doctoral students are socialized to research. Knowledge acquisition, investment, and involvement are considered key to the socialization process of graduate and professional students. These core elements (knowledge acquisition, investment, and involvement) are acquired through involvement with peers, the graduate or professional program, and by the student becoming invested in the knowledge and skills of the program, all of which, result in the graduate performing effectively in his or her area of professional practice. For purposes of this study, one of the core elements (knowledge acquisition) will be the focus of this paper. Knowledge acquisition involves the process of acquiring cognitive and affective knowledge. Affective knowledge includes an awareness of professional role expectations and an assessment of one's ability to perform role expectations successfully [4]. Figure 1 displays the theoretical frame. The highlighted section refers to the focus of this study.

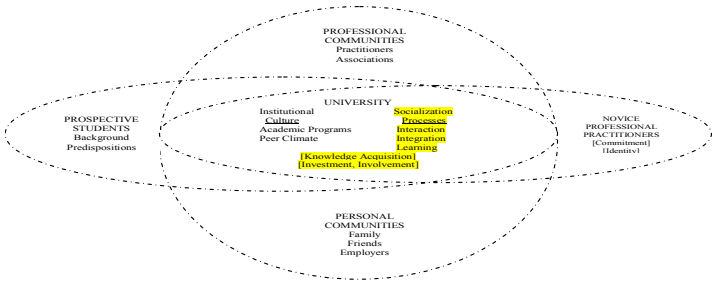

FIGURE 1
CONCEPTUALIZING GRADUATE AND PROFESSIONAL STUDENT SOCIALIZATION.

METHODS

Twenty full-time doctoral students (N=20) in engineering fields at four Predominately White Research Institutions (PWRIs) from the Northeast, Midwest, and Southwestern regions of the United States participated in this study. Participants were recruited with the assistance of department chairpersons and faculty members from each of the institution's engineering graduate program areas. Purposeful sampling methods [6] were used by selecting engineering doctoral students who were enrolled full-time, had completed their course work, had research experience (e.g., experience conducting research, presenting, or writing for publication), had a faculty mentor, and had aspirations of joining the professoriate upon completing their doctoral studies. Table 1 displays a detailed description of sample participants.

TABLE I
SAMPLE DEMOGRAPHICS OF ENGINEERING SAMPLE PARTICIPANTS (N=20)

Department	*Number*
Bio-engineering	1
Mechanical	8
Computer Science	3
Programming Languages	1
Civil	2
Chemical	2
Environmental	1
Electrical	2
Gender	
Male	15
Female	5
Ethnicity	
Asian/Pacific Islander	4
Caucasian	10
Black/African American	1
Hispanic/Latino(a)	3
Did not identify	2
Age	
20-30	14
31-40	6
41-50	0
Year in program	
Second	3
Third	5
Fourth	7
Fifth	4
Beyond fifth	1

Data Collection

Semi-structured telephone interviewing was used as the technique for gathering data. Interviews were audio-taped and transcribed verbatim. Each interview lasted for approximately 45 minutes to one hour and followed the same interview protocol. Participants were asked questions about their research collaborations with faculty, particularly, what they learned about research during this process.

Analysis

Data were analyzed using the constant comparative method, a method for code building where the researcher compares data from various sources (e.g., interviews, documents) to find similarities and differences. This process results in patterns, themes, and ultimately overarching conclusions related to the experiences of participants [5].

Trustworthiness

Trustworthiness in qualitative research ensures that quality and rigor of the research process was achieved. Trustworthiness is typically achieved using four criteria: credibility, transferability, dependability, and confirmability [7]. To enhance the quality and rigor of this study, I employed several steps using these criteria.

Credibility refers to how trustworthy a study's conclusions are and how close those conclusions match to the reality of participants [8]. Stated another way, a qualitative study is credible if the study's findings are believable to an outside reader [9]. I employed member checking during and after the interview process with participants by probing and restating participants' comments and sharing interview transcripts with participants after interviews were completed. This step ensured that I interpreted participants' statements accurately. I later shared findings with participants after the analysis was complete to verify accuracy. This step ensured that there was congruence between the participants' views of their experience and the researcher's interpretations of those experiences.

Transferability in qualitative research refers to how generalizable the study's findings are. That is, how well can the study's conclusions be generalized to a larger population [9]? This was achieved by using purposeful sampling, thick description, and piloting the study [8]. I intentionally sought engineering doctoral students who had research collaborative experiences (prior to the dissertation), had completed their course work, had a faculty member they considered to be their mentor, and had aspirations to be a faculty member after completing their programs. Thick description was achieved by gathering demographic information (e.g., discipline, program area, number of years in program, gender, ethnicity, age, amount of time in mentoring relationship, rank of mentor) about each participant during the pre-screening process prior to interviewing, to help the outside reader gain some context of the type of participant being represented in the data. A pilot study was conducted, prior to this study, using a smaller sample of engineering doctoral students at a similar institutional type (PWRI). This step allowed the researcher to anticipate findings from the larger study.

Dependability in qualitative research is concerned with how reliable a study's research process is. The researcher takes care to ensure that the research process is logical, traceable, and well documented [8]-[9]. This was achieved by maintaining an audit trail [10]. An expert

reviewer, trained in qualitative research, examined all aspects of this research process. For example, the expert reviewer examined (a) the purpose statement, (b) the interview protocol, (c) the theoretical framework, and (d) the data and notes relevant to the analysis process to see how the researcher reached conclusions and findings from the study. An independent reviewer was also used to inspect the research process, including the analysis. The independent reviewer had no connection to the study.

Confirmability in qualitative research refers to measures the researcher took to control the introduction of biases or selective perception [9]. The researcher is particularly concerned with linking assertions and interpretations to the data. To control for this, I took notes (i.e., journaling) throughout the research process, about my own biases and judgments so that they would not get in the way of me developing objective findings. For example, I had to remove my ideas and notions of what I thought about graduate education or what it would be like to be an engineering doctoral student conducting research with a faculty member.

FINDINGS

Through interaction with faculty mentors, doctoral students in engineering disciplines perceived that their research skills and ability to critically approach research improved. As sub-themes to learning about the research process as a whole, participants learned how to communicate research, the realities of research, how to conduct problem solving research, and about the competitive nature of research in their respective fields. Table 2 displays initial codes established during the analysis process and definitions of those codes. Table 3 displays categories established from the initial codes.

TABLE 2
CODING DICTIONARY

Code Name	Code Description
Conducting research	The act of analyzing data, interviewing participants, conducting literature searches, running experiments participants engaged in
Designing research	Conceptualizing a research study from beginning to end
Research methods	Involves the process of designing a research project and the process of conducting research
Publishing process	Involves the process of writing scholarly/research work for publication purposes in journals or reports
Presenting research	Involves the process of presenting orally scholarly/research findings to various audiences (e.g., professional associations, granting agencies, secondary or post secondary communities)
Doesn't go as planned	Occurrences in the research process that were not planned and/or led the research process in a different or unexpected direction
Answering unknown	The process of conducting research that involves solving a problem that is unknown in a particular field
Research takes luck	The nature of the research process that appears to happen by chance
Grant process	Involves the process of learning about grant funding, writing proposals to secure external funding to support research
Translational work	Involves research that is conducted that has the potential to apply to (or translate to) a different setting (work setting, secondary education, postsecondary education, etc.)
Competitive field	Includes research that is cutting edge or the pressure/importance of publishing research or securing grant funding

Note. Coding dictionary includes definitions for initial codes developed throughout the analysis process.

Communicating Research

Communicating research involved writing research findings for publication purposes, presenting research findings at research conferences or national meetings or other venues and writing research for grant purposes. Twelve participants (n=12) discussed how to write and verbally communicate research results to different audiences. Consider the quote from Bruce, a third year programming languages doctoral student:

It's important to be able to explain why you're doing what you're doing. Sort of be able to motivate it to a diverse set of audiences from people who are more or less outsiders to computer science all the way to people who are, you know, technical experts in my particular area and know all those little details and so they want to know what makes my particular aspect of the problem interesting. Sort of selling what I'm doing.

From his experience, Bruce was able to figure out ways to "sell" his research to different audiences.

TABLE 3
KEY FINDINGS

Category Name	Participant Quote
Research Process	I've done everything from experimental design through analysis to synthesis into a paper and followed that with writing grants for future research (Iggy, environmental)
Communicating Research	I've learned how to be a better writer and orator or speaker, and most importantly, how to do what you would call good research, which is, having a well-thought out experimental design that fits well into the literature and can be presented well both orally and in written form. (Joyce, computer science)
Realities of Research	Seeing how people get involved with a bigger project, seeing things come out more incrementally in terms of publishing. So that surprised me at first, it was the first paper we wrote, and I felt like we were kind of three quarters of the way through finishing our results, but, you know, the demands of wanting to get it published in this year's journal meant, okay, let's write it up now. So, that was a surprise to me, and then I guess just the kind of the more you know, after two years, how do you decide whether to continue or work on new questions or discard everything and work on something completely different. Those are things I hadn't really thought about. (Tom, computer science)
Conducting Problem Solving Research	As far as an approach I think the take from him [mentor] would be certainly you always have mini problems to attack, and what's the most important? What is going to give you the biggest bang for the buck so to speak? Don't solve menial problems when there's a much larger problem to solve. (Christopher, mechanical)
Competitive Nature of Research	The thing I've learned is that first of all you do the research that's going to get the funding. So, I mean the basic technical skills are there, and the tools are there, but you are going to have to keep forming research questions that are aligned to whatever the most funded types of research are. You have a chance of not being successful. So, you look at what's being funded either by the federal organizations or the government or companies and then you try to see how your skills and techniques fit with those and you align your research to those. (Amy, mechanical)

Note. This table represents a snapshot of key findings, including quotes from some of the study's participants. Communicating research, realities of research, conducting problem solving research, and competitive nature of research are sub-themes to the main finding, research process.

Realities of Research

Thirteen (n=13) participants talked about some of the "realities of research" they experienced during their research collaborative experiences. For example, participants described the research process as being time consuming, not going as planned, and being competitive. Consider the statement by Jacob, a fifth year, mechanical engineering doctoral student who states: "*One thing I definitely found out is that experiments go wrong and they take a lot of time, a lot more time than you actually plan and so now I've learned to account for that when running experiments*."

From Jacob's experience, he was able to anticipate the uncertainties that come with conducting research. He now plans accordingly.

Conducting Problem Solving Research

Participants spoke about approaching research projects with the end goal of solving problems. Sixteen participants (n=16) described the nature of running experiments to solve engineering problems. Kelsey, a second year civil engineering student spoke about how the work she is doing now in her doctoral program is challenging her to tackle engineering problems at a much deeper level than she was used to doing in industry.

Well, the work that I did previously, like I said in consulting is very different. Much more kind of using established tools and maybe solving a particular problem in different ways, but you're not really trying to get them to the core or the theoretical basis of things and pull it apart where in research it's really what you are doing is kind of questioning everything, starting something from the bottom up and looking at the steps you do along the way and how, what everything means along the way. I'm doing hydrological modeling, which I've applied the models and used the models before, but now I have to look at it in much more detail and really think about how the model is working, asking questions that I never asked myself before that are really difficult questions to answer and to understand so it is much more taxing mentally.

Competitive Nature of Research

Participants also talked about the competitive nature of the research they were conducting with their mentors and in their field in general. Most shared stories of how difficult it is to publish in their field and how important it is to craft research ideas to granting agencies, for example, to ensure funding. Coco, a third year mechanical engineering doctoral student spoke about the importance of having new ideas and techniques to publish in his field. He states:

I consider that in my field, for example, it's a field that has been growing for 100 years. It's becoming more and more difficult to publish compared to other fields. So, it is required that I have really good insight, really good background, and also new techniques. (Coco, mechanical)

Similarly, Martin, a fifth year, chemical engineering major talked about conducting sound research and publishing it. He comments:

The publication of successful work, demonstrating that you can carry the project to a successful conclusion or produce some meaningful results is critical in establishing yourself as a potential faculty candidate.

This comment illustrates an important value learned during this student's research collaborative experience with his mentor.

DISCUSSION

This paper examined what knowledge and skills engineering doctoral students learned about research during their research collaborative experiences with faculty mentors. Using the core element (knowledge acquisition) of the Graduate and Professional Student Socialization Model [2], engineering doctoral students aspiring faculty careers gain a holistic perspective about research, which involves learning about the process of conceptualizing a research idea, conducting experiments, and disseminating research results to a broader audience. Specifically, engineering doctoral students learned how to communicate research, the realities involved with conducting research, what it means to conduct research that solves problems, and the competitive nature of the research process.

Consistent with the literature, participants gained the necessary skills and knowledge to conduct research as a future faculty member [2]. Stated another way, participants were socialized to the research role of faculty life by engaging in research collaborations with faculty mentors. Participants learned what was considered valued in their fields—conducting sound research, publishing, and securing grant funding for research [11]. From their experience, participants perceived that their skills and ability to conduct and write about research improved. This may enable them to be competent researchers as faculty members in the future.

IMPLICATIONS

Findings from this study have implications for practice and research. In terms of practice, engineering doctoral students, considering faculty careers might uses these findings to get a realistic view of what a faculty role might entail. For example, participants in this study not only learned how to conduct research and the importance of publishing research in their fields, but they also got a clearer picture of how competitive their fields were and the unexpected turns that research could take. Identification and discussion of this realistic faculty duty—conducting research and all that is involved with maintaining a scholarly life, may be useful to engineering doctoral students thinking about a career in the professoriate.

Graduate faculty who supervise and take on the role of "research mentor" to engineering doctoral students might also find this study useful. As primary socializing agents for doctoral students [2], graduate faculty members are in a unique position to provide realistic pictures of their roles and to ensure that doctoral students are acquiring the knowledge and skills needed to be successful conducting independent research. In terms of the actual research process, faculty members can make intentional efforts to be fully engaged in the research process with their students. For example, faculty might talk about the research process, analyze data, and write the study's results together. These activities may prove beneficial for doctoral students during this learning process.

This study also has implications for future research. I explored research related activities that contribute to the socialization of engineering doctoral students. Future studies might explore how engineering doctoral students are socialized to the teaching and service roles of a faculty career. Participants in this study were all from research universities. Additional studies might explore the socialization experiences of engineering doctoral students at different institutional types (e.g., comprehensive, private, minority serving institutions). Future studies might also consider the socialization experiences of specific groups (e.g., women and ethnic minority engineering doctoral students) to learn if there are differences in what these students are learning about research that prepares them for a faculty career.

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