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The chemical engineering research laboratory as context for graduate students' training: The role of lab structure and cultural climate in collaborative work

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ABSTRACT

The current study investigated the experiences of engineering graduate students in two interdisciplinary research laboratories studying materials engineering, their perceptions of influences on their learning and goals, and the collaborative tasks needed to produce quality journal articles. In a qualitative inquiry using constant comparison methods, data came from individual interviews of lab members and observations. Findings coalesced in three themes. First, the lab structure and lines of communication seemed to influence group collaboration and individual learning. Second, the importance of peer collaboration seemed crucial to students' knowledge acquisition through lab work. Finally, a lab's climate and culture influenced individuals' productivity and motivation to participate in research, sometimes facilitating, sometimes impeding progress in becoming fully participating lab members. Contributions include providing a better understanding of how engineering graduate students' lives in the lab are situated and intertwined with group collaborative processes.

1. Introduction

With this study, we hoped to contribute to the literature on the nature of collaboration in engineering graduate education by focusing on engineering graduate students' experiences when working on large projects as lab members. We wanted to explore the various subjective experiences of graduate students as they engaged a group environment relatively new to them as part of their professional development, the engineering research lab setting. Finally, we were interested in the cultural challenges graduate students experienced as they met the particular social and cultural characteristics of their lab on their way to becoming scientists and engineers.

2. Literature review

We draw on three bodies of literature to support this study of graduate engineering laboratory life. First, we reviewed what is known about characteristics of engineering graduate programs including the cultural diversity of U.S. engineering graduate

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programs. Second, we describe studies about learning as it occurs in the collaborative environment of engineering research laboratories. Lastly, the literature on the climate and social context of the engineering laboratory is reviewed as a way to understand better engineering graduate students' learning in a collaborative environment.

2.1. Engineering graduate programs

Engineering graduate programs in the United States are designed to educate students to conduct sophisticated research in particular sub-fields of engineering, often through participation in research projects. Saddler (2008) noted that it is common for engineering graduate students to participate in research projects with faculty members in a designated research space that is linked to their interest. In a few years of training, students need to be able to produce quality research reports within their disciplinary area (MacLachlan, 2006). In order to graduate, engineering graduate students are often required to produce several peer-reviewed quality research papers in the field and one capstone dissertation project to demonstrate independent research ability (Keltikangas & Martinsuo, 2009). Engineering laboratories at major research universities typically embody a large and complex lab structure consisting of a principal investigator (usually a faculty advisor), together with postdoctoral fellows, graduate students, and undergraduates, working on projects designed to fulfill the advisor's funding plans (Crede & Borrego, 2012).

Another aspect of engineering graduate schools is the increasing inclusion of international members in the laboratory. Sowell, Allum, and Okahana (2015) reported that there are noticeable numbers of international engineering graduate students pursuing graduate degrees in U.S. research universities making significant contributions to research projects. Le and Gardner (2010) claimed that cultural understanding, and a consideration of differences in language, sociocultural environment, and educational experiences become crucial contributors to the productivity of engineering labs. Potential barriers, and especially language and cultural differences, may affect lab members negatively in both their social and academic lives, blocking the collaboration that is essential to successful lab projects.

2.2. Learning in the collaborative environment of engineering research laboratories

One aspect that distinguishes the experience of engineering scholars from several other disciplines is the great reliance on collaborative work that engineering endeavors require. Saddler (2008) described characteristics of engineering graduate school as a collaborative learning environment that often includes members from widely diverse cultural backgrounds and working experiences. Anderson and Swazey (1998) reported that engineering graduate students generally spend intensive time in their lab engaged in collaborative projects with faculty advisors and fellow students. In an ethnographic study of science and engineering graduate students, Bucciarelli (1994) emphasized the importance of interactions among students and the socio-cultural aspects present in modern university engineering research labs. Crede and Borrego (2012) described the need that engineering graduate students have to learn how to conduct experiments through interactions with fellow lab members because faculty members are often not accessible, especially in labs that include many researchers and multiple projects. Similarly, in an investigation of the learning that occurred in a biochemical engineering laboratory, Nersessian et al. (2003, July) highlighted how new lab members learn fundamental procedures, such as how to handle lab equipment, from more experienced fellow lab members.

Further, Loui (2005) claimed that engineering graduate students are required to have a proactive attitude for their learning, and they need to collaborate with their lab members to acquire their disciplinary skills. Seixas (2000) reported engineering doctoral students often experience difficulty when they try to obtain technical knowledge needed to choose, set up, and use the equipment necessary for their specific research topic because there is no formal learning structures in the lab. In addition, as Crede, Borrego, and McNair (2010) and Anderson and Swazey (1998) reported, there is a great need for engineering graduate students to develop sufficient interpersonal communication skills in order to learn in their research lab, a need recognized by engineering graduate students themselves.

Therefore, it is common for engineering graduate students to experience stress and discouragement from relationship issues and role conflicts in the lab. Crede, Borrego, and McNair (2010) reported that lack of social interactions among engineering graduate students in their lab negatively influenced students' professional development. In addition, they addressed that engineering graduate students often experience problematic tension with other lab members that significantly influences their well-being and prevents them from generating new research ideas and best practices. Katz and Martin (1997) addressed that the benefit of collaboration is the transfer of knowledge or skills because it can be time-consuming for an individual to acquire massive new information in the field on his/her own. They added that collaboration in the lab is one way of transferring and confirming new tacit knowledge before it is sent out to the world. Therefore, research collaboration in the lab requires not only scientific and technical expertise, but also the social and management skills to be part of a team. Katz and Martin (1997) emphasized that these social skills may not be readily taught in the classroom.

Finally, Bozeman and Corley (2004) addressed how well collaboration among lab members provides various benefits to engineering graduate students. For instance, scientific collaboration in the lab often plays a critical role in developing individual research abilities, especially in those cases where the collaboration takes on mentoring characteristics and a more experienced graduate student collaborates with newer graduate students. When new graduate students partner with senior students, they can develop a wide variety of knowledge, craft skills, and know-how, as well as the ability to structure and plan research, and make contacts with other scientists, industry, and funding agents.