Buried Bones: The Treasures of Implicit Knowledge and the Graduate Engineering Student Experience

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Abstract

Returner graduate engineering students—those students who have spent five or more years in industry before returning to the classroom—have constructed identity through their practice that involves not only the path to expertise, but also a worldview that incorporates lessons learned in the practice of engineering [1]. Our research shows that their view of their graduate studies differs from that of their direct pathway peers—those students who have spent less than five years in industry before attending graduate school. Returners bring with them the notion of community of practice, which denotes a group of people engaged in “a process of collective learning” for a specific purpose [2]. Much of the learning from communities of practice is implicit, that is, learned episodically and enroute to solving the problem at hand, and situated—within a social and contextual environment. Our participants discuss the differences they see between workplace and classroom learning that involve the notions of implicit knowledge and situated learning that benefit all students. We make recommendations for professors of engineering to leverage these aspects of their students’ workplace learning to create a more robust community of practice.

Introduction

Professional identity is the state of knowing in which a person looks at the world through the lens of the particular habits of mind cultivated through practice [3]. There is implicit knowledge [4] as well as training in the field. Work experience builds the capacity of individuals to assume a professional identity. This begins with undergraduate studies, but deliberate practice helps shape expertise [5]. Communities of practice (CoP) have been seen to be instrumental in creating knowledge and in mentoring [1]. Assumptions on professional identity and ways that instructors might be able to leverage the experience and expertise of graduate engineering students who have had more than five years in the field as professional engineers before returning to the classroom—is instructive to the engineering education community. For this research, it was instructive to study the responses and experiences of two groups of graduate engineering students, returners, those students who have elected to return to graduate school after five or more years in industry. Direct pathway students in this study, a separate group, are considered to be those who spent less than five years in industry before returning to formal education. This includes those students who completed bachelor’s and master’s level degrees simultaneously.

Returners as a group are not a tracked demographic, although there are statistics on the number and ethnicities of graduate engineering students [11]. This study sought to better understand the differences between returners and direct pathway engineering students. An intriguing theme was that returner engineering graduate students have skills and habits of mind that they willingly utilize in graduate work. Instructors can draw on these skills in a more intentional manner to increase learning for all students.

Literature Review

Communities of Practice

The contributions of experienced workers relate to the notion of communities of practice [1]. In a professional context, Communities of practice (CoP) allow for shared problem-solving within a specific domain [2]. An exciting aspect of CoPs is that they allow for learning to take place around real-world challenges. CoP create an environment of shared practice for a specific goal [6]. For researchers, it is a way to better understand adult pedagogy within a constrained environment such as a workplace and to document ways that workers in any industry change their approach to learning in general as well as ways individuals interact in particular: the new CoP is a type of social network based on the workplace that shares not only knowledge, but values and experiences [7], [8].

Contributions of Returners

Returners have been identified in the literature [9], [10]. Graduate engineering students are a tracked demographic [11], but the different levels of on-the-job experiences of students before attending graduate school is not. Their reasons for attending graduate school vary [12]. The average of years that returners wait before attending graduate school is 9.5, whereas for direct pathway it is 1.3 [12]. Ostensibly, they practice as engineers for this length of time before returning to the classroom. These years of practice hone the professional identity of returners.

Professional identity

Professional identity formation (PIF) refers to the level of internalized identification with a specific group of professional individuals. Professional identity is cultivated intentionally in schools of engineering [14]. It is further shaped by experiences in practice and involves not only explicit knowledge, such as how to apply engineering principles, but also in implicit knowledge that is learned from colleagues, mentors, and leaders in the organization [1]. Implicit knowledge informs PIF [1], [2], [4]. It is situated, that is, tied to the particular topic or problem that is being solved [15]. This knowledge is subsumed into the identity of professionals. Reflective practice as outlined by Schön is also an aspect of PIF. Identity is shaped not only by the community of practice, but also by constant reflection on action [16-18] and is essential to the emergence of expertise.

Teams

In formal education, group work as a concept can be abhorrent to many students. The main reason seems to be that the value of working with others to complete a task seems an added layer of complexity [19]. Group work is designed to allow students to develop communication skills [20]. Individuals may find group work frustrating, because there is an artificial framework around completion of the tasks that does not draw on the strengths of the individuals involved, nor on their acumen to complete the task. In a well-organized team setting, on the other hand, the expertise of the individuals is valued [21]. Engineering teams are made up of coworkers with strengths in different disciplines [12]. The implicit knowledge remains with the team and helps to maintain professional identity [2]. Engineers do not work as individuals to complete lone projects, and team members know the disciplines of their fellows [12].

Methods

This mixed-methods study was part of a larger National Science Foundation project to graduate engineering student learning specifically, and how participants' experiences between undergraduate and graduate studies affect their approaches to learning in graduate school. The project involved a convenience sample of graduate engineering students in the United States who had also completed their undergraduate degrees in the U.S. Approximately 80 graduate schools of engineering were contacted to find participants. Internal Review Board approval was sought and received. Data collections involved surveys and in-person interviews, a validated calculus concept inventory, and concept maps generated by the participants. The anonymized surveys were first field-tested and then deployed via the platform Qualtrics to over 300 respondents, both returner and direct pathway. Of these, 21 returners and 20 direct pathway students were interviewed in person. The interview questions were also first field-tested to ensure accurate responses and were centered around participants' learning habits and experiences in graduate school.

Results

These results are part of a larger study that included not only interviews, but also surveys, a calculus concept inventory, and concept map construction. The responses of the two groups of students—returners and direct pathway—were similar in many areas. The calculus concepts inventory [22] showed that the two groups were similar in remembering these mathematical concepts. Understanding of software types, such as excel and others, was similar as well. There were some key differences. In the survey, three statements regarding engineering self-efficacy showed statistically significant responses. These were:

- Synthesize information to reach conclusions that are supported by data and needs
- Identify the safety concerns that pertain to a project that you are working on
- Analyze the tradeoffs between alternative design approaches and select the one that is best for your project

Regarding lost learning or understanding concepts introduced in class, returners stated that they opted to read textbooks and use the internet as their method to understand concepts or refresh their memories regarding specific topics. Direct pathway were more apt to try to understand the content in terms of connecting it to what they already knew. When asked about specific supports students found most helpful, returners much more than direct pathway believed that a teamwork approach to learning was the best way to foster learning. They stated that they believed, as one respondent put it, that "graduate school is a team sport." More than one returner mentioned taking the initiative to create a study group independent of instructor or teaching assistant suggestions. The response of one returner was that he was confounded by the lack of interest in these types of support systems, as he felt they would be extremely beneficial. When asked about teams that students participated in at work, everyone agreed that they knew the discipline and specialty of everyone on the team. When asked whether the practice of engineering was what they envisioned that it would be, many said that the amount of teamwork involved was different than they expected. Undergraduate experiences made them believe that they alone would work on a process or project, but they said that the practice is much more interdependent than they expected.

Discussion

The statistically significant areas where returners had higher levels of self-efficacy (Synthesize information to reach conclusions that are supported by data and needs; Identify the safety concerns that pertain to a project that you are working on; Analyze the tradeoffs between alternative design approaches and select the one that is best for your project) all imply the application of an underlying body of knowledge. Because returners have had experience in these areas, they are more apt to hit on a conclusion without really being able to articulate their tacit understanding. If direct pathway were able to tap into this wealth of knowledge, it might help them become more able to identify these aspects of an engineering project as well. Returners are coming to graduate school with the notion of Communities of Practice (CoP) firmly embedded in their daily experience. CoP is situated, contextual environment where people come together to solve a problem [1]. The knowledge within CoP is tacit [15]. Because it is tacit, people learn from one another in practice. Another aspect of the use of the model of CoP in graduate school is that tacit knowledge helps grow expertise [23]. Returners have knowledge regarding the practice that can be passed on to less experienced engineering students just by working with one another. Since learning is situated, it is best to learn in contexts that best mimic where this learning will be put into practice.

Returners know that teamwork approaches to problem-solving not only helped in their work but is intrinsic to the success of any engineering project. The fact that many participants stated that the practice of engineering was not what they thought it would be was telling. It seemed to be a misapprehension of many direct pathway students. Many respondents stated that they thought they would be working alone in an office, contributing by completion of assigned tasks. Although this is certainly an aspect of engineering work within industry, respondents remarked that in practice there was much more interaction and deliberation regarding the work. One way to counteract this and to help students to understand this framework is to emphasize systems thinking in the classroom in order to train students to think in terms of the whole goal rather than individual targets. This seems to be an indication that their undergraduate work (and even work up to college) was never really understood within a larger context. Once engineers gain experience, they realize that they not only cannot know everything necessary to complete a project, but also that the team is responsible to one another as well as to the work. Returners know this and can lead less experienced students in this understanding. Instructors can emphasize the utility of many knowledgeable people working together can create something that is actually better than its parts alone can be. Intentional support and encouragement of study groups in terms of levels of experience, discipline, and interest may help students at all levels to surpass what they could do alone.

Conclusion

The conclusions this investigation generated were not only from the interviews, but also the fress response questions in the anonymized survey. Participants had experience both online and in person. This mode of delivery did not seem to make a difference~ the returners consistently identified the teamwork aspect of learning that seemed to grow from their experience in industry. Participants were contacted through schools of engineering, not all of which consented to share the call for participants. Returners are generally more experienced than direct pathway in the principles of engineering, although both are in the same classes together. This can be seen in the self-efficacy data. It makes sense to capitalize on the needs and strengths of both direct pathway and returners by cultivating a community of practice within the student experience to mutually benefit both groups of learners.

Limitations

The participants who were part of this study were a convenience sample. This was a limitation, because there was no randomness involved. Students self-assigned their willingness to complete the survey as well as well as consenting to be interviewed. As well, the experiences of students who now have had to work while in lockdown due to the pandemic might give more nuanced results regarding teamwork and Communities of Practice. However, the graduate engineers in this study were focused and persistent in their pursuit of the degree, and returners felt that teamwork to tackle the problems introduced in the classroom was ultimately the best way to learn.

Recommendations

In further research, it would be informative to ask returners directly why working together to learn is better than traditional methods. As well, the engineers who did not choose to go to graduate school have not been sampled. Why they chose not to return and how schools of engineering might support them either informally or to offer specific and tailored learning in the workplace for credentialling may also be informative in terms of building engineering identity as well as communities of practice within industry. It is of interest to note that, while the main bulk of students did not hold another degree, a few students had pursued and obtained a master's in business administration before returning for a technical degree. Perhaps in order to better serve graduate engineering students, portions of this degree or a joint degree might be a draw for more students.

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