The Laboratory Practice of K-5 Teachers in an Engineering RET: Triangulating Perceptions and Experience

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Abstract

This study advances our team's overall design and development goal of creating a valid and reliable observation protocol for science and engineering practices (SEPs) experienced by teachers working in research laboratories under the auspices of Research Experience for Teachers (RET). This protocol offers the potential for addressing a wide range of persistent questions related to the experience of RET participants by looking inside the blackbox of apprenticed professional research practice. Framed by cognitive apprenticeship and situated in an engineering RET for K-5 teachers, we independently document the SEPs that were consistently experienced across laboratory contexts and thus define a generalized teacher experience. Further, we identify key associations among the teacher's perception of their work, an independent observation of that activity and the perceptions reported by their graduate student mentors. Findings indicate that teacher participants' perceptions of involvement and not actual experience was a more important predictor of confidence in practice. Perhaps most striking was the negative relationship between teacher confidence when working with mentors ($r = -.242$), which is similarly described by the mentors for working with teachers ($r = -.356$). This implies a strong need for further work and support for helping these unique individuals to understand each other's goals and perspectives and for finding a way to work together that generates mutual feelings of confidence and satisfaction.

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In an educational context, the term *research experienc*e is most often used to denote a first-person, domain-specific inquiry practice that is intended to educate and produce new knowledge. In engineering as well as the various domains of the physical and life sciences, such forms of participation most often involve working in a research laboratory. Research experiences can occur across the educational continuum, including internships and other forms of field-based activities, but empirical research has focused on their use with only two primary populations, undergraduate students and as short-term summer programs for in-service teachers. The U.S. National Science Foundation has historically supported two programs that target each of these audiences. Namely, Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET). Such experiences are principally used as a form of science education for two reasons: 1) as a means for building identity with and/or skills appropriate for the domain (i.e., supporting career interest and persistence) and 2) for supporting a curriculum development or lesson planning process where an approximation of what was experienced is used with younger students [1].

Though the general goal of a research experience is well articulated, little is known about the activities and interactions that actually occur in the laboratory space. An entire range of fundamental questions persist regarding the nature of the experience and the assumptions about how these engagements impact participant development. For example: *Once placed in a research laboratory, what sequence of practices do participants experience?* or *What set of practices and expected duration generalize across all research contexts?* and finally, *Which sequence of practices and duration are most effective for building positive participant beliefs about themselves as researchers as well as their research skills?* Answers to these types of questions have thus far only been available by self-report through such sources as surveys or personal journals [2].

This study advances our team's overall design and development goal of creating a valid and reliable observation protocol for science and engineering practices (SEPs) experienced by teacher participants working in engineering research laboratories under the auspices of RET. This protocol offers the potential for addressing the persistent questions related to participant experience by looking inside the blackbox of apprenticed professional practice in the authentic context of a research laboratory. Data derived from this method, which can be viewed holistically or chronologically, can be used to triangulate and enhance other forms of data, for defining new processes or explaining outcomes, and ultimately for enhancing the function of this form of science education. Framed by cognitive apprenticeship and situated in an engineering RET for K-5 teachers, we sought to address the following:

- **RQ1.** What SEPs are consistently experienced across contexts and thus define the teacher experience?
- **RQ2.** What relationships exist among the teacher participant's perception of their work in the laboratory, an independent observation of their practice, and the perception of their graduate student mentors?

Theoretical Framework

Apprenticeship is a term used to describe the social process of coming to know and participate in the practices of a profession [3]. This process is recognized as involving a reciprocal relationship among more experienced people (i.e., a mentor or multiple mentors) and a less experienced mentee or protégé. Historically, apprenticeship has implied the learning of a trade or collection of motor skills, such as those involved with repair or construction. However, as the process has been subjected to more rigorous study, the theory of cognitive apprenticeship has emerged, which encompasses the thought processes as well as the skills to solve complex problems within a domain [4].

Donovan & Bransford [5] define cognitive apprenticeship as "the process through which a more experienced person assists a less experienced one, providing support and examples, so the less experienced person gains new knowledge and skills" (p.363). The theory is grounded in findings that show that experts are not born with special abilities [6], they are developed with access to information, support, mentoring, and focused intensive practice [7]. In addition to the declarative and procedural knowledge of a domain, the processes of cognitive apprenticeship include heuristics, mental models and habits of mind [4]. This implies that mentors need to be reflective about learning goals, methods of learning, the sequence of activities, and the optimal learning environment [8]–[10]. Successful apprenticeships occur when thinking and practice are made explicit by mentors so that they may be studied and acquired by protégés in an interactive and systematic fashion. Apprenticed learning is recognized as involving four dimensions:

A. **content** – the types of knowledge,
B. **method** – the ways to promote development,
C. **sequencing** – the order of events, and
D. **sociology** – the social characteristics of the environment.

These dimensions are further divided into 16 components, such as heuristic and control strategies for the content dimension or modeling, coaching and scaffolding for the method dimension. This hierarchy of dimensions and components provided the basis for understanding and interpreting the activities of a research laboratory as situated forms of professional practice.

Research Involving RET's

Prior to the inception of the NSF RET program, the first large scale evaluation of teacher research experience programs was initiated as *The SWEPT Study* [11]. Findings from this study of eight SWEPT sites showed that participating teachers experienced a gain in science content knowledge, positive attitudes towards science and interest in engaging in inquiry-based instructional practices. Following the SWEPT study, other significant evaluations indicated that teachers engaged in literature searches and reading about concepts related to the research in their laboratory, performed a variety of procedures, experienced and overcame frustration, applied logic and creative insight to analyzing their data, presented their research to peers, and contemplated ways to transfer lessons learned into their teaching [12], [13]. While these studies did not support the finding that all teachers were engaged in all five of the features of scientific research, the activities they described were consistent with an authentic research practice experience.

The first broad-scale RET program evaluation was conducted by SRI International that examined all of the 2001-2006 funded programs [2]. Given that RET sites were funded as a sort of extension of REU's, it was surprising for the findings to report that, "the undergraduate experience focuses heavily on doing research, whereas the teacher experience focuses much more on watching, listening, and developing classroom plans" (p.18). In fact, only 55% of RET teachers reported that they "collected and/or analyzed data or information to try to answer a STEM research question" (p.18) compared to 86% of reporting REU students in a similar study. Additionally, in a question related to allocation of time during the RET, "participants were much more likely to report that they had spent too little time than too much time on hands-on research and curriculum development activities" (p.22) and only 50% of respondents reported being "very satisfied with the extent to which they were an integral part of a research team" (p.26). Still, in questions related to the lasting impact of RET, teachers often cited aspects of the research experience itself as powerful catalysts for change.

Methodology

This study involved a single case descriptive and correlational study of an engineering RET for K-5 teachers that focused explicitly on the summer research experience. Participants included teachers from the local school district (N=20) working in pairs, each assigned to a pair of full-time engineering graduate student researchers (N=20) (henceforth, GAs). Data were derived from two years of implementation with different participants, from the years 2018 and 2019. Participant perspectives were captured in a series of daily activity logs. The teacher activity log asked them to: 1) describe their work in the lab, 2) indicate the number of hours they worked, 3) rate their involvement in the work (4pt; 1-minimally to 4-extensively), and 4) rate their satisfaction and confidence (5pt. Likert-type scales). The GA activity log asked them the same questions in relation to their perspective on the work of the teachers.

Research practice was assessed by direct observation using version three of the Science and Engineering Practice Experience Protocol (SEP^2) [14], a two-tier hierarchy based upon eight main SEP categories, which are broken down into observable activities. Two independent observers rotated among the laboratories and at approximately one half-hour intervals and observed the participants briefly at work, then recorded the exact time and date as well as the following for each teacher participant: 1) Activity—what they were doing (e.g., buffer preparation), 2) Social Arrangement—who they were working with (e.g., whole group), and 3) the Level of Involvement (4pt; 1-minimally to 4-extensively). For RQ1, the unit of analysis was defined as the individual teacher and it was addressed by building a profile of the average amount of time spent on each of the categories over the summer experience (Figure 1). For RQ2, a day in the laboratory served as the unit of analysis and was addressed by using Pearson correlation to associate the perspective of the teacher participants with that of the independent observation of their practice as well as with the perspective of their GA mentors (Table 1).

Results and Brief Discussion

Teacher participants had varying experience with the practice categories, having had much exposure to *General Lab Procedures*—those not involving specific experiment or manipulation of variables and *Science Communication*—creating artifacts that are intended to express the work of the laboratory to others—but little with *Engineering Practice*—as defined by NGSS (Figure 1). Considering that these were engineering research laboratories, the results are particularly surprising as one could make the case that they appear to better resemble what is described as a science research laboratory. Though this result provides evidence of a generalizable experience for all teachers it also provides further evidence for the variability of teacher experience based upon the nature of the research done in each laboratory.

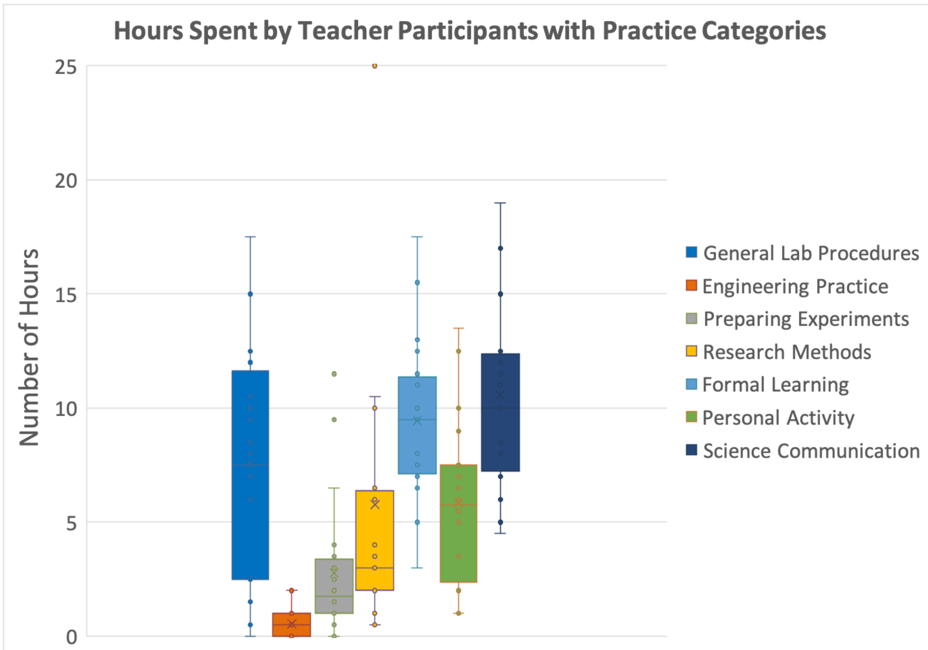

Figure 1. The distribution of hours spent by teacher participants in each practice category over the summer institute.

The correlations in Table 1 provide strong evidence that if teachers perceive involvement with a practice, this is the significant predictor of their satisfaction ($r = .478$) and subsequently their confidence ($r = .437$). These relationships are similarly perceived by GAs, suggesting a shared perspective on achieving the goal of the experience. However, teacher participants only felt involved with General Lab Procedures ($r = .229$), none of the other practices were associated with their involvement and thus were not likely to impact their confidence. This is not to say that teachers were not participating in these practices. In fact, many were strongly associated with significant amounts of time (e.g., science communication).

Table 1. Pearson correlations among variables involving the teacher participant perception, the practice categories that were observed and the perception of their GA mentors.

Correlations

		Observed Practice								Observed Arrangement				
		Hours	General Lab Procedures	Engineering Practice	Preparing Experiments	Research Methods	Formal Learning	Personal Activity	Science Communication	Working Individually	Working with Teacher Partner	Working with Other Partner	Working in Small Group	Working in Whole Group
Observed Practice	Hours	1	.269**	-0.005	.192**	.284**	.419**	.273**	.385**	.559**	.315**	0.0886	.306**	.285**
	General Lab Procedures		1	-0.102	-0.053	-.181**	-0.066	-0.04	-.107*	-.113*	.342**	0.0337	0.0882	.241**
	Engineering Practice			1	-0.083	-0.057	0.0195	-0.03	-0.043	0.0411	-0.044	0.0695	-0.019	-0.073
	Preparing Experiments				1	-0.027	-0.069	0.0645	-0.081	.115*	-0.099	.137**	.308**	-0.048
	Research Methods					1	-.126*	-0.013	-.177**	.443**	-0.067	.107*	0.0617	-.202**
	Formal Learning						1	-0.098	-0.06	-0.04	.136**	-0.093	.317**	.455**
	Personal Activity							1	-0.013	.272**	-0.023	0.0956	-0.01	0.0399
	Science Communication								1	.396**	.183**	-0.024	-0.084	-0.003
Observed Arrangement	Working Individually									1	-.227**	0.0529	-0.063	-.260**
	Working with Teacher										1	-.196**	-0.056	0.0691
	Working with Other Partner											1	-.126*	-.170**
	Working in Small Group												1	-0.022
	Working in Whole Group													1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at

Key	
	r =>0.5
	r =>0.3 & <=0.4
	r =>0.2 & =<0.3

The associations for time spent with individual practice categories further supports the finding for RQ1 that there is a generalizable experience, but it favors personal activity and science communication over other forms of practice, such as engineering design, which would better represent the basis for providing teachers with such a first-person research experience. Perhaps most striking is the negative relationship between teacher confidence when working with GAs ($r = -.242$), which is similarly described by GAs for working with teachers ($r = -.356$). This indicates that the more a teacher and GA work together the less confident the teacher becomes, which is the exact opposite of the goal for them to be working together in the first place. This finding suggests a strong need for further work and support for helping these individuals understand each other's goals and perspectives and for finding a way to work together that generates mutual feelings of confidence and satisfaction.

Conclusion

The results of this study provide evidence for a generalizable teacher experience across this RET that favors general laboratory experiences and science communication over other forms of empirical practice that are promoted as more critical for successful translation of the RET experience [15]. In addition, teacher perception of being involved in research and not the actual experience itself was a better predictor of a positive influence on their confidence. This has significant implications for designers of RET programs. Also noted was that even with a significant investment of time and resources before the start of the summer institute for preparing GAs to work with teachers, further work and support are merited so that their interactions can serve the goal of building teacher confidence. Finally, the SEP^2 appears to be a powerful tool for understanding the experience and perceptions of participants in research experiences.

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