Experience with Authentic Practice in an Engineering RET: Perceptions of Teachers, Mentors and Independent Observation

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-Abstract-

This study advances our design and development goal of creating a valid and reliable observation protocol for science and engineering practices (SEPs) experienced by participants working in research laboratories under the auspices of RET. This protocol offers the potential for addressing persistent questions related to participant experience by looking inside the blackbox of apprenticed professional research practice. Framed by cognitive apprenticeship and situated in an engineering RET for K-5 teachers (EEC-1711543), we independently document the SEPs which were consistently experienced across contexts and thus define a generalized teacher experience. Further, we identify key associations among the teacher's perception of their work, an independent observation and that reported by their graduate student mentors. Findings indicate that perception of involvement with any particular practice and not actual experience was a more important predictor of confidence. 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 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 experience* is most often used to denote a first-person domain-specific practice of inquiry that is intended to educate and produce new knowledge as outcomes (Linn et al, 2015). 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, but empirical research has focused on their use with 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, 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 in the domain (i.e. supporting career interest and persistence)(Chemers et al., 2010) and 2) for supporting the translation of this experience through a curriculum development or lesson planning process where an approximation is used with younger students (Enderle et al., 2014).

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 questions persist that relate to the nature of the experience and the assumptions about participant development. For example: Once placed in a research laboratory, what sequence of practices do participants actually experience? Is there a set of practices and expected duration that generalize across all research experiences? Which sequences of practices and duration are most effective for building positive beliefs about self as well as skill? What forms and duration of mentoring or coaching are provided and how can they be optimized? Answers to these types of questions have thus far only been available by self-report through such sources as personal journal or broad scope surveys (Storm & Lichtenstein, 2019).

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 participants working in research laboratories under the auspices of RET. This protocol offers the potential for addressing those persistent questions related to participant experience and development 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 research questions:

1. What SEPs are consistently experienced across contexts and thus define the teacher experience as a participating member of a laboratory group?
2. What relationships exist among the teacher participant's perception of their work in the laboratory, an independent observation and that reported by their graduate student mentors?

Theoretical Framework

Donovan & Bransford (2007) 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). Experts are not born with special abilities; they are developed with access to information, support, mentoring, and focused intensive practice (Ericsson et al, 1993). This implies that mentors need to be reflective about learning goals, methods of learning, the sequence of activities, and the optimal learning environment (Collins, 2006). The cognitive aspect of the theory implies that the thought processes as well as skills to solve complex problems within a domain are made explicit by mentors so that they may be studied and acquired by learners in an interactive and systematic fashion. In addition to declarative and procedural knowledge, these thought processes include heuristics, mental models and habits of mind. Such apprenticed learning involves four dimensions: (a) content – the types of knowledge for expertise, (b) method – the ways to promote the development of expertise, (c) sequencing – the order of events, and (d) sociology – the social characteristics of the learning environment. These dimensions are further divided into 16 components, such as sociology: cooperation, methods: coaching or content: heuristic strategies. This perspective and detailed framework provided the basis for understanding and interpreting the intent for aspects of the observed experience of teacher participants.

Research Involve RET's

Prior to the inception of the NSF RET program, the first large scale evaluation study of teacher research experience programs was initiated as *The SWEPT Study* (Dubner et al., 2001). Findings from this evaluation of 8 SWEPT sites showed that participant teachers experienced a gain in science content knowledge, positive attitudes towards science and interest in engaging in inquiry-based instructional practices as compared to similar teachers who did not participate. Following the SWEPT study, other significant evaluations indicated that teachers engaged in literature searches and reading about concepts related to the research in their lab, performed a variety of laboratory procedures, experienced and overcome frustration, applied "logic and creative insight to thinking about and analyzing their data, presented their research to their peers, and contemplated ways to transfer lessons learned in the research experience into their teaching (Barrett & Usselman, 2006; Westerlund et al, 2002). 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 experience.

The first broad-scale RET program evaluation was conducted by SRI International examining all of the 2001-2006 funded programs (Russell, 2007). Given that RET sites were funded as a sort of extension of REU's, it was surprising to find 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 the RET, teachers often cited aspects of the research experience itself as powerful catalysts for change in their perspectives and teaching approach. Although previous reviews have characterized learning as a result of laboratory experience (e.g., (Hofstein & Lunetta, 2004; NRC, 2005), the corpus of research evidence focuses on cognitive or skills-based outcomes, as opposed to practice-based or process activity.

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 where teachers are embedded as contributing members of engineering research teams. Participants included teachers from the local school district (N=20) working in pairs, each assigned to engineering graduate student researchers (N=20)(henceforth, GAs) who were also working in pairs. A coupled pair of teachers and GAs worked collaboratively in a laboratory that was sponsored by a Principal Investigator (PI). The GAs were existing members of each laboratory group and were working full-time under the direction of the PI. Data were derived from two years of implementation with different participants, 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. Daily logs were collected via online surveys at the end of each day.

Research practice was assessed by direct observation using version 3 of the Science and Engineering Practice Experience Protocol (SEP2) (Authors, 2019). The SEP2 is a two-tier hierarchy based upon eight main SEP categories, which are further broken down into observable activities (Figure 1). Observers rotated among the laboratories and at approximately one half-hour intervals they observed the participants briefly at work, then recorded the exact time and date as well as the following in a spreadsheet for each teacher participant: 1) Activity—what they are doing (e.g., buffer preparation, collecting data), 2) Social Arrangement—who they were working with (e.g., whole group, with a partner, etc.), and 3) the Level of Involvement (4pt; 1-minimally to 4-extensively). For research question one, the unit of analysis was 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 2). For research question two, 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 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 laboratory procedures*—activities or behaviors that do not involve specific experiment or manipulation of variables and *science communication*—activities or behaviors that involve creation of artifacts that are intended to communicate the work of the lab to others—but little with *engineering practice*—as defined by NGSS (Figure 2).

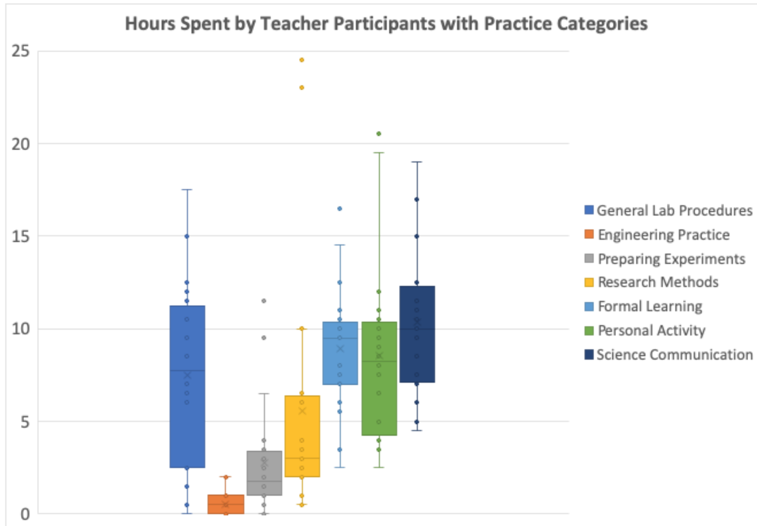

Figure 2. The distribution of hours spent by teacher particpants in each practice categoriy over the summer institute.

Considering that these were engineering research laboratories, these results are particularly surprising as one could make the case that from this perspective they appear to better resemble what is described as a science 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 the laboratory.

The correlations in Table 2 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 Laboratory 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). The associations for time spent with individual practice categories further supports the finding for research question one; there is a generalizable experience, but it favors personal activity and science communication over other forms of practice, such as engineering design, which represent the basis for providing teachers with such a first person 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 implies 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.

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

		Teacher Perception				Observed Practice								Observed Arrangement					GA Mentor Perception				
		Hours	Involvement	Satisfaction	Confidence	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	Hours	Engagement	Involvement	Satisfaction	Confidence
Teacher Perception	Hours	1	.262**	.121*	-0.062	.233**	.117*	0.0958	.166**	-0.072	0.09	.216**	0.0342	.210**	-0.007	0.0892	.124*	0.0221	.546**	-0.085	.222**	.285**	.161*
	Involvement		1	.478**	.309**	0.0732	.229**	0.0192	0.1032	.180**	-.107*	-0.078	-.177**	0.06	0.0822	.112*	-0.035	-0.084	-0.002	.136*	.211**	0.07	-0.095
	Satisfaction			1	.437**	-0.006	0.0991	0.0038	-0.03	0.0207	0.0073	-.169**	-0.064	0.0143	-0.023	-0.022	-0.068	0.0061	0.0749	0.0745	.118*	0.0611	-0.103
	Confidence				1	0.0881	0.0839	0.0197	-0.083	0.0787	0.0111	-.137*	-0.033	0.0043	0.0565	-.242**	0.018	0.0677	-0.084	.119*	.139*	.132*	.271**
Observed Practice	Hours					1	.190**	-0.045	.215**	.267**	.286**	.387**	.364**	.522**	.225**	0.0666	.329**	.161**	.316**	-0.011	0.093	-0.003	0.121
	General Lab Procedures						1	-0.103	-0.05	-.176**	-0.063	-.108*	-0.101	-.106*	.349**	0.0363	0.0894	.240**	-0.107	-0.022	.130*	0.0718	-0.067
	Engineering Practice							1	-0.084	-0.056	0.028	-0.062	-0.042	0.0396	-0.046	0.0701	-0.019	-0.073	0.0194	0.0567	0.07	0.0728	0.0168
	Preparing Experiments								1	-0.021	-0.086	0.0649	-0.081	.114*	-0.095	.138**	.308**	-0.041	.120*	-.133*	0.0883	-0.016	0.1451
	Research Methods									1	-.114*	-0.017	-.173**	.432**	-0.063	.119*	0.0667	-.198**	0.0947	0.0857	-0.035	-0.081	-0.023
	Formal Learning										1	-.134*	-0.051	-0.04	.148**	-0.098	.303**	.426**	.161**	0.0767	-0.006	-0.101	0.109
	Personal Activity											1	-0.044	.159**	-0.043	0.0127	0.0402	-0.031	0.1075	-.138**	0.0529	0.109	0.0617
	Science Communication												1	.379**	.182**	-0.019	-0.078	0.0124	.152**	.110*	-0.082	-0.044	-0.063
Observed Arrangement	Working Individually													1	-.235**	0.0543	-0.062	-.252**	.204**	0.0896	-0.051	-0.035	-0.042
	Working with Teacher														1	-.196**	-0.038	0.055	0.0083	.104*	0.0325	0.0671	0.045
	Working with Other Partner															1	-.124*	-.168**	0.0651	-0.09	-0.013	-0.088	-.356**
	Working in Small Group																1	-0.035	0.0312	-.144**	0.0664	-0.059	.315**
	Working in Whole Group																	1	.115*	-0.024	0.0939	-0.046	0.0836
GA Mentor Perception	Hours																		1	-0.016	.330**	.261**	-0.034
	Engagement																			1	-.115*	-0.037	-0.086
	Involvement																				1	.467**	.419**
	Satisfaction																					1	.361**
	Confidence																						1

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

*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The results of this study provide evidence for a generalizable teacher experience across this RET that favors involvement with general laboratory experiences and science communication over those that would be deemed more critical for the assumption that first person experience with SEPs for teachers are c ritical precursors to their translation of the RET experience through the curriculum development or lesson planning process (Enderle et al., 2014). In addition, teacher perception of involvement and not actual experience was a more important predictor of a positive influence on their confidence. This has significant implications for designers of research experiences. In addition, even with a significant investment of time and resources before the start of the summer institute for preparing GAs to work with teachers in their laboratories, further work and support are merited. Finally, the SEP2 appears to be a powerful tool for understanding the experience and perceptions of participants in research experiences.

Contribution to the Teaching and Learning of Science: This study makes an important contribution to the teaching and learning of science by providing some of the first reported observation evidence on the experience of participants in a research experience. As demonstrated, this evidence affords an empirical evaluation of the assumptions underlying this designed phenomenon as well as the potential for more detailed models of the actual processes involved.

Contribution to the Interests of NARST Members: This study speaks to this year's conference theme-*School, Community, Citizenship: Science Education across Places and Contexts*-because of its basis in the comparison of various participant perspectives with new forms of observational evidence from an authentic context. It will be of particular relevance to those members interested in research experiences for undergraduates as well as teachers, including the use of course-based undergraduate research experiences (CURES).

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