AC 2011-2897: EFFECTS OF HANDS-ON RESEARCH EXPERIENCE AND SUPPLEMENTARY SESSIONS ON CONFIDENCE IN TEACHING STEM-RELATED SKILLS

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Effects of Hands-On Research Experience and Supplementary Sessions on Confidence in Teaching STEM-Related Skills

Abstract

Professional development programs for teachers involving hands-on research have been shown to improve student performance. However, the mechanisms by which this occurs are unclear. After preliminary investigation, teacher confidence appeared to be one metric that may be affected by participation in our research program. Quantitative survey data fail to confirm this hypothesis, though. Qualitative essay data suggest external factors that impact confidence and thus our interpretation of survey data.

1. Introduction

National Science Education Standards established by the National Research Council in 1996 suggest that science teachers "encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science."[1] Exposing students to this expansive representation of science is expected to improve their skills as technical workers and as thoughtful citizens. Pedagogical theories suggest that the most powerful way to become proficient at a profession is to practice it or at least *approximate* its practices.[2] Evidence from laboratory-based professional development programs suggests this is true: teacher participation in research experiences can augment student achievement in a variety of measures.[3, 4] However, one comprehensive study suggests that teachers participating in the National Science Foundation's Research Experiences for Teachers (RET) Program may not actually be conducting hands-on research.[5] Often, teachers are involved in curriculum projects rather than research projects.

Considering these studies collectively, it is unclear which aspects of successful "research" programs are actually responsible for positive outcomes, since not all teachers are conducting hands-on research. Principal Investigators of individual labs conceive of summer projects for teachers to participate in with minimal oversight, and these projects are typically purposed to provide research and curriculum deliverables for the *university laboratory* rather than the middle school or high school *classroom*. Thus, the Stanford Engineering RET site (SERET) implements supplemental programming from a variety of perspectives to maximize potential impact on K-12 education in addition to laboratory objectives. First, we strive to expose our middle and high school teachers to as authentic a scientific research experience as possible. Second, we seek to create a lasting professional community for the teachers, both as education professionals and science/engineering professionals. Last, we hope to promote and scaffold translation of the summer experience into tangible curriculum changes.

To achieve these goals, we devote one day a week to related programming. Thus, teachers spend 80% of their time in their respective laboratories across the university under the direction of their mentors, and the remaining time in talks and workshops coordinated by the Office of Science Outreach (OSO) (figure 1). As part of these enrichment activities, we have designed and implemented interactive seminars, which take place for approximately 90 minutes during the day of programming and are thematically organized around professional practices of scientists and

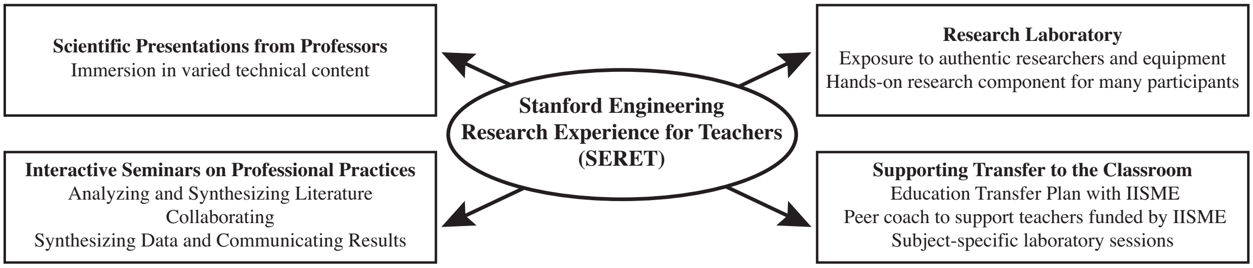

Figure 1. Program components for the Stanford Engineering Research Experience for Teachers site. Between 20-25 middle school and high school teachers participate each summer.

engineers. This focus on professional practices serves a dual purpose. First, by creating opportunities to engage in professional practices as a cohort, we create a more authentic experience for teachers who are not receiving extensive hands-on experience in the laboratory. Second, the idea of approximating professional practices provides a framework for teachers to use to incorporate their summer experiences into the classroom, as subject-specific content is rarely readily transferrable from the laboratory.

SERET also incorporates invited speakers to supplement laboratory-based work and the seminars. OSO coordinates many talks from professors and researchers across the university to present to the teachers. This survey of research being conducted across our research university provides teachers with a breadth of knowledge to which they would not otherwise be exposed. These talks serve many purposes but among the most prominent are to treat teachers as science professionals by engaging them in a traditional research presentation format, to encourage a continued interest in cutting edge research, and to stimulate innovative classroom curriculum.

Additionally, we benefit from a partnership with Industry Initiatives for Science and Math Education (IISME), a local nonprofit that arranges summer fellowships for over 150 area teachers each year. This partnership provides two components that are critical support mechanisms to ensure classroom transfer of new content and methodology. First, IISME appoints veteran teacher Peer Coaches to work with teachers to plan and create lessons, materials and resources for classroom use. Second, all teachers are required to produce at least one lesson or curriculum module, called the Education Transfer Plan (ETP), before returning to the classroom. Teachers are given a great deal of freedom to develop an ETP that reflects their summer experience and will be useful to them, but the ETPs must meet rigorous standards and be aligned with California State Teaching Standards. ETPs and accompanying materials needed to implement them are shared with the broader teacher community via website: http://community.iisme.org.

2. Seminar Modules

While SERET implements a variety of tools to assess our program, we recently focused specifically on the impact of the profession practice-focused seminars. These weekly seminars were thematically organized around the following professional practices of scientists and engineers:

- Analyzing and synthesizing research literature, including planning experiments and writing proposals;
- Collaboration, specifically the skills required to navigate diverse backgrounds, distributed tasks, and individual goals but shared resources;
- Synthesizing data and communicating results, including formal and informal mechanisms.

These themes were the focus of 90-minute workshops throughout the eight-week fellowship experience (6 workshops in 2009, 4 workshops in 2010). We also provided preparatory support to the teachers before they entered the laboratory and a closing reception for which they prepared poster presentations of their laboratory experiences.

A. Analyzing and Synthesizing Research Literature

To engage teachers in relevant literature, we emailed project-specific journal articles recommended by their host and excerpts from *At the Bench* [6] to each teacher, along with an introduction to the seminar series and suggestions on how to read technical articles for information. During a later seminar, we held a "journal club," which served multiple purposes. The activity itself modeled a professional practice common to many research groups and provided an immersive experience for the teachers. Additionally, the content of the articles[7-11] was loosely related to reading technical writing in a K-12 setting, thus providing the teachers with ideas about how to scaffold this practice in their own classrooms.

In addition, we discussed as a large group the common professional practice of proposal writing. Our seminars highlighted writing proposals for many reasons; first and foremost, grant writing is a highly accurate approximation of practice to scientists and engineers *and* a skill that benefits teachers in their primary role as classroom teachers. Written proposals in various forms are also common to both academia and industry. Teachers were encouraged to write proposals for various local grant opportunities, and office hours were held to offer editing help.

B. Collaborating

Seminars were also crafted to address the importance of interpersonal skills in the laboratory environment. In order to help teachers gain a better understanding of their research group, we suggested they informally interview their mentors about the mentor's own educational background, view of his/her role in the laboratory, and pros and cons of being a researcher. In 2009, an additional cooking activity was used to promote collaboration; group members were given different portions of a recipe and then asked to combine forces and create a dish. Teachers collectively shared their findings on the variety of roles, motivations, and personalities present in the laboratory after both activities. Additional time was spent in small groups brainstorming ways to modify classroom activities to promote a similar diversity of roles and personalities.

C. Synthesizing Data and Communicating Results

K-12 classrooms often condition students to expect a "right" answer to tough problems, but in the research lab, there are typically many solutions to a given problem. We opened one seminar with a journal article about data presentation[12] and focused subsequent group conversation around ways that critical analysis of both published and classroom work could be encouraged. Later conversation identified ways in which researchers communicate their results to various audiences. Teachers then identified ways to approximate these communications in their classroom assignments.

To engage teachers in an approximation of practice and to enhance the community of teachers, we held a closing reception and poster session for the teachers. Teachers were asked to prepare a conference-like poster detailing their efforts over the summer, and instructional materials and computer lab time were provided to help teachers complete their posters. The last week of the program, we held a reception where the posters were on display to emulate a conference setting.

3. Assessment of Program Impact

A. Instruments of investigation

In order to assess the impact of professional practice-focused seminars within the broader research experience, we sought first to understand where and how professional practices fit into existing classroom practices by asking the preliminary research question: *What factors promote or hinder teachers' ability to teach mathematics- and science-related subjects in ways that mirror professional practice of these fields, including engineering?*

We used two instruments to probe for answers to the research question, an open-ended essay and a survey. For the essay, participants were given a prompt at the beginning of the course and asked to add to and revise their responses over the course of the seminars (see Appendix A). The survey, loosely adapted from a survey widely used by RET programs around the country, was given to participants at the beginning of summer 2009. The survey sought to examine participants' educational and professional background, teaching tendencies, and experience with the summer program. Additional questions about learning goals, teaching methods, and course content provided information on teachers' current practices and perception of their potential impact.

B. Quantitative analysis of teacher confidence

After cross-correlating many aspects of the survey data, the significant finding from our exploratory study in summer 2009 was related to teacher confidence. At the beginning of the summer, teachers show statistically lower confidence in teaching certain approximations of practice than other teaching methods (table 1). Since some of the programming at our site focuses on professional practices, we repeated the survey at the beginning and end of the summer 2010 to assess that aspect of our program's impact with the revised research question: *Does participation in our RET site program change teacher confidence in different teaching practices?*

Of the 20 teachers participating in the survey 2009 and 25 teachers in 2010, only 17 matched pair surveys were completed. A matched pair was considered to be either a 2009 survey and 2010 pre survey (after one summer of participation for teachers starting in 2009) or 2010 pre survey and post survey (for teachers new to the program in 2010). No significant changes in confidence were noted for matched pairs. However, when considering all first-time, pre-participation responses (n = 35), there were significant differences noted in normalized confidence ratings (table 1). Teachers were slightly more confident in their ability to apply concepts to everyday life and give presentations than their average personal score. Further, teachers were slightly less confident than average in their ability to supervise collaborative group projects and to teach literature analysis, which were two highlighted professional practices. Interestingly, teacher confidence in teaching these two practices on the post survey did increase enough to eliminate significant differences from the Average Confidence (table 1; note smaller *n* for post test).

C. Examining alternate effects

Our initial research question sought to understand factors that influence teachers' inclusion of professional practices or approximations therein in their science, technology, engineering, and mathematics (STEM) classrooms. We believe exposure to professional practices to be a potentially valuable part of the research experience; thus, we felt our seminars combined with hands-on experience may impact teachers' ideology and/or behavior. However, we did not see substantial changes in the metric chosen for teacher confidence level after participation in our program. We believe this to be affected by at least two factors: (1) response to state and local expectations and (2) differences in educational background and technical work experience.

Based on essay responses, teachers are, on the whole, supportive of including professional practices in the classroom. By and large, teachers support professional practices because of their relevance across a variety of "real world" applications, including other non-STEM professions.

Table 1: Teacher Confidence Levels Related to Participation in Our RET Site

Confidence in Different Aspects of Teaching	**Mean Normalized Rating[a]**	
	Pre (n=35)	*Post (n=18)*
Your knowledge about the application of the subject to everyday life	1.178**	1.136**
Your ability to make presentations at in-services or professional meetings	1.110*	1.065*
Your ability to use inquiry-based instructional practices	1.034	0.982
Your ability to link course content to applications in professional settings	1.017	1.022
Average Confidence	*1.000*	
Your ability to teach students how to lead effective discussions/presentations	0.956	0.905
Your ability to supervise student research projects	0.947	0.973
Your ability to conceive of and supervise long-term, collaborative group projects	0.921^	1.011
Your ability to teach students to read and synthesize literature from the field	0.837**	0.906

**p-value < 0.005, *p-value < 0.05, ^p-value = 0.0597

[a]Average Confidence score was calculated for each teacher based on arithmetic mean of eight responses on Likert scale for the different aspects of teaching (1 = low, 4 = high). Normalized rating was calculated for each teacher by dividing the reported Likert score by the individual's Average Confidence; therefore, a normalized rating above one indicates the individual felt more confident in that area than overall. Reported number is arithmetic mean of all normalized ratings. Wilcoxon signed-rank non-parametric comparison of means established significance of mean normalized rating above or below Average Confidence score of 1.000 as indicated.

Teachers also acknowledge the importance of approximations, particularly regarding reading literature. When teachers offered conditional endorsement of professional practices, however, their hesitations largely revolved around standards and other administrative concerns. In the essays, those who view standards and administrative oversight as oppressive respond with either resignation and a sense of despondency or disregard and a sense of aversion. The clear emotional impact that standards and oversight have on some teachers may serve the opposite purpose than we desire; highlighting and promoting professional practices—which teachers are generally in support of but are not mandated by the state—may be increasing teachers' frustration with state standards and impacting their perception of their own teaching practices.

Responses to the open-ended essay prompt also suggest teachers without explicit STEM training feel at a disadvantage regarding professional practices; some teachers directly referenced their own STEM content knowledge or lack thereof (table 2). It appears that an 8-week program may not be sufficient to mitigate factors related to years of degree work. Correspondingly, the definition of and focus on professional practices may actually be increasing teacher anxiety about teaching in this manner, thus confounding confidence scores.

4. Discussion and Implications for Researchers

Based on teacher responses on the open-ended essays, our focus on professional practices may be contributing to teacher frustration and anxiety rather than improving their confidence. Because of these confounding factors, we are reconsidering using confidence in teaching professional practices as a metric for evaluating the impact of our program. We still believe that exposure to and promotion of professional practices is an important part of the summer research experience, but, given the diverse responses to these ideas, perhaps there are better metrics of program impact than confidence. Namely, metrics regarding teacher understanding of professional practices, exposure to professional practices in the lab, and contribution of seminars to overall understanding will be investigated in the future. Additionally, more traditional measures of impact, such as those used in the broad RET evaluation done by SRI International[5], may yield more significant results. We also found our surveys to yield largely inconclusive results, and thus our qualitative data were extremely valuable. While qualitative data can be harder to analyze, they are likely an important component of effective program assessment.

6. Conclusion

Stanford laboratories have been individually hosting local teachers for more than a decade. We added programming to bring together the individual teachers as a cohort five years ago, and most recently, we added the seminar series at the heart of this discussion to focus on professional practices. However, we are new to evaluating our program and understanding its impact. As we have shown with these data, it is unclear what impact, if any, our program has on teacher confidence in teaching professional practices. Through qualitative data, though, we have gained insights into questions to ask about our program and others in the future.

Table 3. Excerpts from open-ended essay prompt

Teacher **support** for professional practices	○ "Analyzing and synthesizing research literature is an important tool in the HS science classroom. It helps students 'see' the real process of experimentation, complete with data and experimental error." Colleen, STEM Major, 20 years teaching ○ "The goal of HS education is to prepare students for secondary ed. and professional world, so it's important to provide open-ended, critical thinking, collaborative, interpersonal research-based, challenging situations where self-learning, self-pacing, metacognition are required." Rebecca, STEM Masters, 13 years teaching
Teacher **skepticism** of professional practices	○ "This skill [collaboration] is not as high a priority as research, performing investigations, drawing conclusions from evidence, etc." Mitch, STEM Major, 2 years of teaching
Frustration with admin. constraints	○ "Personally, I think it is important to include analyzing and synthesizing research literature…However, there is always the issue of time and the need to cover the State Standards that need to be considered. The students already have limited time to finish the standards, and adding or incorporating the said practice won't help." Keone, STEM Major, 15 years teaching
Disregard for admin. constraints	○ " I don't do enough of this [collaboration] and am discouraged by admin. from doing so. Having actively encouraged this in the past I continue to foster it but in a clandestine manner." Brian, STEM Major, 32 years teaching
Indifference toward admin. constraints	○ "I have ambitious goals for the quantity and depth of the material I teach which go way beyond the science standards…" Heidi, STEM PhD, 2 years teaching ○ "Factors [re: literature]…directly connecting the research to CA state standards so that I can justify why I am doing it." Eliza, Stem Minor, 7 years teaching
Teacher **confidence** in STEM-related skills or knowledge	○ "What I end up doing is trying to teach a skill I learned as a grad student in reading lit[erature]…" Dustin, STEM Masters, 12 years teaching ○ "We can teach all of the skills for reading primary literature—all of the metacognitive tools that we have as (more) expert readers." Joon, STEM Major, 2 years of teaching ○ "I often have to prune text or write papers myself, to meet these criteria." Rebecca, STEM Masters, 13 years teaching
Lack of confidence in STEM-related skills or knowledge	○ "My background is actually pretty limited in terms of real lab experience, so I fear not being able to demonstrate science profession experience into my class… It is still sometimes a challenging thing for me to do well." Ana, STEM Minor ○ "…but then I feel I don't have the science knowledge or pedagogical experience to get them there." Everett, STEM Minor

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Appendix A

Name or Other Identifier: ______________________________
**Please be consistent with what you have used previously, thanks!*

In-Class Essay on Factors that Influence Teaching Secondary Math and Science in Ways that Mirror Professional Practice

One of the goals of the seminar series is to expose teachers to professional practices in Science, Technology, Engineering, and Mathematics (STEM) fields. The hope is that exposure to these practices will help promote their inclusion in secondary classrooms and curriculum.

1) Do you feel the professional practices of a) *analyzing and synthesizing research literature,* b) *utilizing interpersonal skills and collaboration,* and c) *synthesizing data and presenting results* are important to include in your middle school or high school curriculum? Why or why not?

2) What factors (curriculum, policy, your background, student ability, etc.) would affect inclusion of these professional practices in your curriculum?

3) Are there additional professional practices that you feel are important to include in your curriculum that are not addressed above?

You can respond to these questions one by one, or integrate your responses in a single paper.