AC 2009-786: PARTICIPATION IN A RESEARCH EXPERIENCE FOR TEACHERS PROGRAM: IMPACT ON PERCEPTIONS AND EFFICACY TO TEACH ENGINEERING

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Participation in a Research Experience for Teachers Program: Impact on Perceptions and Efficacy to Teach Engineering

Keywords: Teacher efficacy, Self-efficacy, Research Experiences for Teachers, K-12 teachers

Abstract

This paper utilizes social cognitive theory to investigate the impact of a National Science Foundation-sponsored Research Experiences for Teachers program on participants’ knowledge about and perceptions of the field of engineering, as well as efficacy for teaching engineering topics. Eleven middle and high school teachers participating in the summer 2008 program completed pre-program and post-program surveys and took part in individual semi-structured interviews. Key findings included participants’ positive changes in perceptions of the engineering field, confidence to answer students’ questions about engineering and discuss engineering career options, and increased efficacy to teach engineering topics in formal learning environments. Results are discussed in terms of specific programmatic elements, and recommendations for designing effective teacher programs are given.

Introduction

The engineering education community is well aware of the need to promote activities that will lead to a larger and more diverse pool of students interested in pursuing engineering as a college major and career. To this end, many colleges and universities, not-for-profit and professional organizations, engineering corporations, and individual professionals regularly engage in outreach activities to promote awareness of the field. Certainly, these types of activities are important; however, as Brophy, Klein, Portsmore and Rogers pointed out:

But it is questionable whether such outreach efforts are enough to attract the numbers of students needed in the field or if they can provide these learners with the experiences needed to succeed in the formal post-secondary engineering programs that they are being encouraged to pursue.

In addition to supporting outreach efforts through technical and engineering education grants, the National Science Foundation (NSF) recognizes the need to engage K-12 teachers in order to promote engineering to pre-college students. The NSF Research Experiences for Teachers (RET) program supports collaboration between colleges and universities and K-12 teachers or community college faculty by providing funding for their participation in engineering research. The RET proposal solicitation asserts that, “Encouraging active participation of teachers in NSF projects is an excellent way to reach broadly into the teacher talent pool of the U.S. so that they can teach engineering concepts to K-12 students to encourage and stimulate them to pursue engineering careers.” RET awards are made through two mechanisms: RET site grants, which provide a research experience to a cohort of in-service or pre-service teachers, and RET
supplements, which fund a principal investigator to include a teacher in an ongoing NSF-funded research project.

The NSF request for proposals suggests that teacher participation in engineering research will lead directly to effective formal learning environments and subsequent student interest in the field. However, Brophy and colleagues\(^1\) presented several challenges inherent in expecting teachers to develop effective formal learning environments related to engineering, including, “teacher readiness and professional development with respect to engineering education content.” They posit that, “This is a significant human capital issue which requires systematic attention in the form of research and development.” Despite substantial NSF funding for RET sites and supplements, limited rigorous research has been conducted to determine the effects of such funding on teacher participants and subsequent student learning. Our work examines the impact of a Research Experiences for Teachers site conducted at a large university in a major U.S. city. The work consists of two phases: (1) investigation of the impact of the program on teacher participants’ perception of the field and efficacy to teach engineering and (2) impact of RET-developed teaching modules on students’ perceptions of the engineering field and motivation to study engineering. Results from the first phase of this ongoing project are reported in this paper; future publications will document the second phase of the work.

**Background**

The eleven middle and high school teachers who participated in the RET site during the summer of 2008 spent six weeks conducting research under the mentorship of an engineering faculty member. Teachers typically interacted with a graduate student(s) or a post-doctoral fellow on a day-to-day basis. Program deliverables included several short presentations on research progress, a scientific poster for their classroom describing their research project, and the creation of a teaching module related to their engineering research project, which teachers were to implement during the subsequent academic year. Professional development activities took place once or twice per week during the summer program. Some of these sessions were directly related to fulfilling program requirements such as creating a technical poster, while others consisted of lively discussions about challenges and opportunities of fostering a new generation of engineers. To support participants in developing a teaching module related to their summer research, a consultant presented a one and one-half day training session on developing and delivering a “Legacy Cycle” teaching module. Full details regarding the Legacy Cycle theory and implementation can be found elsewhere\(^1,3\). In short, the Legacy Cycle method is based on developing curriculum using the four types of “centeredness” identified in *How People Learn*\(^4\): knowledge-centeredness, learner centeredness, assessment centeredness, and community centeredness. The learning cycle starts with the instructor posing a “challenge question” to the students. Students are then led through a series of steps entitled: Generate Ideas, Multiple Perspectives, Research and Revise, Test your Mettle, and Going Public\(^3\). By the end of the Legacy Cycle training, teachers had developed a plan for linking their summer research to their classroom teaching. The consultant guided teachers in ensuring that their teaching module met relevant state standards and contributed to their regular curriculum topics.
Theoretical Framework

This work employs a social cognitive theoretical framework to investigate the influences of the RET program on teachers’ 1) knowledge about and perceptions of the field of engineering and the work engineers do and 2) efficacy to teach engineering-related topics. The conceptualization of teacher efficacy is rooted in Bandura’s self-efficacy theory, which identifies four sources of efficacy: mastery experiences, vicarious learning, verbal persuasion, and physiological arousal.

The conceptualization and measurement of teacher efficacy, or “individual teachers’ beliefs in their own abilities to plan, organize, and carry out activities required to attain given educational goals” has received significant attention over the last 30 years from educational researchers. One reason this has been a popular subject is that there is “compelling evidence positively relating teacher efficacy with student outcomes such as motivation and achievement.” Additionally, teacher efficacy impacts teacher-specific outcomes such as persistence, goal setting, and openness to innovation.

Teacher efficacy is dependent on the subject matter and context, and for that reason, studying teacher efficacy as it relates to engineering subject matter is an important aspect to consider in designing professional development for teachers which lead to formal pre-college learning environments.

Research Questions

1. How does a research experience for teachers influence participants’ knowledge about and perceptions of the field of engineering and the work engineers do?
2. How does a research experience for teachers influence participants’ confidence to teach engineering-related topics and to encourage students to consider engineering as a college major?

Participants and Procedure

The sample for this work included 11 middle and high school teachers (six female, five male; mean age = 37.5 yr, SD = 7.95) participating in a RET site at a large university in a major U.S. city during the summer of 2008. The teachers were diverse in self-reported ethnicity, with three Black/African-American, three Caucasian, two Asian/Asian-American, two Hispanic, and one Hispanic/Caucasian. Participants taught a variety of STEM-related subjects, including Biology, Chemistry, Physics, Technology Applications, Environmental Science and Integrated Physics and Chemistry courses. Participants were drawn from two public school systems in the metro area, as well as a public college-preparatory charter school. Nearly all participants taught in schools serving large numbers of under-represented minority students; in fact, 10 of the 11 teachers came from schools serving 90% or more minority students.

A mixed-methods approach was utilized to study the research questions. Quantitative data were obtained from surveys consisting of items adapted from the engineering education and educational psychology literatures, while semi-structured interviews formed the basis for the qualitative portion of the study. Following quantitative and qualitative data analysis, the results
were triangulated. This paper briefly presents the quantitative results as a means to lend credibility to the qualitative data.

Teacher participants completed the pre- and post-program survey instruments on the first and last days of the program, respectively. The surveys included items from the Pittsburgh Attitudes of Engineering Survey\textsuperscript{5,6} as well as items assessing confidence and use of the Legacy Cycle developed by Klein\textsuperscript{18}. In addition, we administered the Ohio State Teachers’ Sense of Efficacy Scale (OSTSES)\textsuperscript{7}, which was adapted for STEM classes and the engineering context. This scale included three factors for measuring teacher efficacy: efficacy for instructional strategies, efficacy for classroom management, and efficacy for student engagement. In addition, the items in this last subscale were edited to be specific to engineering, creating a more domain-specific measure of efficacy for student engagement in engineering along with the more general efficacy for student engagement.

Individual semi-structured interviews were conducted with each teacher during the last week of the program, providing an open-ended format for exploring the research questions and allowing participants’ experiences to be captured in their own words. Interviews were recorded with the participants’ permission. Following transcription, the interviews were coded by two researchers, who conducted several rounds of inter-rater comparison to identify emergent themes and compare coding. First, each researcher read the transcripts and made a list of emergent themes. During the first round of inter-rater comparison, the individual researchers’ lists were discussed and combined into a list of 13 major themes with up to eight sub-themes each. Interview transcripts were then coded by each researcher using these themes. Coding was conducted at the paragraph level and analyzed using NVivo8, a software package for qualitative data analysis. During the initial round of individual coding, additional sub-themes were identified by one or both researchers. Following the initial coding, the two coding files were combined and both themes and coding references were compared. Some sub-themes were deleted, combined, or reworded, resulting in a final count of 13 major themes and 61 sub-themes. Using the updated combined file, a final round of inter-rater comparison was conducted, whereby all coding differences were negotiated to consensus, resulting in a final inter-rater agreement of 100%.

NVivo8 was used to produce coding reports for each theme which summarized the number of participants ($n$) who discussed a given theme, as well as the total number of references to a given theme in the collection of transcripts; these are denoted parenthetically throughout the results section. Seven major themes were selected for inclusion in this paper; three relate to Research Question 1 and four relate to Research Question 2. Additionally, we begin the qualitative study section by briefly mentioning four major themes and associated sub-themes relating to motivation to participate in the program.

**Quantitative Results**

Data from the pre-program and post-program surveys were entered into SPSS 16.0 for analysis. Variables measuring the constructs of interest were created by taking the mean of several individual items as supported by previous research. Cronbach’s alpha was computed for each variable, and all were determined to be acceptable, with the exception as noted below. Findings
reported here should be interpreted with caution due to the small sample size and lack of a control group of non-RET teachers.

1. How does a summer research experience for teachers influence participants’ knowledge about and perceptions of the field of engineering and the work engineers do?

Teachers responded to items assessing their knowledge about majoring in engineering, using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). A sample item was “I understand the career opportunities in engineering.” A paired samples t-test indicated that their knowledge about majoring in engineering increased, \( t(10) = -2.96, p < .05 \). Teachers also responded to items assessing their perception of the work engineers do and the engineering profession (Besterfield-Sacre, 1998; 2000), using the same Likert scale. A sample item was “Engineering is an occupation that is respected by other people.” A paired samples t-test indicated that teachers’ perception of the work engineers do and the engineering profession also increased, \( t(10) = -2.42, p < .05 \).

2. How does a research experience for teachers influence participants’ confidence to teach engineering-related topics and encourage students to consider engineering as a college major?

Teachers responded to 3 items at pre-program and post-program assessing their confidence to teach using the Legacy Cycle\(^{18}\) using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). A sample item was “My background and training make me very confident in using a technique such as KWL or the Legacy Cycle in my classroom.” One of the items at pre-program was dropped from the calculation of the variable in order to increase the Cronbach’s alpha to an acceptable .73 instead of .32. A paired samples t-test indicated that teachers’ confidence to teach using the Legacy Cycle increased, \( t(10) = -3.18, p < .05 \). However, there were no changes in teachers’ reports of their use of the Legacy Cycle or confidence in teaching their course content, \( ps > .05 \).

Teachers also responded to items that were used to measure various aspects of teacher efficacy\(^{7}\), using a 9-point Likert scale (1 = nothing, 9 = a great deal). Teachers’ efficacy for classroom management was assessed by items such as, “How much can you do to get students to follow classroom rules in your STEM classes?” A paired samples t-test indicated that teachers’ efficacy for classroom management increased, \( t(10) = -2.38, p < .05 \). In addition, items were administered to measure teachers’ efficacy for instructional strategies, such as, “How well can you craft good questions for your students in your STEM classes?” No significant differences were found pre-program to post-program on efficacy for instructional strategies, although the \( t \)-test approached significance (\( p = .06 \)). There was no significant difference in teachers’ efficacy for general student engagement. However, teachers’ efficacy for student engagement in engineering (sample item “How much can you do to help your students value learning engineering in college?”) did increase, \( t(10) = -4.00, p < .01 \).
Table 1. Quantitative Results

<table>
<thead>
<tr>
<th>Construct</th>
<th>No. of Items</th>
<th>Cronbach’s α</th>
<th>Pre-program M (SD)</th>
<th>Post-program M (SD)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge about majoring in engineering</td>
<td>5</td>
<td>.86</td>
<td>3.96 (.84)</td>
<td>4.71 (.24)</td>
<td><em>p &lt; .05</em></td>
</tr>
<tr>
<td>Perceptions of work engineers do and</td>
<td>7</td>
<td>.85</td>
<td>4.49 (.46)</td>
<td>4.78 (.37)</td>
<td><em>p &lt; .05</em></td>
</tr>
<tr>
<td>engineering profession</td>
<td></td>
<td>.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confidence to use Legacy Cycle</td>
<td>3</td>
<td>.73 (2 items)</td>
<td>4.27 (.51)</td>
<td>4.64 (.38)</td>
<td><em>p &lt; .05</em></td>
</tr>
<tr>
<td>Use of Legacy Cycle</td>
<td>3</td>
<td>.71</td>
<td>3.48 (.97)</td>
<td>3.67 (1.18)</td>
<td>NS*</td>
</tr>
<tr>
<td>Confidence in teaching course content</td>
<td>3</td>
<td>.64</td>
<td>4.48 (.56)</td>
<td>4.67 (.47)</td>
<td>NS*</td>
</tr>
<tr>
<td>Teachers’ efficacy for classroom management</td>
<td>4</td>
<td>.89</td>
<td>7.68 (.90)</td>
<td>8.16 (.73)</td>
<td><em>p &lt; .05</em></td>
</tr>
<tr>
<td>Teachers’ efficacy for instructional strategies</td>
<td>5</td>
<td>.63</td>
<td>7.67 (.82)</td>
<td>8.15 (.82)</td>
<td>NS*</td>
</tr>
<tr>
<td>Teachers’ efficacy for student engagement</td>
<td>4</td>
<td>.88</td>
<td>7.11 (1.27)</td>
<td>7.50 (1.23)</td>
<td>NS*</td>
</tr>
<tr>
<td>Teachers’ efficacy for student engagement in</td>
<td>4</td>
<td>.93</td>
<td>6.77 (1.40)</td>
<td>7.75 (1.40)</td>
<td><em>p &lt; .01</em></td>
</tr>
<tr>
<td>engineering</td>
<td></td>
<td>.95</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*NS denotes a non-significant result.

Qualitative Results

Before investigating the research questions, we were interested in learning more about teachers’ initial motivation to participate in the program and to teach engineering in general. We felt that a better understanding of participants’ reasons for pursuing a summer research in engineering would contribute to efforts for our program’s future recruiting efforts as well as RET programs across the country to market similar opportunities to K-12 teachers. When asked about their motivation to participate in the program and to teach students about engineering, responses ranged from personal/professional growth opportunities and interests such as:

- Interest in STEM subjects (*n = 4; 4 references*)
- Improvement and expansion of teaching (*n = 9; 18 references*)
- Desire to have a research experience (*n = 5; 12 references*)
- Interest in STEM subjects and in research with a desire for new and deeper understanding of engineering (*n = 11; 47 references*)

to wanting to be part of the “solution” to increasing the engineering workforce:

- Recognition that engineering is important to America or society (*n = 4; 10 references*)
- Recognition that there is a gap in engineering workforce, particularly with respect to under-represented students (*n = 6; 13 references*)

to aspiring to improve their teaching:

- Desire to bring real world applications to classroom (*n = 5; 8 references*)
- Inability to answer student questions in the past (*n = 4; 7 references*)

and an interest in learning about engineering to be able to encourage students to pursue engineering as a profession and to provide career advice as a way to expand the employment options of students (*n = 11; 61 references*).
Three major themes emerged from interview data relative to Research Question 1: “How does a research experience for teachers influence participants’ knowledge about and perceptions of the field of engineering and the work engineers do?”

- A. Teachers experienced positive changes in their perceptions of engineers and the engineering field.
- B. Teachers articulated characteristics which indicated students’ potential for pursuing engineering as a college major.
- C. Teachers felt a “responsibility” to teach engineering as a result of their new knowledge and perceptions.

A. Perceptions of Engineers and Engineering Field

All eleven teachers talked about the program in terms of bringing about positive changes in their general perception of engineering \( (n = 11; 38 \text{ references}) \). While many already had favorable perceptions prior to the program, initial levels of knowledge varied greatly in accuracy. While initially a few participants were aware of various engineering disciplines (particularly the “traditional” fields such as civil and electrical), others viewed engineers as people who “make machines” or “do construction work” or do “something with the application of science.” In general, participants reported that the program opened their eyes to new applications of engineering of which they were not previously aware. In particular, teachers gained a better understanding and appreciation of the breadth of the field, its contribution on everyday life, and its potential as a good career choice for their students. One teacher described it as a “180 degree” shift. By the end of the program, teachers articulated several perceptions of engineers and the engineering field: (a) engineers are problem-solvers (b) engineering is a broad discipline (c) engineers help society (d) the field of engineering provides many unanticipated career opportunities.

The idea of engineers as problem-solvers, which was emphasized in the professional development sessions and illustrated in the Legacy Cycle training came up repeatedly \( (n = 9; 21 \text{ references}) \) as participants described in their new perceptions about the field. The following quotes from two participants illustrate this perception:

*Interviewer:* Do you think this experience has changed your perception about engineering?
*Participant:* Yes, definitely, definitely. I certainly see it as a much broader discipline than what I used to. So I definitely see it as much broader, and a process about solving problems, not about just building stuff.

[My perception is] totally different. I used to think of engineering as just doing something with an application of science. But for me now, I see it is problem solving… It’s good for society. It’s a different definition for me.

Many teachers were surprised by the breadth of the engineering field \( (n = 7; 16 \text{ references}) \) and through their research, were exposed to applications of engineering that they had never considered before. Several were involved in projects with engineering faculty that they previously did not even realize were under the umbrella of “engineering.” One participant said:
You see . . . like this bio-sensor [I worked on in the lab], I didn’t even think that engineers were involved in the making of it, you know? . . . Big things; engineers do big things. They make roads, they make cars, even things like a bio-sensor. I didn’t even know that they fabricated it. . .I didn’t even know. . .I wasn’t even thinking that it was part of engineering.

Another teacher responded, “I certainly see it as a much broader discipline than what I used to. So I definitely see it as much broader, and a process about solving problems, not about just building stuff.”

Though generally teachers entered the programs with a basic understanding of certain ways that engineers impact society, it was also a theme in \((n = 4, 8\) references) their description of how the program changed their perceptions of engineering, “I realized engineers have a lot to do with today’s society. . . We can’t function without engineers.”

Additionally, several teachers \((n = 4; 12\) references) were surprised to learn that engineering can provide many unanticipated career opportunities, even serving as a “jumping off point” for students who may be interested in other fields such as medicine or law. One teacher said, “Also, some of them wanted to be a doctor. So if they want to be a doctor, why not go into [bio] medical engineering?”

**B. Characteristics of a Potential Engineer**

Participants were also asked about characteristics they would look for in identifying students whom they would encourage to consider engineering as a college major and career. Participants named four main characteristics: solid math and science background \((n = 7; 16\) references); problem solvers \((n = 9; 22\) references) critical thinking skills \((n = 5; 8\) references); and creativity \((n = 4; 7\) references). While math and science background was mentioned by seven of the eleven teachers, by the end of the summer, many described these subjects as a “tool” needed for engineering, rather than an end-goal. One teacher described math as the “language” used by engineers. Another commented on his/her change in thinking:

I really think. . . you know, it used to be just good grades in math and science, but I’m not convinced it’s just about good grades. I think it’s about what they enjoy doing. So, if they enjoy hearing problems presented, and coming up with creative ideas about how to solve those problems, or if when I’m teaching something and they ask “What if I did this or what would happen then?” [then they might be a potential engineer]. The inquisitiveness, the interest in solving those kinds of problems [are traits I’ll look for]. Because if they want to solve the problem, then you can teach them all the other stuff that they need.

**C. Responsibility to Teach Engineering**

Several participants \((n = 5; 10\) references) described feeling a responsibility to teach engineering or encourage students to consider the field now that they better understood the field itself as well as the need for a larger and more diverse engineering workforce. Representative comments include:
Well, I’ve just got to teach it... because I notice there is a huge, big crack [through which] we are losing a huge amount of the students, especially Hispanics and females. I need to be like a missionary in my high school so they can learn what I learned and experience what I had [this summer].

I feel like I have a responsibility now. I’m so concerned... about how much the country needs this. I feel like it’s our responsibility. Not just science and math teachers. I think all teachers need to.

I used to kind of think that to teach ninth and tenth graders... I don’t really have to worry about being a “college guidance counselor”... you know, I don’t have to worry about that stuff, because they’re not thinking about it. I definitely see myself now... now because of this program, as somebody who really is there to show them what the options are. I don’t just see myself now as a ninth grade biology teacher. I see myself more as somebody who is a resource to them as they start to think about what they are going to do later on. That’s really a big part of my job is to show them their future and help them on that path. I really need to be there to help them to figure that out.

In exploring Research Question 2, four major themes emerged from the interviews: “How does a research experience for teachers influence participants’ confidence to teach engineering-related topics and encourage students with appropriate talents to consider engineering?”

D. Teachers gained confidence to answer questions about engineering and talk about engineering career options.
E. Teachers gained efficacy to teach engineering topics.
F. Teachers were proud of their summer accomplishments.
G. Teachers perceived support for teaching engineering from the RET program.

D. Confidence Gains Related to Engineering Career Options
All eleven participants described their increased confidence to answer questions about engineering or talk about engineering career options (n = 11; 29 references). When participants were asked if they were more confident to talk to their students about engineering as a result of the program, one teacher said:

Yes. I probably would have said at the beginning, “I’m really not a good person to ask, why you don’t go ask your physics teacher.” But now, if they ask me, I can give them an idea, and based on their area of interest. If they have a specific interest in knowing more about, I could talk about a little more and explain the process a little more to them.

Another commented:

I’ve always avoided math and physics that wasn’t required of me... that when my students kind of expressed an interest in engineering... I have nothing to say about it, because I don’t really understand it. I’ve kind of avoided it, I guess. It’s just hasn’t been interesting to me in the past, because I thought it was like... you know, electronics, circuits and I never did that kind of stuff, so I didn’t feel like I could, you know help my students develop a plan or get excited about it. Now I’m glad I know the college of
Another participant said:

I feel more confident about encouraging my students about going into engineering. Before honestly I would not have much to say. I would have said you’d have to be good in math and that is probably about it, honestly. But now … I know we need to have a work force. I know the kids need to have work. And if the two can come together, then they’ll have a job — and a good one.

In addition to increased confidence, several teachers also felt motivated to discuss engineering career options specifically with their students from low socioeconomic backgrounds, and to encourage them to consider a career in engineering as an alternative to the blue-collar jobs to which their students often aspired. Representative comments included:

And I think that our students need to realize, especially our low socioeconomic students, that there are options available to them that they may not have considered because of their families are not having these conversations with them.

If you ask the majority of my students what they want to do, the majority say “be a mechanic.” Only a few of them want to go to college. That’s why I want to expose them to new ideas and let them know that it’s alright to go to school and have your own ideas, own decisions. You know, you don’t want to just follow your parents. You want to be better than your parents.

I think it [engineering] is a wonderful career for them. I work in a school that is in a low income area—we have 93 percent on free lunch— and it makes me a little bit sad to see some of our students are painting houses, mowing grass, or whatever. I believe in going to college and learning engineering is much, much better. They usually are working construction…. they like working with their hands… but [a hands on approach] is something that can make them interested in engineering.

E. Efficacy to Teach Engineering Topics

Some participants realized that they had just hit the “tip of the iceberg” over the summer, and were therefore a bit more hesitant because they realized that even though they knew more than before, there still was a lot to learn:

I feel that I can give a general overview [about engineering careers]. I’m not feeling like I can be too specific about career options. I feel like I’m kind of still in that “general” category. I think probably because there are so many different ways engineer is kind of manifest themselves, but I feel I can’t describe all of them, but I feel like you know, if a student expresses a certain interest and want to know details, I certainly know where to get that information or where to send them to.
All eleven teachers felt that the Legacy Cycle training was valuable \((n=11; 25\text{ references})\) and were confident to teach their RET-developed modules, particularly due to ties to their summer research and the curriculum development training session. Many \((n=5; 9\text{ references})\) described the summer program, and particularly the Legacy Cycle training, as valuable for multiple areas of teaching, not just the course in which they planned to implement their module. These participants described the RET program as having an impact on their entire perspective on teaching. All eleven participants said that the Legacy Cycle training and/or the RET program changed their future teaching plans \((n=11; 23\text{ references})\). Some planned to carry the theme of engineering throughout their courses. For example, one participant said that, “…engineering will be a theme that I’ll carry. At any given point or time that I can introduce it.” Others described a shift in thinking about their teaching methods towards a project-based or challenge-based approach, which inspired them to think creatively about their teaching methods in general. One teacher said that he/she no longer wanted to be a “copy cat” and simply do as told by the chairperson. Others said:

I’m excited about my module. I’m excited about if I really extend the idea of what it could be or what it could turn into, it could turn into a major long semester-long experience or activity. So, again, I don’t feel that it is polished or finished yet, but I’m really excited about moving towards that kind of teaching.

It really changed the way that I look at how I teach and the reason why I teach, and it just great to be in a lab in and do some real science and interact with real scientists and have conversations at different levels than what we normally do. I also feel like I have some great contacts to come in and talk to students and help us with engineering. So, just all around [it was] really valuable.

**F. Feelings of Pride**

All participants spoke at length with great enthusiasm and pride about their summer accomplishments \((n=11; 46\text{ references})\). Specific activities which contributed to their efficacy to teach engineering and encourage students to consider the field included their laboratory research, poster creation and Legacy Cycle module development. Two comments are shown below:

My project — that’s like my major accomplishment. I’m really happy about it. I mean, I worked hard this summer, or at least I tried to get everything done that I wanted to get done. And to actually see that he actually appreciates it makes me feel good.

*Interviewer:* Do you feel a sense of accomplishment?
*Participant:* I do! A lot! I mean, I got a lot done. I think my goal initially was to at least finish, but I started and was able to do that. So, that’s what I’m most proud of…that in that short time, I got to finish everything.

**G. Feelings of Support**

In addition to the participants’ technical and curriculum accomplishments, participants talked about two specific aspects of the RET program support which contributed to their efficacy to teach engineering after the program ended: supportive faculty mentors and teacher colleagues
and available continued resources. All participants \((n = 11; 24\text{ references})\) talked about feeling supported by their summer research mentors and/or other participants. One participant said:

I think from day one, he [faculty mentor] understood that we were high school teachers and so, we definitely wanted to get the research experience, but he saw the big picture and that we wanted to get an experience that we could take back to a high school classroom. So it was obvious to me that he got that — from the very first day.

Another commented:

I think getting to know some of the different teachers, and getting to know some of the professors and talking to them [made me feel supported]. I have found so many other teachers and resources that maybe I wouldn’t have known about, especially with the other teachers.

Participants \((n = 10; 50\text{ references})\) also described resources made available to them through the RET program, which ranged from a PowerPoint™ presentation about various fields of engineering to information about the university’s summer camps, offers of classroom visits by faculty/graduate student mentors, and plans for field trips to the university. When participants were asked if they felt they had resources available to them to continue their interest in teaching engineering, a representative response was:

Yes, a lot. I’m going to try to bring my kids [to the university] in January, and the professor I’m working with is really excited about giving demonstrations to my kids. He wants to go give at least one or two demonstrations to my kids, which is great! He’s even talked about maybe trying to bring some of my kids in this summer, and maybe getting them to work in his lab for a couple of weeks.

Discussion

By examining the sources and specific causes of teacher efficacy resulting from participation in a Research Experiences for Teachers program, we aim to better understand the potential utility, and perhaps limitations, of RET and similar teacher professional development programs related to engineering. Triangulation of data from participants’ pre-program and post-program surveys served to validate qualitative data from teacher interviews. Data from both research methods revealed increased teacher efficacy for teaching engineering and positive changes in their perceptions of engineering. The use of a semi-structured interview technique allowed participants’ perceptions and experiences to be captured in their own words, adding depth and elucidating quantitative results.

Brophy and colleagues\(^1\) urged the engineering education community to consider formal learning experiences in pre-college education as instrumental to solving our nation’s workforce issues. They identified teacher readiness as a major challenge in doing so, and inherent in teacher readiness is teacher efficacy. As these researchers put it, “Teachers are typically uncomfortable teaching content they do not understand well and thus they will often shy away from such content for fear of being unable to answer students’ questions”\(^1\). Our data support this idea; prior to their participation in our program, teachers were reluctant to answer student questions about
engineering subjects and career options and avoided teaching engineering due to lack of knowledge and familiarity with the subject matter. The research experience, although relatively brief, served as a mastery experience\textsuperscript{8} which not only increased participants’ efficacy in their own ability to conduct research, but consequently, formed the basis for efficacy to teach engineering. Certainly, it is feasible that other mastery experiences (such as coursework, for example) could serve the same purpose, but in this case, the mastery experience seemed to be especially potent because participants not only gained content knowledge, but also a deeper understanding of the process of engineering problem-solving through scientific research.

Another source of teacher efficacy stemmed from participants’ relationships with their faculty and graduate mentors and other teachers in the summer cohort, which supplied both vicarious learning experiences and encouragement (verbal persuasion)\textsuperscript{8}.

While the above-mentioned sources of efficacy relate primarily to the participants’ laboratory experiences, we purport that a research experience alone is not necessarily enough to increase teacher efficacy to the point that they are confident to teach engineering topics in their regular courses. In our program, the problem-solving process that teachers experienced first-hand in the application of a real-world problem was then translated into training for a specific classroom instructional technique, the Legacy Cycle. Through the Legacy Cycle training, teachers were able to relate state-mandated standards and curricula with their research and the modules they developed as part of the program. This is what Brophy and colleagues call the combination of “domain knowledge” and ability to “effectively manage its learning”\textsuperscript{1}. By overcoming both barriers to a successful formal learning experience, teacher efficacy was increased as a result of program components.

Brophy and colleagues\textsuperscript{1} assert that many teachers do not view engineering as an “accessible” career for many students — that is, they perceive it as an intellectually elite field that requires a love for science and math. The consequence of this notion, they point out, is that teachers

\[\text{...may interpret the inclusion of engineering education as an additional curriculum area serving only a few students. Therefore, they will focus their attention instead on teaching content they perceive as helping all their students achieve outcomes defined by national or state STEM content standards and assessed through state-mandated standardized tests. They therefore look to outreach and enrichment programs as the opportunity for the engineering bound students to learn the specific content for engineering and technology careers, but this is not enough.}\]

Our data show that by directly addressing these teacher misconceptions with specific program elements such as faculty-led discussions and panels, teacher participants learned (more) about the need for more students and greater diversity in the engineering talent pool, and made connections between characteristics (such as problem-solving abilities) they frequently saw in their students and those desirable for pursuing engineering. Furthermore, teachers’ increased perceptions about engineering and career opportunities, particularly those related to the breadth of the engineering field, enhanced existing beliefs or motivated teachers to expose their students to engineering topics — some using terms like “responsibility” and “missionary” to describe their goals in teaching engineering. Many participants felt that engineering offered an opportunity for their students of low socioeconomic status to achieve a valuable professional
degree with four years of higher education.

Teachers also indicated that they planned to supplement formal learning experiences (e.g., their RET-developed Legacy Cycle module) with informal learning experiences throughout the academic year to further reinforce engineering messages and provide their students with additional experiences related to engineering. These informal experiences included field trips, guest speakers, serving as unofficial guidance counselors, and creating an engineering club, among others.

Overall, we attribute the success of this NSF-funded teacher development program in raising teacher efficacy to the combination of a positive engineering research experience with specific curriculum development training, which guided them in incorporating their new engineering content knowledge into a formal learning experience for their students. Although not originally anticipated by program organizers, Legacy Cycle training also resulted in an additional positive outcome: the profound impact on several teachers’ future plans and teaching philosophies.

Based on these data and the body of knowledge on teacher efficacy, the following recommendations are given for others designing RET and similar research-based teacher professional development experiences:

- Provide a well-planned research experience designed within the necessary time constraints. While achieving a balance between realizing meaningful data and conducting original research within a short time span can be difficult, a well-designed project can serve as a powerful mastery experience which will help participants develop a sense of accomplishment and efficacy for research.
- Expose participants to pedagogical training to help them incorporate their new content knowledge into a formal learning experience. With limited experience in engineering, teachers will likely have difficulty translating their new knowledge into their regular curriculum, so guidance during this process is critical. Helping teachers to map engineering topics to state standards will help them not only create meaningful formal learning experiences, but will assist them in gaining administrative buy-in.
- Include formal and informal program elements that directly address teachers’ perceptions (and misperceptions) about the field of engineering, and that help teachers to make conscious connections between student characteristics and traits that are useful for engineering studies (e.g., problem solving abilities).
- Provide support for teachers throughout the academic year to create informal learning experiences such as field trips and guest speakers to augment the formal learning experience of teaching engineering.

**Ongoing and Future Work**

Teacher participants from the summer 2008 program are in the process of teaching their RET-developed Legacy Cycle module during the 2008-2009 academic year. The second phase of this research involves studying the impact of each teacher’s Legacy Cycle module on students’ perceptions about engineering and motivation to study engineering-related topics. Following the end of the academic year, these results will be forthcoming in future publications.
This work has contributed to a better understanding of the utility and limitations of RET (and similar) programs to effectively bring engineering knowledge to the pre-college classroom. We have offered suggestions for those desiring to contribute to teacher development programs which prepare teachers to design and deliver effective formal learning experiences related to engineering. While additional rigorous research is necessary to fully understand the potential of teacher development programs to contribute to the increased participation of students in engineering, our work demonstrates that well-designed experiences such as those funded by the National Science Foundation’s Research Experiences for Teachers program have the potential to positively impact teacher efficacy related to engineering.

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Bibliography


