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Teachers in an Interdisciplinary Learning Community: Engaging, Integrating, and Strengthening K-12 Education

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Abstract

This study examines the inputs (processes and strategies) and outputs (perceptions, skill development, classroom transfer, disciplinary integration, social networking, and community development) of a yearlong, interdisciplinary teacher learning and development experience. Eleven secondary math and science teachers partnered with an interdisciplinary team of university engineering mentors in a yearlong engineering education and project implementation program. It consisted of a 6-week on-site resident professional development and collaboration experience, with an ongoing support and follow-up including digital systems. Mixed-method, multisource data indicate that teachers engaged with motivations combining personal, intrinsic interest and classroom integration goals. They formed and sustained an active community of learning and practice that supported their success, on-site and through classroom integration, thereby promoting innovations. Teachers reported positive perceptions throughout the program and demonstrated significant, productive trajectories of change-over-time. Teachers learned and transferred task-specific engineering and scientific skills, as well as more general inquiry-based pedagogical strategies to their secondary classrooms.

Keywords

professional development, mixed methods, teacher learning

Challenged by federal mandates, K-12 teachers are expected to educate and motivate youth to seek careers in math, science, and engineering (National Academy of Sciences, 2007). To do so, those teachers must first be educated, motivated, and inspired themselves. One strategy to achieve this end is by immersing them in a community of learning and practice, thereby engaging them in collaborative projects and drawing on the insights of mentors and peers. This is the intent of the National Science Foundation's Research Experience for Teachers (RET) programs, as a journey of learning, self-discovery, and change (National Science Foundation, 2008).

Thinking and feeling are naturally and reciprocally related and mutually interact with the learning environment to influence learning and development (Dai & Sternberg, 2004). Real and lasting change requires experience that affects thinking and feeling and reaches out to influence personal and professional identity. This study is based on an integrative conceptualization of human learning and development in which cognition and emotion interact with each other and with elements of the learning environment to facilitate skill transfer and lasting change.

Background/Literature Review

Learning and cognition (how people gain and manage information and ideas) are linked to emotions and creativity, integrally connected in the brain (Imordino-Yang & Faeth, 2004). Metacognition (how people monitor information) goes on continuously and learners who are intentionally metacognitive gain critical control over those processes (Zimmerman, 2006). Metacognitive self-awareness supports learning, motivation, and perceptions that guide growth, change, and identity formation (Sandi-Urena, Cooper, & Gatlin, 2011). Perceptual awareness fuels monitoring and refinement of skills, helping people build and improve what they know and can do. A few studies can be found investigating metacognition and perceptions of teachers but none

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tracking as many complex and influential characteristics of teachers learning and transferring engineering knowledge and skills with multiple administrations.

Engineering Education

Engineering, as a field, is increasing in complexity and diversity connected to the nation's economy, technological innovation, and sustainability (Atman, Kilgore, & McKenna, 2008). Engineering, as a learning space for teachers, provides an opportunity to understand how math and science can be useful and influential in the world (National Science Foundation, 2008). Thus, engineering offers a potential to enhance students' perceived utility and motivation to learn math and science in the early years and strengthen the educational pipeline to science professions including, and beyond, engineering. For these reasons, the public has a cultural stake in engineering education and professional preparation, which begins in K-12 math, science, and reasoning (Sheppard, Macatangay, Colby, & Sullivan, 2009). Yet, there remains a gap in our understanding of how K-12 teachers cross the disciplinary and cultural boundaries to see the inside of engineering and take their insights back to their own students and classrooms.

Teacher Education and Development

High-quality professional development can change teaching practice and improve student learning. In professional development, teachers take on the identity and experiences of learners, with their relational and interpretational processes, driven by perceptions of self and others (Battey & Franke, 2008; Musanti & Pence, 2010). Teachers must learn what they will teach: be lifelong learners and innovators to prepare students for futures of change; and be collaborators to prepare their students for team-based work environments (Dresner & Worley, 2006; Duderstadt, 2008). Professional development is enhanced by including peer collaboration toward meaningful knowledge and skill-sharing that produces knowledge development in communities of learning and practice (Guskey, 2002; Hadar & Brody, 2010; John-Steiner, 2000; Wenger, 1998). Effective teacher development for lasting change requires (a) new idea acceptance; (b) understanding of new practice integration; (c) sharing complex, tacit knowledge; (d) external support for change; and (e) sustaining community to facilitate change (Baker-Doyle & Yoon, 2011; Duke, 2004). With research that more fully illuminates and informs these elements of effective teacher development, we can more consistently design opportunities that enable teachers to cross disciplinary boundaries and innovate for lasting change in their classrooms.

Motivational Factors

The effort, energy, and persistence required for teachers to learn and transfer new skills depend on strong, personally important and productive perceptions, along with a supportive environment (Borko, 2004; Charness, Tuffiash, & Jastrzembski, 2004). What enters classrooms from professional development depends on teachers having positive and productive perceptions of what they are learning and how likely they are to succeed at it, perceptions that position them to invest in, learn, and transfer new skills to their classrooms (Barnes, Hodge, Parker, & Koroly, 2006). Teachers often lack positive perceptions for unfamiliar content and skills (such as engineering) and unfamiliar strategies (such as inquiry-based instruction), but professional development can support efficacy and promote utilization (Powell-Moman & Brown-Schild, 2012). Ultimately, teachers invest in activities they see as useful and feasible for their students and teaching, but they sometimes face challenges that threaten implementation of new skills (Hardré, Nanny, Refai, Ling, & Slater, 2010). Existing research has demonstrated the prevalence of challenges but not how to help teachers overcome them and promote persistence to follow through in learning new applied interdisciplinary skills such as engineering. Given the power of perceptions and motivation to promote learning, development, and transfer, it is essential that systematic professional development research continue delving deeply into understanding teachers' motivational characteristics as they engage in learning and transfer efforts.

Social Networks and Network Analysis

Social networks are connections between people in and across organizations and communities, including social structures and relationships that influence learning and change (Resnick, 1991). People use social networks to share information and to support and leverage connections to benefit themselves or society (Borgatti & Foster, 2003; Scott, 2010). Social capital (knowledge and resources) to support teaching practice is accessible through networks consisting of peers with similar goals and diverse expertise (Kabilan, Adlina, & Embi, 2011). Network analysis offers potential to track teachers' development and utilization of social linkages within communities of practice. Tracking and analyzing social networks is one way to verify the creation and sustenance of connections from on-site professional development activities into long-term relationships and supportive communities needed for transformative development.

Identity Development and Transformation

Gaining knowledge alone does not achieve identity development or authentic transformation. These deeper and more lasting changes are achieved through profound shifts in cultural understanding and ways of thinking about the work we do and the worlds in which we live, often facilitated by getting out of familiar and comfortable spaces and immersion in novel and challenging experiences. The context, interactions, and cultures of places are vastly different between university research laboratories and K-12 classrooms, opening doors to transformative experiences if teachers embrace them. Enculturation and shared discourse are components of identity development and professional transformation (Dresner & Worley, 2006). Experience in authentic contexts and engagement in professional discourse shape individual and group identity (Robbins & Aydede, 2009).

Teachers' professional identities mediate transfer and profoundly affect what teachers take from professional development, as they determine what practices fit into their classrooms. Teachers' identities are interwoven with their expertise and further shaped by situated experiences, as teachers internalize meaningful activities from learning contexts and expertise from strong role models (Brown & Melear, 2007; Hanegan, Friden, & Nelson, 2009; Lenz & Lange, 2005). In RET, complementary expertise meets, as engineering educators are experts in domain knowledge and research methods, whereas the teachers are experts in K-12 pedagogy. Together, they needed to develop shared knowledge and function as a community of learning and practice to produce authentic engineering instruction that is meaningful and accessible to K-12 students. Illuminating the nature and development of teachers' unique professional identities through the formation and effects of their interdisciplinary community was a goal of this study.

Communities of Learning and Practice

In communities of learning and practice, trust drives sharing and increases a group's social capital, which is based on resource richness and accessibility (Hadar & Brody, 2010). People tend to be drawn to work with others similar to themselves but innovation results from dissimilar people interacting meaningfully, generating unique competence and identities (Borgatti & Foster, 2003). Collaborative peer groups promote critical examination of practice and adoption of innovative strategies. However, they do not function in a vacuum, as context profoundly affects learning new skills, and immersive experiences can draw learners out of their comfort zones to accept novel ideas and innovate (Brand & Moore, 2011; Smith & Conrey, 2009). Most previous studies of the teacher communities of learning and practice have not included the development of task-specific and general interdisciplinary skills along with trajectories of motivational characteristics over time and across contexts as this study did.

Research Questions

The overarching purpose of this study was to investigate teachers' experience in terms of perceptions and behaviors in the yearlong, multievent mentoring experience and the support structures that resulted from it. Specific questions addressed were,

Research Question 1: How did the teachers, mentors, and others form and engage in a community of learning and practice?

Research Question 2: What are the trajectories of perceptions in teachers' experience and their relation to teachers' engagement and success throughout the study?

Research Question 3: What specific engineering-based (and general) knowledge and strategies did teachers learn and transfer to classrooms?

Research Question 4: What were teachers' experiences regarding implementation, dissemination, and integration (in their schools and communities); how did the teachers respond; and how did those experiences influence the teachers' success?

Method

Study Design

The study followed the teachers through the year of development and support, tracking perceptual and developmental change, learning and transfer from the on-site experiences, through their return to classrooms. Mixed-method data sources included direct assessment, evaluation, and observation designed to track perceptual and behavioral changes over time. Data were collected independently from multiple informed sources, blinded from the responses of others, to maintain their independence and prevent bias.

Intervention Design

The study intervention was a teacher professional development program conducted at a university College of Engineering. It included a 6-week, cohort-based, on-site residency and mentored lab immersion experience, followed by the teachers returning and applying what they had learned in the experiences. Application included formally implementing a planned, inquiry-based lesson in engineering and informally integrating learned skills and strategies into their secondary classes. They worked collaboratively in small (lab) groups and large (whole cohort) groups on various activities including formal and informal learning, project development, problem-solving, performance, and feedback.

On-site. While on-site, teachers were assigned to small groups working in one of five different engineering laboratories. They were supervised and guided by a university faculty specializing in one of five subdisciplines of engineering, whose teaching and scholarly work were very different. Each small group identified a problem or need in which they were interested and worked to address an open-ended research challenge using all of the resources they had. The small groups worked together all day and the large group from all the five labs met at least weekly for presentations and discussions, as well as for workshops to develop general skills (e.g., proposal development, grant writing, pedagogy). Throughout the project, teachers were also encouraged to identify elements of the lab experience they could translate to the K-12 curriculum and use in their own math and science classes.

Back home. After teachers left the university to return home, they continued working on proposals for their formal implementation projects, for which they could earn grant funding (e.g., for equipment and materials the students would need). There were few scheduled face-to-face meetings and most contact was digital. Teachers kept in contact with mentors and peers through email and discussion boards in the learning management system (LMS). Each had the assignment of designing and proposing a lesson to apply some of what they had learned in engineering to their classes, including collecting data on student learning. Once the teachers' proposals were complete and submitted digitally, they were scored by multiple faculty mentors, given specific feedback, and based on the scores either funded or recommended for revision and resubmission.

Participants

Teachers. The 11 program participants were current math and science teachers (6 math, 5 science) in public secondary schools. They were recruited from schools within a 40-mile radius of the university. There were 7 male and 4 female, ages ranged from 27 to 61 ($M = 47$). As to education, 7 had bachelors degrees and 4 masters. As to race/ethnicity, 9 self-identified as Caucasian and 2 African American. They were employed in nine different schools; 10 taught in high schools and 1 in middle school (Grade 7). Among district types, 9 taught in urban districts and 2 in rural. The teachers had from 2 to 34 years of teaching experience ($M = 17$) and taught the full range of secondary math and science courses (e.g., chemistry, biology, physics, algebra, geometry, statistics) from basic to advanced placement (AP) levels. They were paid for room and board, while on-site, and given a stipend for their participation in the yearlong study.

Engineering faculty mentors. Mentors for the project were six engineering faculty members at a major research university (two campuses) who volunteered as mentors. All possessed earned doctorates, and the interdisciplinary mentor group specialized in the following engineering areas: environmental (1), industrial (2), computer (1), chemical (1), and civil (1). Four were male and two female; they had 7 to 25 years of postsecondary teaching experience and 1 to 5 years of previous experience mentoring K-12 teachers. Teacher/faculty pairing was done through an application process that took into account teachers' preferences and interests.

Data Collection

Data types and sources. Data for the study were qualitative and quantitative, on multilevel, multisource indicators, collected using a range of methods (Reynolds, Livingston, & Willson, 2006; Thornkildsen, 2005). Data addressing the research questions were collected separately and independently from the participating teachers, engineer-mentors, and lab graduate assistants (GAs). Each individual and group was blinded from the responses of the others, except in cases of specific discussion entries and performance materials for which collaboration and feedback were required. Data for the 11 participants were from 25 separate collection events, over the full 12-month program cycle. Table 1 shows the program and study activities.

Data Collection System and Method

During and after the on-site experience, data for questionnaires, discussion boards, and digital journals were collected using a centralized system, a digital LMS. The on-site observations, interviews, and focus groups were done face-to-face, with audio recordings transcribed and thematically coded. Performance measures used a combination of synchronous, face-to-face presentations and asynchronous digital interactions for feedback and revision.

Measures

Data sources from teachers included four multisubscale questionnaires, journals, entries in online discussion forums, products from activities, project proposals, final project reports, and reported interactions with others. Data from mentors included journals, entries in discussion forums, evaluations of teachers' on-site participation, scoring of teacher project proposals, and interviews.

Questionnaires. All the questionnaires used in this study have been used in previous research. All the Likert-type scales in the questionnaire anchored 1 = *strongly disagree* to 7 = *strongly agree*. Subscales included positively and negatively worded items, as a check for agreement bias (Creswell, 2003; DeVellis, 2012). Subscales demonstrated adequate reliability (Cronbach's *alphas* of .70-.97). Questionnaires were administered four times (Weeks 3, 6, 20, and 30). Table 2 shows the summary of performance statistics for the quantitative questionnaires used in the study.

Teacher content and skill perceptions. A set of multisubscale questionnaires assessed perceptions related to the learning experience. The 29 items were selected a priori to assess six different constructs: perceived value, utility, benefits, feasibility, and fit for their classrooms. These constructs have demonstrated influence on transfer from teacher development. Sample items: value ("I recognize how these skills will be valuable in my teaching."), utility ("I see how what I learned here could be useful in teaching my students."), benefits ("I recognize how the skills I learn here benefit me as a teacher"), feasibility ("I see these skills as feasible to use

Table 1. Timeline of Program and Data Collection Activities.

Timing (and date)	Participants	Activity/event	Tool and system	Community
Week 1 13 June	Teachers Mentors	Whole-cohort meeting Orientation, LMS training Work in lab and research groups	Digital surveys Open-ended items (LMS)	Face-to-face and digital Whole cohort and small groups Structured and unstructured
Week 2 20 June	Teachers Mentors	Begin journals—private Teacher writing prompts Mentor writing prompts Pedagogy Workshop I	Journals (LMS) Discussions (LMS) Digital surveys	Face-to-face and digital Synchronous and asynchronous Whole cohort and small groups Structured and unstructured
Week 3 27 June	Teachers Mentors	Q Set Version 1(Time 1) Work in lab and research groups Cohort Research Conference I	Digital surveys	Face-to-face (small groups) Synchronous and asynchronous
Week 4 05 July	Teachers Teacher Mentors	Begin development project Writing prompts Proposal development training	Develop project ideas discussions (LMS)	Face-to-face (small groups) Synchronous and asynchronous Structured and unstructured
Week 5 14 July	Teachers Mentors	Work in lab and research groups Pedagogy and proposal workshop	Direct observation	Face-to-face, synchronous Whole cohort and small groups Structured and unstructured
Week 6 (end on-site) 18 July	Teachers Mentors	Q Set Version 1 (Time 2) Mentor writing prompts Cohort Research Conference II Engineering as a profession	Digital surveys	Face-to-face, synchronous Whole cohort and small groups Structured and unstructured
Week 7 25 July	Teachers	Give feedback on others' "developing project ideas together"	Discussions (LMS)	Face-to-face and digital Synchronous and asynchronous Whole cohort and small groups Structured and unstructured
Weeks 8-10 01 August	Teachers	Complete development ideas, questions and feedback; Write project proposals	Discussions (LMS)	Digital Asynchronous
Week 9 08 August	Mentors	Mentor evaluation of online discussions	Digital surveys	Digital Asynchronous
Week 10 15 August	Teachers	Submit project proposal	Submit by email or LMS Dropbox	Digital Asynchronous
Week 14 12 September	Teachers Mentors	Mentor evaluations and feedback on proposals (funded, not/revise)	Digital rubrics	Digital Asynchronous
Week 18 10 October	Teachers Mentors	Teacher writing prompts Mentor writing prompts	Discussions (LMS)	Digital Asynchronous
Week 20 24 October	Teachers	Q Set Version 2 (Time 1)	Discussions (LMS)	Digital Asynchronous
Week 30 02 January	Teachers	Q Set Version 2 (Time 2)	Digital surveys	Digital Asynchronous
Week 35 06 February	Teachers Mentors	Teacher writing prompts Mentor writing prompts	Discussions (LMS)	Digital Asynchronous
Week 40 12 March	Mentors	Report on project results and upload	Discussions (LMS)	Face-to-face, Synchronous Small groups
Week 42 26 March	Mentors	Mentors evaluate project reports Give teachers feedback	Digital surveys	Face-to-face, synchronous Whole cohort and small groups
Weeks 53-54 6-15 June	Mentors	Exit interviews	Face-to-face	Face-to-face, synchronous
Week 54 22 June	Teachers	Focus groups	Face-to-face	Face-to-face and digital Whole cohort Structured and unstructured

Note. Table presents all RET activities, goals, and methods by week. LMS = learning management system; RET = research experience for teachers.

Table 2. Performance Statistics for Questionnaire Subscales.

Subscale	Number of items	*M*	*SD*	Alpha[a]
Value	5	6.63	0.39	.91
Utility	6	6.50	0.35	.97
Benefits	6	6.50	0.39	.92
Use	6	6.00	0.77	.90
Efficacy	5	5.78	1.04	.97
Challenges	1	4.73	1.41	[b]
Feasibility	6	6.00	0.60	.91
Fit	5	6.04	0.42	.93
Change	4	5.99	0.64	.91

[a]Reliability as Cronbach's alpha statistic, average across all administrations.
[b]Reliability could not be computed for environmental changes because scale consisted of one item.

in my teaching"), and fit ("The ideas I am learning here are a good fit for my needs in my own teaching"; Cronbach's *alphas* .79-.97 over 4 administrations).

Teacher self-efficacy to transfer. The teachers' self-efficacy to transfer the content to application for their classes and students was assessed using a five-item subscale (Likert-type). Sample item: "I am pretty sure that I can apply the skills attained in RET correctly" (Cronbach's *alphas* .88-.97 across 4 administrations).

Teacher use and integration of content. The teachers' intent to use (Weeks 3 and 6) and then actual reported use (Weeks 20 and 30) were assessed using a six-item subscale (Likert-type). Sample items, "I am integrating the ideas attained during RET into my own teaching," and "I effectively use the skills from RET in my teaching" (Cronbach's *alphas* .87-.90 across 4 administrations).

Teacher participation and engagement. The complex outcome of teacher participation and engagement was assessed using multiple measures and sources. Mentors using a standardized observation scoring rubric (7-item, Likert-type, 5-point scale, "not at all true" to "very much true"), captured teachers' participatory and engaged behaviors, verbal and nonverbal, at two administrations (Weeks 3 and 6) (Cronbach's *alphas* .73-.97 across 2 administrations). Mentors also documented behavioral evidence with qualitative descriptions, plus independent notes and observations on participation (ongoing). In addition, mentors also reported the teachers' individual and group participation and engagement in interviews, at the end of the program period (Weeks 38-39).

Attribution of change. After the middle of the on-site experience (times 2-4), the perception questionnaire contained an additional subscale, attribution of change. It consisted of four items that assessed the extent to which growth using engineering-related research principles in the classroom could be attributed to the RET program. Sample items: "The RET program helped me to integrate engineering research into my classroom" and "I am implementing more engineering research into my classroom due to my experience in the RET program" (Cronbach's *alphas* .78-.91 across 3 administrations).

Social networks. The formation of social connections and their duration through the study period were assessed using a social network assessment (Cowan, 2011). This instrument presents the names of the individuals and asks each participant to report several aspects of their relationship: first, whether they knew each other prior to the intervention; second, at what point they connected during the intervention and who initiated contact; and third, how frequently they were in contact during the at-home part of the intervention and who initiated contact. The social network analysis then combines the multisource data reporting by all individuals (teachers and mentors), verifies consistency through cross-reporting, and produces a number of independent linkages attributable to the study project, with a frequency and duration of independent connections among the members of a study-based community and social network.

Journals and discussions. Teachers and mentors entered data into two types of generative tools within the LMS. Journals were private and open-ended, guided by the participants' desire to document experiences. Journals generated a total of 249 separate entries by the teachers over the study period. Discussions were shared and interactive, structured through prompts. The mentors' discussion board entries were visible to other mentors while the teachers' entries were visible to all, inviting community response. Nine discussion events (five for teachers, four for mentors) were given throughout the yearlong project cycle, each with multiple prompts that functioned to cue responses. Each presented 4-6, open-ended items required responses. Sample question—teachers: "What specific things did your peers in the research experience do that helped you to see how to integrate the skills into your classroom? Why did that help you so much?" Sample question—mentors: "Since the beginning of RET, have you seen an increase in team confidence to integrate skills from RET into their classroom teaching? Please provide evidence that you have observed." The 31 discussion questions/prompts for teachers generated 218 responses, and the 16 for mentors generated 64 responses.

Online implementation planning and discussion. Teachers engaged in online implementation and planning discussion to support transfer and integration of the engineering-related research principles. Eight prompts elicited teachers' thinking for transfer and integration into their classrooms; then, they were asked to respond to peers' postings. Their responses and comments were analyzed for a range of perceptions and strategies to integrate.

Performance-based products. Sets of performance-based products were included to reduce response bias and provide objective sources of the evidence of engagement and learning.

Proposals. Teachers wrote research action plans (called Engineering Research Implementation Projects [ERIP]), implementing elements of their research experience into classrooms. Proposal documents included the research plan and the lesson plan. Proposals were scored by two mentors using a standard rubric (3-pt. numeric scale, 10 criteria) aligned with performance goals.

Project implementation reports. After project implementation, teachers submitted reports containing results. The reports were evaluated with a rubric similar to the one for the proposals.

Other data sources

Email conversations. The wealth of email that flowed among mentors and teachers provided critical insights into what was occurring in the program, particularly after the teachers left the on-site experience. We collected 39 email messages as naturalistic data for analysis.

Teacher focus group. Teachers participated in a semi-structured focus group near the end of the study period (Week 47). Questions addressed the perceptions of learning in the RET experience, project implementation, and school support.

Mentor interviews. Mentors participated in systematic, semi-structured, individual interviews with the evaluators at the end of the program cycle (Weeks 43-45). They reported on their personal perceptions and reflections, as well as on their teachers' learning, development, and productivity.

Analysis

Quantitative measures were tested for reliability, internal (as Cronbach's *alpha* coefficients) and external (consistency across administrations), and all performed well (see Table 2). Analysis included a variety of methods as appropriate to our questions and data types (Creswell, 2003; Mertens, 2010). For quantitative data we generated overall means, then compared them for the trajectories of change, magnitude, and the statistical significance of change-over-time (Denzin & Lincoln, 2003). For qualitative data, multiple researchers independently coded responses and generated themes. These themes were compared for patterns of meaning and change. Results from both types of data were synthesized and triangulated to address the research questions (Fraenkel & Wallen, 2006; Mertens, 2010).

For example, data from multiple sets of questionnaires (quantitative), teacher focus groups, and several individual teachers' private journals (qualitative) independently described the same patterns of initial optimism, then "reality check" followed by efficacy recovery and feelings of increased optimism and decreased worry over challenges to implementation. Teacher questionnaires (quantitative) and discussions, as well as mentor interviews and journals (qualitative), independently reported similar levels of teacher engagement and effort and attributions of change. Teacher focus groups and journals, mentor interviews and journals (qualitative), and project performance documents (quantitative and qualitative), all independently supported the types of knowledge and skills that the teachers learned and transferred, as well as how teachers learned from each other, on-site and off-site. In each case, some or all the data triangulated for these findings were blinded among the sources, and each drew from different data collection events.

The "Results" section addresses each of the research questions including (a) the key findings relevant to that question, (b) how the key terms and outcomes are operationalized, (c) what data sources were drawn from to generate findings for that question, and (d) the examples of the data patterns from across the relevant sources.

Results

The data generated by this study underscored the dynamic interaction of what the teachers and mentors brought to the university immersion experience with the structures and resources, designed into the RET experience over its entire lifecycle. The data further illustrated the process of teachers' adoption of new pedagogical methods and integration of those methods into their teaching. Causal assertions are drawn from the teachers' and mentors' independent (and consistent) attributions, as well as from the consistency of indicators in the multisource, mixed-method data.

Formation of Learning Community

Our first question was, "How did the teacher, mentors, and others form and engage in a community of learning and practice?" Data sources for this question were teacher and mentor discussions and journals, social network analysis, project documents, and mentor interviews. Formation of community is apparent in the creation of social connections that emerged as networks among the teachers and mentors. Teachers' engagement in the community operationalizes as taking advantage of connections to address needs and support. Teachers engaged in community-based learning in their mentoring groups and in the whole-program cohort, face-to-face and in the online LMS. In terms of observed behaviors, they attended events and became actively involved. Inside the labs, teachers teamed up to develop new skills together and leverage complementary skills. They also documented

Table 3. Numeric Summary of Networks Created Due to RET.

	Connections from participant		Connections to participant	
Name	Pre-RET	Added by RET	Pre-RET	Added by RET
Donald	2	1	2	0
Emma	0	6	2	1
Jamie	1	0	2	0
James	3	2	6	1
Logan	3	0	2	1
Maya	3	2	6	0
Matthew	0	0	3	1
Nathan	2	2	4	0
Samantha	2	3	0	1
Ron	0	0	0	0
Sal	0	3	0	1
Total	16	19	27	6

Note. This table presents preexisting connections as well as connections created during RET per participant. RET = research experience for teachers.

the inclusion of the lab GAs in their communities. As Table 3 illustrates, network analysis demonstrated that participants carried these relationships beyond the on-site experience and found them important in supporting project planning and implementations. Sal shared how their community dynamic operated: "During our research time we are very engaged in what is going on, even when we are observing. There is a discussion going on about procedures, questions being asked in both directions." One mentor captured an example of teachers collaborating and learning:

> I see Logan[1] and Emma definitely working together as a team. Logan, who has the greater scientific expertise, often takes on the role of leader and teacher . . . in the lab. He guides her through the process, and . . . She works hard to make sure that she contributes equally in the lab. The two of them work very well together.

A mentor commented on the teachers extending the community of learning and practice beyond the program to others: "They took initiative to find online resources . . . They emailed many people asking for help. I can see that they are taking this seriously and want to do many great things in their classrooms." Teachers demonstrated development of rich relationships engaging socially with the mentors and peers (not just "putting in time"). They emphasized the importance of their shared goals and diversity of skills. In data collected near the end of the year, the teachers and mentors verified that many of the partnerships developed on the site continued back in their schools and communities.

Teachers identified particular others in the community with skills they needed, mentors, peers, and GAs working in the labs. These GAs were not attached to the study program, but through sharing the lab space with teachers naturally became a part of their community. Sal shared: "I certainly have been fortunate to get Samantha as a partner and the assistance we have gotten from the grad students [names] has been nothing short of phenomenal." He emphasized that having complementary skills supported their mutual learning and said they planned, "collaborating with each other during the school year."

Community-Based Teacher Learning and Growth

The teachers recognized that they were learning new skills in a new cultural space. Jamie shared her risk-taking and its benefits: "I am definitely out of my comfort zone and challenged to expand my areas of knowledge and incorporate important information that will help my students be better prepared for their future and to be better thinkers."

Emma reported overcoming a personal weakness to strengthen her teaching:

> My weakness is chemistry . . . to improve as an environmental science teacher I must learn more and be able to teach the chemistry side of my class better. This experience is connecting some dots for me in the chemistry world.

Many teachers shared in their journals about learning skills (such as chemistry lab processes) from each other and about collaboratively brainstorming with their teacher-peers on ways to share what they were learning with the students.

Lab groups bonded closely and collaborated in ways that leveraged unique skills and strengths. One mentor wrote:

> Matthew and Nathan . . . work closely together on every aspect of RET research and project. Each of them is in charge of some tasks . . . and they help each other in understanding and going forward with the research.

Perhaps more subtle but important is the prevalence of the use of "we" throughout the data, referring to subgroups (we teachers, we mentors) or to the whole RET community.

Beyond the formal assessments, some teachers also reported that they communicated with each other on public social networks (e.g., Facebook, Twitter, LinkedIn). Although it was not required, some teachers arranged with their mentors and brought their students on field trips to the university engineering labs. Some mentors also visited their teacher participants' classes and schools, as guest speakers or to observe their project activities during implementation. Some teachers visited the classes of peer teachers to help or observe in their teaching or project activities. These kinds of voluntary activities grew out of the connections begun at RET and demonstrated in ongoing community relationships through the study year and beyond.

Social network analysis revealed that 16 unique connections were created among teachers and mentors through RET and that email was their dominant off-site communication method

Table 4. Teacher Perceptions Subscale Scores Over Time.

	Time 1	Time 2	T2-T1 difference	Change (%)	Time 3	T3-T2 difference	Change (%)	Time 4	T4-T3 difference	Change (%)
Value	6.70	6.96	+0.26	+4	6.06	−0.90	−13	6.42	+0.36	+6
Utility	6.51	6.75	+0.24	+4	5.98	−0.77	−11	6.26	+0.28	+5
Benefits	6.62	6.89	+0.27	+4	5.95	−0.94	−13	6.13	+0.18	+3
Use	6.48	6.81	+0.33	+5	5.20	−1.61	−23	5.10	−0.1	−2
Efficacy	6.60	6.72	+0.12	+2	4.62	−2.10	−30	4.96	+0.34	+7
Environmental challenges	5.45	6.32	+0.87	+12	3.90	−2.42	−35	3.30	−0.6	−15
Feasibility	6.58	6.41	−0.17	−3	5.33	−1.08	−15	5.33	0	0
Fit	6.20	6.50	+0.30	+5	5.50	−1.00	−14	5.50	0	0
Attribution of change	—	6.65	—		5.37	−1.28	−18	5.57	0.2	+4

Note. All mean values rounded to two decimal places and percentages rounded to whole numbers. Change (%) is calculated as percentage of the full range of the scale. The empty column at the center denotes the break when the teachers returned home.

of choice. Teachers cited busyness of life as limiting their more active communication, yet expressed belief that their community was authentic and important. Donald articulated this belief:

> I have been very busy, and haven't had a lot of spare time to develop my relationships with [mentor] or my peers . . . I do believe that we have forged true relationships, however, and believe that we will be in touch in the future.

Teacher Perceptions and Motivations

Our second question was, "What are the trajectories of perceptions and their relation to the teachers' engagement and success throughout the study?" Data sources for this question were questionnaires, teacher and mentor discussions and journals, project documents, and mentor interviews.

We analyzed the questionnaire data in several ways. First, given the small sample and mixed-method data, we examined the overall magnitude and patterns of change across the nine perceptual variables, comparing them with each other and triangulating their patterns of change with relevant qualitative data from the teachers and mentors. Second, we ran statistical tests, including F tests of significance in change-over-time, and multivariate power and effect tests (using *Wilks's Lambda*) for the multiadministration questionnaire scales. These analyses helped us to consider our data from multiple perspectives.

Table 4 shows the means of teachers' perceptions (e.g., value, utility, benefits) of content and skills over that period. Times 1 and 2 were during the on-site RET and Times 3 and 4 were during their at-school implementation. Figure 1 shows a line graph of the patterns of scale means of the teacher perceptions over the study period.

Time 1 of the questionnaire administration is in Week 3 of the RET on-site experience. Even then, at the midpoint of immersion, the teachers reported positive perceptions of the content and skills for their teaching (all M = 6.20 or above) and relatively low environmental challenges to their success (M = 5.45).

At Time 2 (Week 6) the end of the immersion experience, they report higher scores for both (M = 6.32-6.89). It is also worth noting that at Time 2 they are reporting at the top of the 7-point scale, so there may be a ceiling effect constraining scores at this point. Clearly, these teachers are very positive about what they are learning and its potential for their teaching.

The increase in perceived challenge (arguably a less productive perceptual factor than the others) demonstrates that even as they saw increased value, utility, and benefits for their students, they were processing practical constraints that might exist for taking the engineering skills back to their students. However, efficacy also increased, illustrating that they were willing to take on challenges that they saw presented and that they expected to succeed in spite of them. These scores demonstrate important and productive patterns of change that predict success for these teachers.

The teachers' perceptions of value, utility, benefits, and fit supported them in working through challenges, as they recognized gains toward their short-term goals of learning skills and long-term goals of transfer. Teachers reported high initial efficacy for tasks of learning engineering and taking it back to classes (M = 6.60). Those perceptions increased while on-site (to M = 6.72) as they developed better skills.

At Time 3 (Week 20), after returning home and beginning implementation, the teachers' scores adjusted downward some (M = 3.90-6.06). This is typical of individuals moving from a learning environment to a transfer environment, indicating that they were experiencing a "reality check" as they worked more independently to transfer skills.

However, by Time 4 (Week 30), these scores, except perceived challenges, recovered upward again (M = 4.96-6.42), thereby becoming more similar to where they had begun at Time 1. Perceived challenges remained below their Time 1 starting point, demonstrating that the teachers' perceived barriers had been adjusted through development. This shift seems to have resulted from their success in implementation.

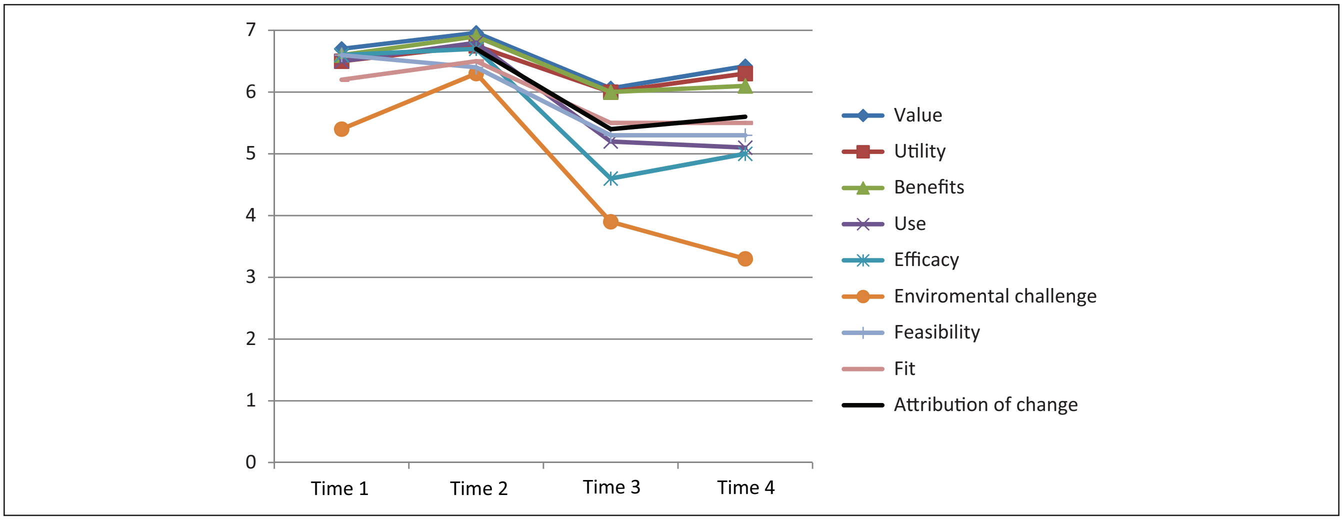

Figure 1. Teachers' perceptual trajectory of change over time.
Note. Figure 1 presents group means on all perception questionnaire subscales over four administrations.

All the productive perceptual characteristics (except feasibility) were highest at Time 2, showing a pattern of positive and productive perceptions, strongest when teachers were immersed in a supportive community of learning and practice. All the characteristics dropped, demonstrating a "reality check" when the teachers left the immersive experience and tried problem-solving on their own and with unrelated, authentic life constraints. However, five factors recovered in a positive direction and three more stabilized at Time 4, as the teachers experienced various degrees of success or particular challenges in implementation, and continued to be supported by the community.

The qualitative data generated independently from multiple sources over these same time periods is consistent with these quantitative findings. The patterns in the qualitative data support the development of positive perceptions including an efficacy in response to challenge, along with an increased willingness to take on challenges in engineering as they progress through the experience. Early in the process, some of the teachers expressed questions about their own ability, or self-perceptions of skill below those of their peers, but those perceptions adjusted upward as they gained successful experiences and received positive feedback from the learning community.

Mentors gave examples of how their teachers exceeded expectations and requirements to achieve their goals. One described how teachers used the web strategically to stretch grant funds:

> Both teachers are planning to purchase special equipment so that they can run some of the assays we are doing in the lab . . . they need incubators, and spectrophotometers. It turns out that [online site] is a wonderful resource to find decent quality used equipment.

Another mentor shared that his teachers took, "amazing initiative and have emailed top scholars in this domain (and have gotten replies!) . . . evidence of their interest and motivation toward the topic." Some teachers with high efficacy and skill went well beyond expectations and engaged in reciprocal teaching activities and product creation in their labs. One mentor shared,

> Logan has gone beyond the scope of the project and developed a new design for a rotating biofilm reactor that will allow us to grow biofilms in water–oil systems . . . His design was eventually modified into a new reactor system that we now use extensively in our research.

There was an initial drop in perceived efficacy after teachers left the ever-present, on-site community, but it recovered well when they began implementation, demonstrating the effects of success of their efficacy to transfer. The continued downward trajectory of the perceived challenge was overall a healthy development pattern of self-perceptions. The teachers' self-reported social perceptions indicate that they feel connected to the other teachers, referring to each other as "friend" and "partner," and to their mentors in terms of respect and admiration.

With regard to the second, more formal statistical analysis, we conducted multivariate tests of power and effect size, as well as tests of significance in the change between our four data points of administration. Based on the small sample size, our target level of significance was $p < .05$. Table 5 shows the summary of these initial analyses.

On significance tests for the variables—value, utility, benefits, and fit—the multivariate tests indicate no overall statistically significant difference between administrations. However, for the variables' use, efficacy, perceived challenge, and feasibility, they indicate at least one significant

Table 5. Effect Sizes and Observed Power for Change Over Time.

	F statistic	*p* value	Effect size	Power
Value	$F(1, 10) = 8.10$	.389	.075	.129
Utility	$F(3, 7) = 1.547$	.285	.399	.228
Benefits	$F(3, 7) = 2.684$	.127	.535	.417
Use	$F(3, 7) = 9.478$	.007	.802	.930
Efficacy	$F(3, 7) = 15.714$	.002	.871	.994
Environmental challenges	$F(3, 7) = 5.137$	.034	.688	.700
Feasibility	$F(3, 7) = 9.547$	.007	.804	.931
Fit	$F(3, 7) = 4.241$	.053	.645	.611
Attribution of change	$F(1, 10) = 12.067$	.004	.751	.956

Note. Effect size and power statistics are computed using *Wilks's Lambda*, effect as partial *eta*-squared. Significance target of difference between means is $p < .05$.

Table 6. Follow-Up Significance Tests of Change.

	Significance of incremental change scores (*p* value)			Significance of nonincremental change scores (*p* value)		
	Time 1-2	Time 2-3	Time 3-4	Time 1-3	Time 2-4	Time 1-4
Use	*ns*	.003	*ns*	.027	.006	*ns*
Efficacy	*ns*	.003	*ns*	.003	.001	*ns*
Environmental challenges	*ns*	.016	*ns*	*ns*	.024	*ns*
Feasibility	*ns*	.003	*ns*	.003	.001	*ns*
Attribution of change	NA	.007	.002	NA	.002	NA

Note. NA = not applicable as this subscale was not administered at Time 1; because it is an attribution of change, no initial assessment was possible. *ns* = nonsignificant change.

difference between administrations. Those significant changes were not in all cases between points of administration in sequence (e.g., they might be T1-3, rather than T1-2, T2-3, or T3-4). Because of our interest in the trajectory of change-over-time, we chose to report only the sequential significance tests. Table 6 shows the significance tests for all sequential points of change-over-time.

Consistent with the less formal mean comparison table and trajectory line graph, the greatest changes occurred when the teachers returned home from the immersion experience. With the small sample size and apparent ceiling effect, even these changes were not all statistically significant. Some of the mean differences showed identical percent change but differential significance. This may also be attributed to the combined effects of the small sample size (sensitive to small differences in statistical characteristics such as standard deviations) and the differences in the power of the nonsignificant variables. Fit came very close to the target of statistical significance (off only $p = .003$).

Among the five variables that achieved statistically significant change scores, all are significant in the comparisons of Times 2-3 and Times 2-4, between the on-site and off-site experiences. Given their magnitude and stability during the on-site period, none demonstrated significant change Times 1-2. Given their relative recovery by the final administration, none showed significant change Times 1-4 (the perceived challenges were not given Time 1). Only the perceived challenges showed significant (continued downward and productive) change Times 3-4.

Learning and Transfer of Skills Into Practice

Our third question was, "What specific engineering-based (and more general) knowledge and strategies did the teachers learn and transfer to their classrooms?" Data sources for this question were the teacher and mentor discussions and journals, project documents, teacher focus groups, and mentor interviews. The teachers shared things they were learning, unique to their needs and interests, based on the modeling of inquiry-based learning. Because many of these were not articulated by mentors, they serve as evidence of the teachers engaging and personalizing the RET experience. Donald wrote that he learned, "how to use the engineering cycle to solve problems," and "how universities work hand in hand with other entities to promote the welfare of the public." Emma reported learning a range of lab skills such as use of new scientific equipment and conceptual knowledge across the types of scientific research.

Mentors also independently reported specific knowledge and skills that the teachers were developing. One shared, "Logan and Emma have mastered the fundamentals of preparing simple microbial cultures using sterile techniques, as well as mastered doing the necessary calculations and techniques to make chemical solutions of accurate concentrations." Another mentor wrote,

> The teachers are learning more on how to execute their experimental plan in terms of setting up stimuli, planning the procedure of the experiment, and so forth. They made good progress in this regard . . . I can see they are learning and they are very motivated to incorporate their research experience in their classrooms.

Critical to the teachers' transfer goals was the balance of development in scientific technique and inquiry-based pedagogy. The teachers noted that they found important knowledge and skill gaps relevant to their teaching, enabling them to teach more effectively. Those who did not already have well-developed skills and style in inquiry-based lesson design and teaching struggled to learn the content and the pedagogy at once. Those who came in with strength in one or the other (or both) found it much easier to integrate engineering principles. One mentor illustrated:

> Logan has a better grasp on inquiry-based learning than Emma, as evidenced by his ideas for engaging his students with chemistry concepts. Emma is moving in the right direction . . . I think as she gains more experience with research, she will become less concerned with technical details and will be able to focus on the conceptual design of inquiry.

Some teachers found it challenging to translate complex skills they were learning for foundational courses. Donald shared the challenge of reorienting thinking, "I am challenged to learn to think like an engineer to solve problems . . . I will be able to help my students to think more like engineers." He found some online resources to help with the support and translation:

> This morning we [peer group] learned about the National Science Digital Library (NSDL) and a pathway within the NSDL called TeachEngineering. I hope to make use of this knowledge in the coming school year as it appears to be a way to access valid, pedagogically sound curriculum for math and science classes.

One mentor discussed the problem-solving:

> [my teachers] are struggling with how to use something as experimentally complex as biofilms to teach fundamental biology or chemistry concepts. I keep suggesting we start with the PASS skills and build from that base. I also remind them that they don't necessarily need to grow biofilms in their classroom as a course lab. They could do it with a special student group (after-school science club, or science fair project).

Considering alternative but authentic contexts and applications of the skills (instead of previously-used "scaled-down," or "recipe-style" lab activities) was one of the big hurdles for teachers across groups. This represented a major paradigm and strategic shift that most of them made, albeit at different speeds and in different ways. Emma used related activities disseminated online to help her bridge the gap. Her mentor wrote that she had, "found several simple [and relevant] labs on the Internet and is working with me on how to modify them for her course."

The teachers recognized modeling that was occurring, and mentor modeling emerged as one of the strongest strategies that supported learning and transfer. Sal wrote that his mentor,

> gave us a problem and told us to solve it. He gave us access to people who could supply the equipment . . . the idea was, I am sure, to force us to develop our own procedures, to use our own thought processes.

The teachers recognized the expertise of their mentors and consistently admired how complex content was made accessible to them. Jamie marvels,

> How amazing for them to be able to explain the information and their research to me so that I could understand it and share this experience with my students . . . encourage them to find out more about engineering and the research that is happening all around them!

Some mentors expressed surprise at the level of thinking into engineering that the teachers demonstrated in such a short time. One mentor observed that even though the teachers lacked the technical language of engineering, the depth of their thinking into the engineering tasks surprised him:

> Both James and Maya have been actively engaged in creating a data set to attempt to predict bridge behavior. They have used analytic tools and scale models . . . We have had discussions concerning anticipated results . . . Their intuitive ideas concerning behavior have been based on complex buckling issues. This is a more advanced thought process than I had expected.

The mutual respect built in the whole cohort and in small (lab) groups carried the teachers through the challenges and supported innovative thinking reported by the teachers and mentors. Sal shared,

> I am planning on using my grant monies to purchase a photospectrometer for my classroom. …However, I will also take back this new way of looking at problems/experiments and the way these experiments fit in with my students—the discovery aspect.

A mentor noted that the teachers in his lab were learning much more basic skills to use and teach, "experiencing RET has opened new ideas . . . about what they might be able to do in their classrooms," not only project-specific ideas, but in the other areas of science. Another mentor noted that for one teacher it seemed that, "just the stimulation of being in the lab and doing research has invigorated his creativity."

The teachers dared to envision bringing authentic and rigorous applications of their university lab projects into their secondary school courses and labs. Their mentors were careful not to discourage their big ideas but to support them. One mentor shared this example:

> At the beginning it was not at all clear how it would be possible to integrate tissue engineering into a high school situation. I actually had low expectations for doing any work with cells . . . Both Sal and Samantha are now making plans to do tissue culture in the classroom. I still find that very ambitious.

Implementation Experiences

Our fourth question was, "What were the teachers' experiences regarding implementation, dissemination, and integration (in their schools and communities); how did the teachers respond; and how did those experiences influence the teachers' success?" Data sources for this question were the teacher discussions and journals, project documents, teacher focus groups, emails, and mentor interviews. The straightforward goal of implementation is clearest in teachers' carrying out planned projects with direct peer and mentor support. The more nuanced goal of classroom integration is evident in having ideas and strategies from RET "creep into" regular teaching activities and practice, thereby creating subtle but transformative change. Even with lofty goals and detailed planning, some of the teachers encountered challenges and barriers to their implementation plans once they returned to their schools.

One practical factor that emerged as a constraint for many teachers was time. One element of time is the short school period, which makes it challenging to take daylong activities from the university to the constraints of the secondary school's 50-min period. Another way that time is a constraint is for teachers implementing their projects adapting to the school year schedule and related pressures. Matthew's project preparation interacted with time constraints to delay his implementation: "I shortened the lessons due to the fact that [it was] the last week of school. I delayed the lessons in this project since we had trouble finding someone to complete the racing simulation software." Maya's project implementation was disrupted by requisites for standardized tests: "I was not able to apply all of the lessons I wrote . . . Due to time constraints in covering the curriculum for the AP Statistics exam, I ran out of time."

Another factor is the interdisciplinary nature of the field of engineering. Most of the lab tasks from these engineering specialties did not fit neatly into class categories such as "biology" or "chemistry" but used skills and concepts from across the sciences. This is another way that authentic context of the university lab was challenging to translate into a context of secondary school. Teachers experienced challenges in tying tasks to their own scope of curriculum or ensuring that all students had the interdisciplinary prerequisite skills to be successful.

Yet another factor presenting implementation challenges was the difference between the open culture and adult students in the university and the more protected environment and minor students in the secondary schools. Jamie faced an unexpected barrier of perceptions toward the equipment that required her to rework the implementation plan. Her original project idea raised parental concerns about privacy and civil rights issues, so she defaulted to some existing systems and adapted them. These issues became sharply-defined in the secondary context, whereas they were nonissues in the university.

A few teachers received special allowances as support from their school administrators to set aside policy or practices such as tight curriculum alignment requirements for the benefit of the teaching experiment, and a few others "partnered" with their peer teachers in other sciences to remediate for prerequisites so that they were covered. It is clear that these special arrangements took extra time and effort by the participating teachers and their at-home colleagues and trust from their administrators. Such investments clearly made a difference in facilitating those teachers' success.

Discussion

There is ample evidence of the formation and sustenance of an interdisciplinary community of learning and practice among these teachers, their engineering mentors, and others. They demonstrated several characteristics of healthy and productive communities, including (a) resource-sharing and interdependence, (b) innovative thinking and reciprocal learning through sharing of complementary skills, and (c) metacognitive awareness resulting in critical practice.

Reciprocal teaching occurred not just among peers but also between the teachers, mentors, and GAs. The learning was not one-way, with experts in engineering and traditional research teaching novices (the teachers). It was multidirectional, with experts in engineering and research teaching novices in that area (the teachers) and with experts in K-12 education teaching novices in that specialty (the mentors and lab teaching assistants). Based on the shifts evident across all types of data over time, contexts had a tremendous impact on the teachers' perceptions, learning, and development. This

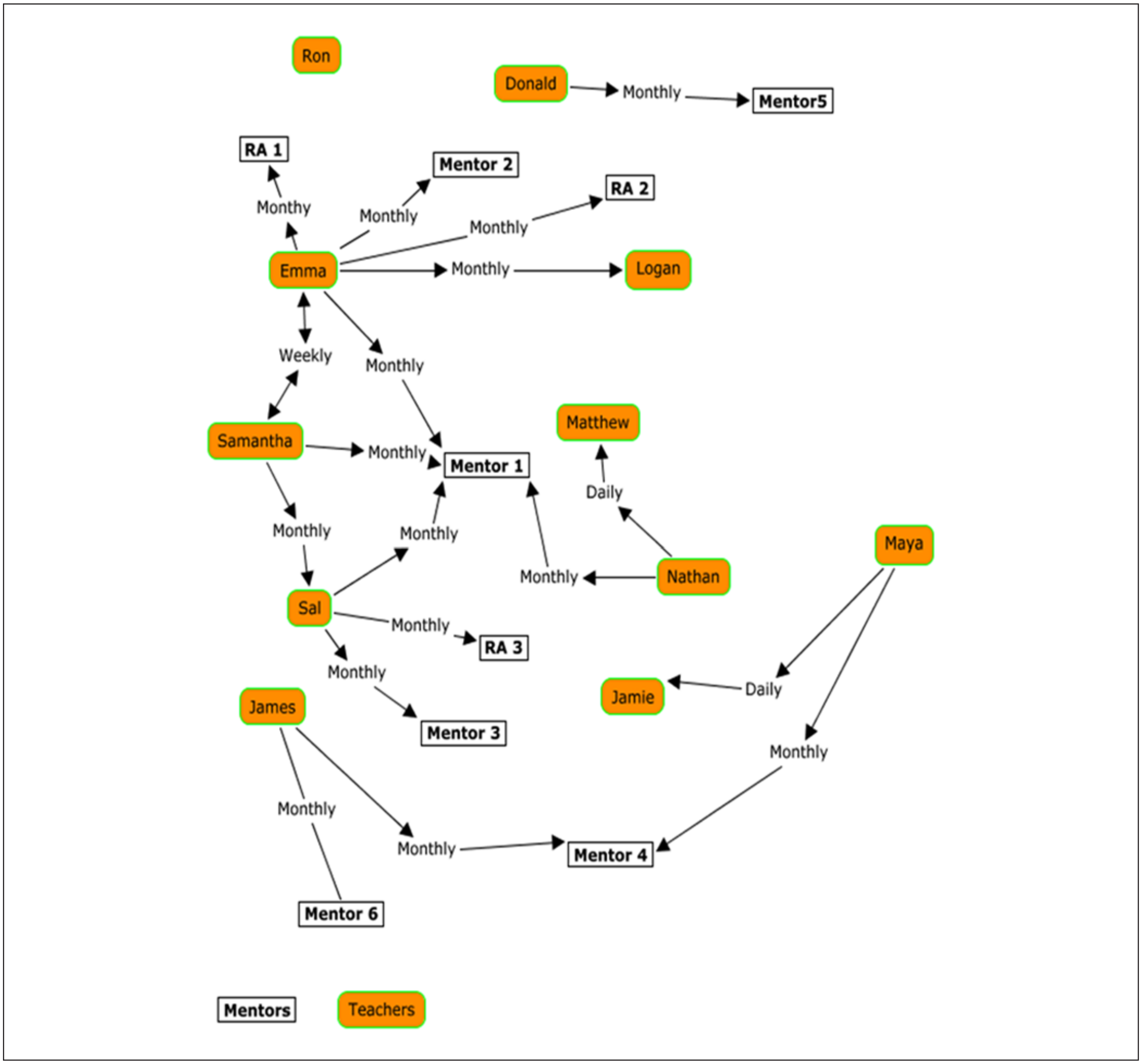

Figure 2. Network map of collaborations from RET.
Note. Links represent relationships established during RET and the frequency of collaboration/communication. Participant "Ron" left the study before data for social network analysis was captured. RET = research experience for teachers.

was similar to previous studies but in this instance, it was supported by more and different data sources.

Enculturation and identity development occurred in concert with the on-site learning process. The teachers came saying that they knew little about engineering and feeling limited by their identity perceptions but left feeling empowered and connected to the many ways they discovered that engineering was present in their daily lives and interests. They carried that message back to their students, making efforts to facilitate the same changes for their students that the mentors had facilitated in them. This pattern of learning and adoption through identity development and modeling is consistent with previous studies (e.g., Hanegan et al., 2009), and our more detailed multisource data map the process in more complete detail than previous work.

This study demonstrated the value of thoroughly documented social network analysis using case profiles to examine interactions illustrating the principles of homogeneity (homophily) versus diversity in teacher professional development. This finding contributes to a deeper understanding of how the similarity of goals and diversity of knowledge and skills interact within a teacher community of learning and practice. It also addresses a gap in measurement methods acknowledged by scholars across funded programs (National Science Foundation review panel discussion, January 12, 2012).

Overall the program experience increased teachers' positive perceptions of their potential to carry out engineering activities in their classrooms and reduced their perceptions that they faced barriers to implementing engineering-based activities in their classrooms and schools. Figure 2 illustrates that through the on-site experience, the teachers' productive perceptions remained high and, in spite of the "reality check" on return to their schools, they recovered those positive perceptions and expectations for implementation. The trajectory of perceived challenges is the only line that continues downward throughout the implementation period (as it should), demonstrating an enduring change over all productive perceptions through the study period. This finding is similar to the perceptual patterns found among graduate-level instructional designers over a similar period (Hardré, Ge, & Thomas, 2007). It underscores the critical and interactive nature of the teachers' motivations and perceptions relevant to learning and transfer. The data also underscore the importance of perceived challenges and actual administrative and peer support influencing the teachers' success in the transfer of professional development to their classes and students.

If teachers enter an engineering-based experience as "science teachers" and are transformed by their experiences and community into "engineering teachers and advocates," or even into "science teachers who understand engineering," then they return to their schools changed and prepared to change others as well. These teachers are not expected to become engineers (like the mentors' regular students) nor engineering educators (like the mentors themselves) but a specialized subgroup of K-12 teachers with some knowledge, skills, and experiences that enable them to understand engineering as a discipline and to bridge to a similar understanding for their own students. The evidence collected in this study tracks this change in individual and group identity and maps it onto the teachers' actual transfer to their classrooms.

Implications for Professional Development and Teaching Practice

Together, these data illustrate the value and benefits of rich data sources in a robust longitudinal design (Fraenkel & Wallen, 2006). Research such as this demonstrates the nuanced value of close community and mentoring to develop teachers in task-specific knowledge and skills and more general efficacy and strategies for math and science teaching. It presents questions about whether the best characteristics of immersion-based professional development could be made to work in school-based communities. It presents opportunity to strengthen the K-12 STEM pipeline (McCray, DeHaan, & Schuck, 2003) and to prepare the next generation of engineers who will be needed in future (U.S. Department of Labor and Bureau of Labor Statistics, 2007).

Future Directions

This study examined teacher growth as a response to the research-based professional development. During the RET program, it became apparent that the experiences had a positive impact on mentors as well as the teachers. Future studies should seek to understand the changes (perceptional, efficacy, communication) that may occur within the mentors, as a response to the professional development experience. To fully understand how to facilitate growth through professional development, future studies should examine additional characteristics that affect teachers' and others' engagement, investment, and productive change.

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