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Genuine Faculty-Mentored Research Experiences for In-Service Science Teachers: Increases in Science Knowledge, Perception, and Confidence Levels

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Genuine Faculty-Mentored Research Experiences for In-Service Science Teachers: Increases in Science Knowledge, Perception, and Confidence Levels

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ABSTRACT
The overall purpose of this multifocused study was to explore how participation in genuine mentored scientific research experiences impacts in-service science teachers and the knowledge and skills needed for their own science teaching. The research experiences resulted from a partnership between the University of Nebraska at Omaha and the Omaha Public School District. This Teacher-Researcher Partnership Program facilitated opportunities in inquiry, science content, interaction with laboratory instrumentation and technologies, critical discussion of literature, and dissemination of findings for participating in-service science teacher professional development utilizing an inquiry-based theoretical framework wherein we examined science teacher preparation via inquiry-based methods in the research laboratory. A mixed-methods approach with a convergent typology (i.e., qualitative and quantitative analyses conducted separately and integrated) was used to investigate the impact of the program on teachers. Our research question was as follows: How do teachers define and approach scientific research before and after a genuine research experience? We observed 3 emergent nodes or themes by which teachers indicated significant gains: science content knowledge, confidence, and perception. Moreover, we determined that participation by science teachers in a mentored research experience using current scientific technologies and tools improved teacher confidence in science and inquiry as well as an ongoing commitment to provide similar types of experiences to their students. These data support the need for the participation of in-service science teachers in genuine research experiences to boost technological and pedagogical content knowledge, con fidence in process and content, and the perception of translatability to the classroom.

KEYWORDS
ecosystem; science education; scientific inquiry; teacher learning model; teacher-researcher partnership program

It is well understood that science teachers and scientists both require active participation in scientific inquiry as they journey toward their teaching and scientific careers (W. A. Anderson et al., 2011; Hoachlander & Yanofsky, 2011; Lopatto, 2007; National Research Council, 2000a,

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2011; National Science Board, 2010; Woodin, Carter, & Fletcher, 2010; Woodin, Feser, & Herrera, 2012). Genuine experiences in scientific inquiry are necessary for these professionals to become part of the growing culture for active learning in science at all levels. Mentored scientific research experiences, either directly under a principal investigator or as part of a course-based undergraduate research experience, are relatively common in undergraduate programs that focus on preparing science professionals. Numerous studies document the positive impacts of these experiences (Auchincloss et al., 2014; Denofrio, Russell, Lopatto, & Lu, 2007; Lopatto, 2007). However, despite the clear benefit of authentic scientific research experience, few programs extend this educational vehicle to preservice or in-service teachers, and even fewer have studied the impact of those programs (Brown & Melear, 2007; Sadler, Burgin, McKinney, & Ponjuan, 2010). In the present article, we describe our efforts to design, implement, and assess the Teacher-Researcher Partnership Program (TRPP). This program involves faculty at the University of Nebraska at Omaha (UNO) and in-service teachers from the Omaha Public Schools (OPS). Over two summers (2015 and 2016), OPS teachers conducted authentic research projects directed by UNO faculty and participated in a number of research-related professional activities. Here we describe how these experiences impacted participating teachers. We analyzed this impact using the inquiry-based framework as described previously (National Research Council, 2000b), particularly inclusive of Standard A, or learning science through inquiry.

Theoretical framework

Inquiry as an instructional approach to learning science has long been utilized to at least some degree in various educational settings, and the importance of its application to student learning is well documented (American Association for the Advancement of Science, 1993; Barrow, 2006; National Research Council, 1996, 2000a, 2000b; Rutherford & Ahlgren, 1991; Van Hook, Huziak-Clark, Nurnberger-Haag, & Ballone-Duran, 2009). Inquiry is a hands-on, minds-on metacognitive approach to investigating phenomena; herein we focus on inquiry in science specifically (R. Anderson, 2002; Bybee, 2000; Huziak-Clark, Van Hook, Nurnberger-Haag, & Ballone Duran, 2007; Wee, Shepardson, Fast, & Harbor, 2007). Inquiry has also been described as a general theoretical framework for effective professional development opportunities for science teachers—ranging from genuine research experiences (as described herein) to immersion experiences and engagement in science and engineering practices (Duschl & Bybee, 2014; Huziak-Clark et al., 2007; Schwarz, Passmore, & Reiser, 2017; Wee et al., 2007).

Four standards describe the learning of science (inclusive of processes and content) for teachers: learning science through inquiry (Standard A), learning to teach science through inquiry (Standard B), becoming lifelong inquirers (Standard C), and building professional development programs for inquiry-based learning and teaching (Standard D). It is through these four types of professional development experiences that science teachers can enhance their preparation for disseminating science content and process in an engaging way in the kindergarten–Grade 12 (K–12) classroom.

Similar to the Science Teacher and Researcher Program (Baker & Keller, 2010) and programs in other teacher-researcher studies (Cox-Petersen, 2001; Rahm, Miller, Hartley, & Moore, 2003; Silverstein, Dubner, Miller, Glied, & Loike, 2009; Varelas, House, & Wenzel, 2005), our program seeks to empower teachers to implement inquiry-based science in the classroom. Specifically, this is via a scientist-guided inquiry process. To accomplish that goal, we provide teachers with the training to design and critically evaluate scientific research, and we provide a postproject support structure for ongoing success and retention. However, our study is one of a very small number that specifically engages in-service teachers. The majority of the published literature focuses more directly on preservice teacher training (e.g., Bleicher, 2004; Brown & Melear, 2007; Holoch, Grove, & Bretz, 2007; Melear, Goodlaxon, Warne, & Hickok, 2000). Herein we focus on in-service teachers.

Research question

In this article we describe the impact on teacher-researchers following 2 years of implementation of the TRPP. Specifically, in the context of teacher–scientist partnerships for learning how to engage in science practices, technologies, and inquiry, we investigate the following research question: How do teachers define and approach scientific research before and after a genuine research experience?

Methods

Study design

This mixed-methods study followed a convergent design typology (Creswell & Plano Clark, 2011). A convergent design typology is characterized by independent data collection and analysis, which means that the collection of one type of data was not influenced by the analysis of the other type of data (see the procedural diagram in Figure 1). Furthermore, concurrent sequencing (or timing) was utilized in this study because the collection and analyses of the quantitative and qualitative data were independent of one another. According to the notational system put forth by Morse (1991), this study can be represented as a QUAL + quan design because although the minimal quantitative (quan) findings provided some insight into the teachers' experiences and potential gains in this program, we used the extensive qualitative (QUAL) findings to confirm and enhance our understanding by gaining a deeper representation of the experience (Creswell, Plano Clark, Gutmann, & Hanson, 2003).

Context of the study

Our TRPP is a result of a collaborative partnership between UNO and OPS initiated in 2015 (Tapprich et al., 2016). We have implemented a framework of general inquiry to specifically model a hands-on, immersive, genuine research laboratory-based professional development summer experience for science teachers. It is important to note that in the TRPP, research investigators work with teachers to cover content knowledge (i.e., science topics of each researcher's expertise), cover pedagogy (i.e., inquiry and the scientific process as well as weekly discussion of active learning strategies in science through a journal club), and utilize technology (i.e., via laboratory equipment, sensors, instrumentation, and data collection and analysis software). This program provides a comprehensive framework for in-service teachers to gain content-based science, pedagogical tools, and

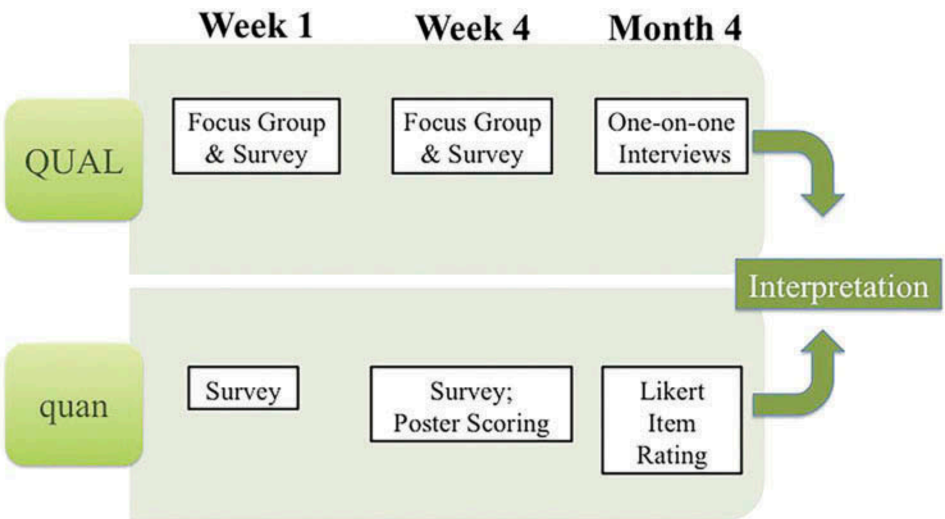

Figure 1. Procedural diagram of a convergent, parallel design for a mixed-methods study of teachers' definition of and approach to scientific research before and after the Teacher-Researcher Partnership Program intervention. QUAL = qualitative; quan = quantitative.

experience with innovative technology. Taken together, these benefits are important for improving science content understanding and ultimate translation to the classroom of inquiry, tenacity, and research experiences for youth.

For detailed programmatic information about the TRPP, please refer to Tapprich et al. (2016). Briefly, this program is a collaboration between OPS and UNO and is part of a larger training grant for comprehensive training for science teachers by the OPS district. The TRPP is overseen by five university faculty coinvestigators and the science supervisor at OPS. Each year, approximately 15 science teachers spanning Grades K–12 are eligible to participate in genuine research with a faculty mentor. Any science teacher within OPS who formally applied to the K–12 Comprehensive Science Teaching and Learning Initiative spearheaded by the OPS science supervisor (and coauthor herein) was eligible to participate. (More information about the K–12 Comprehensive Science initiative can be found in Schaben, Cutucache, Grandgenett, Mulkerrin, & Hougham, 2016). It was recommended that teachers who had previously demonstrated an eagerness to support their students in scientific inquiry and experimentation apply. Moreover, teachers who were the sole teacher at their school with a science endorsement were also encouraged to participate to assist in building a support structure for their work.

Participants and characteristics

K–12 science personnel who participate in the TRPP typically represent a range of academic levels. The 2015 cohort included seven teachers from high schools (Grades 9–12) and four from middle schools (Grades 7–8), whose prior research experience was not formally recorded. The 2016 cohort included nine high school teachers, five middle school teachers, one elementary school (kindergarten–Grade 6) teacher, one elementary/ middle school teacher, and one K–12 science coach (science coaches are thoroughly described in Schaben, Cutucache, Grandgenett, Mulkerrin, and Hougham [2016]). Most 2016 TRPP teachers (~80%) had limited to no prior research experience. All expressed an interest in research with the expectation that such experience would positively impact their classroom.

We paired university faculty members with K–12 science teachers for the genuine research experience. In order to identify faculty interested in serving as mentors, we solicited research study proposals from science faculty across various departments and colleges that included a narrative describing the proposed project, its anticipated budget, and anticipated specifics for how the project would benefit the teacher and his or her students. Since the inception of the program, 26 proposals from university faculty have been funded to support science teachers for the summer. A total of 21 teachers (5% Indian, 5% African American, and 90% Caucasian) have participated, including six who have participated in both years of the program. Beginning with the 2016 cohort, all teachers submitted formal applications that addressed how such a research experience would impact their classroom. In Year 1 (i.e., 2015) university faculty and public school teachers were strategically recruited by program principal investigators and OPS science administrators, respectively, to ensure an efficient launch under a very aggressive timeline.

The teachers in our study spanned a range of prior teaching experience from 1 year through greater than 15 years in length. Moreover, our study was inclusive of science teachers of various grade levels (specifically including elementary through high school teachers). Last, our study is unique in that teachers had a relatively diverse range of projects and mentors to choose from, including topic areas that included contexts such as environmental studies, bioinformatics, rain garden design and economic impact, tumor immunology, virology, soil and rock science, and biomechanics. Given the rapid pace of scientific advancement, particularly in content and technology, our program provides an opportunity for in-service teachers to develop translatable, inquiry-based experiences that will benefit both teachers and youth.

Project format and procedure

After completing an orientation, each teacher began his or her research project and began the minimum 80 hr of scheduled project work that was prearranged with his or her mentor. Summer research projects spanned a range of science disciplines and focus areas (see the Supplemental Material), including interaction with a wide range of research technologies. Faculty mentors became part of the project through a competitive proposal process. A description of the project and request for proposals was distributed to science faculty at UNO via e-mail. The request for proposals directed potential mentors to submit a statement of interest, abstract, research project description, project timeline, proposed budget and budget justification, and description of how the project would translate to the K–12 environment. Proposals were evaluated by the co–principal investigator team. The goal was to identify faculty who were committed to providing an authentic research experience to in-service teachers, committed to developing a translatable project, and committed to participating in all TRPP activities. Faculty selected to be mentors were awarded a summer salary stipend and a supply budget. To arrange productive matches between teachers and mentors, we asked teachers to rank their interest areas by subdiscipline. In nearly every case, teachers were matched with one of their top two choices. Mentors began a research relationship with their teacher prior to the official start of the project by providing project summaries and reprints. During the project, faculty mentors were asked to involve teachers in the actual science that they undertook on a regular basis, including using any specialized laboratory equipment or technologies, and to allow teachers a chance to work with such resources.

A research community involving all teachers and mentors was maintained in a required once-per-week journal club meeting. For the journal club, teacher–mentor pairs took turns finding and presenting a research paper and leading the discussion. The entire research community read the paper and prepared to participate in the discussion. All teachers and mentors also participated in a postproject research symposium in which teachers presented their research in an online poster session. Each online poster was critically evaluated by teams composed of randomly selected teachers and mentors (three of each) using a common rubric.

The summer research project required a minimum of 4 weeks. The journal club continued for 6 weeks. Following the 4-week research program, teachers took part in a focus group with a set of predesigned questions. During Week 5, teachers and mentors participated in the research symposium. Teachers were also interviewed one on one by a TRPP principal investigator 12 to 16 weeks after the end of the research project. The postproject focus group questions, interview questions, and poster assessment rubric questions are listed in the Appendix.

Assessment instruments

Throughout this study, we used assessment instruments such as interviews, focus groups, surveys, and transcribed audio recordings of the individual interviews. These assessment instruments were based on ones that had been previously used, validated, and modified in several National Science Foundation science, technology, engineering, and mathematics (STEM) education projects facilitated in Nebraska (Barker, Nugent, & Grandgenett, 2013; Grandgenett, Ostler, Topp, & Goeman, 2012; Nugent, Barker, Grandgenett, & Welch, 2016) and that were familiar to the educational research specialist on the team. All assessments and other materials collected from participants were also approved under University of Nebraska Medical Center/UNO Institutional Review Board No. 290-16-EX.

Data collection

All interviews of teachers who participated in the TRPP lasted between 5 and 30 min, all focus groups lasted 60 to 90 min, and all surveys were fewer than 20 questions in length. All pre- and post-project focus groups were conducted by researchers certified by the Collaborative Institutional Training Initiative. Notes from the discussion were captured through individual reporting by teachers, and major emerging ideas were noted by a stenographer in the room. Participating teachers took part in an initial orientation day, during which they completed preproject focus group questions independently and as a group. The questions asked of the teachers are included in the Appendix.

Participating university faculty were surveyed at Week 4 as to the mentorship strategy that they deployed with their teacher-researcher as well as their perceived effectiveness of the strategy. Moreover, faculty members were asked to describe how similar the mentorship strategy was to that deployed with their undergraduate or graduate students (see Table 1).

Table 1. 2016 TRPP faculty mentoring strategies.

Question	*n*	%
1. Which option best describes the mentorship style you conducted with your TRPP mentee this summer?		
Apprenticeship style (working side by side)	4	29
Sink-or-swim approach with periodic check-ins	1	7
Guided mentoring for first experiment, then freedom until hitting roadblocks	7	50
Other	2	14
2. How would you rate the effectiveness of your mentorship style for training of your mentee?		
100% effective	2	14
It worked well 75% of the time	10	71
It worked well at least 50% of the time	2	14
Other	0	0
3. Were you able to mentor the teacher this summer in the same way that you mentor undergraduate or graduate students in your laboratory?		
Yes, same as mentoring for undergraduate and graduate students	5	36
Same level of mentoring as I provide for my graduate students, but not for my undergraduates	4	29
Same level of mentoring as I provide for my undergraduate students, but not for my graduate students	1	7
Other	4	29
4. Do you plan to apply to participate in TRPP again in subsequent years?		
Yes	11	79
No	0	0
Undecided	2	14
Other	1	7

Note. (A) University of Nebraska at Omaha faculty mentors were surveyed to determine the type of mentorship style they used with their Omaha Public Schools mentee. (B) Faculty mentors were surveyed to determine the perceived effectiveness of the mentorship style/methodology that was deployed. (C) Faculty mentors were surveyed to compare how they mentored teacher-researchers compared with undergraduate and graduate students in their laboratories. (D) Faculty mentors were surveyed to determine, at that time, how many were considering applying to participate in the program again in subsequent year(s). TRPP = Teacher-Researcher Partnership Program.

Data analysis

After the data were collected, we merged or triangulated the data sets in order to glean a more complete picture of how teachers defined and approached scientific research before and after the TRPP intervention. Specifically, we provide a count of how many teachers included which ratings of responses to different items (e.g., in the poster rubric evaluations, in the Likert item ratings).

We transcribed and analyzed all interviews through a process of open coding using NVivo for Mac software (QSR International, MA, USA) followed by axial coding (Gibbs, 2007). The coded passages were transferred to tables in Word and categorized by node. It is important to note that the raw data from transcribed interviews were completed by a researcher other than those completing the interviews and included subsequent member checking for resultant nodes to avoid implicit bias.

Final integration

Finally, we transformed the qualitative data from both the surveys and the interviews as part of our integration methods for this mixed-methods study. Specifically, both quantitative and qualitative data were collected independently of each other and at different times. Each type of data was analyzed separately. Last, we collated these results (from both quantitative and qualitative data) via previously described integration protocols to gain a more holistic picture of the impact of the program and to inform future projects (Creswell & Plano Clark, 2011).

Findings

Taken together, this study identified three emergent themes as instrumental to teacher professional development through this genuine, inquiry-based research experience (i.e., increase in confidence, a better understanding of the processes and complexities of inquiry-based scientific research, and improved content knowledge; see Figure 2). We have broadly organized our findings according to teacher impact and mentor (i.e., scientist) impact. The impacts on teachers are presented as teacher-reported gains, followed by the impact of the program as a professional development opportunity, and last the general challenges that teachers reported related to conducting a scientific research project. The mentor impact from participating science faculty is described in "Mentoring Strategies and Perceived Effectiveness." Data from both quantitative and qualitative metrics analyzed in the study were triangulated to support each of these themes. All of these resultant themes are consistent with best practices in inquiry as a theoretical framework for study and for incorporation into professional development experiences for science teachers.

Teacher-reported gains

Increase in science content knowledge expertise

Results from the postproject teacher interviews indicated gains in scientific knowledge (see Figure 2). For example:

> I figured out how to start your stuff from nowhere and you have to start from zero by reading something and then you come up with something new or a new idea or hypothesis or I learned that how much knowing the background info relating to the lab is important to you.

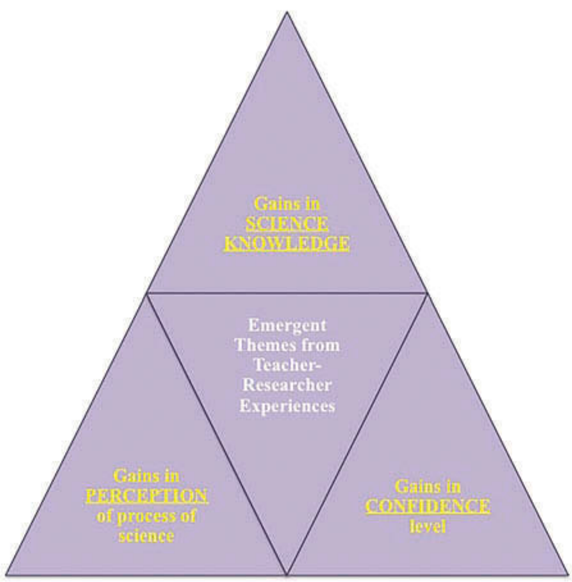

Figure 2. Summary of emergent themes/nodes from post-research experience interviews from science teachers.

> … of the research on the [pathogen] so that just opened my eyes to just more knowledge because all I was hearing was things off the news and social media sites so I learned a lot more about it … kids were … mentioning [pathogen] I could kind of talk about that more and shed some light on it.

Increase in perception (i.e., confidence)

Before the project, teachers hoped that their instruction would improve and that they could apply what they learned, gain confidence, develop new lab(s), and gain a deeper background understanding, thereby building their confidence. Teachers expressed enthusiasm about conducting research but also expressed trepidation. Following the TRPP, teachers had much greater confidence in science, an effect that postproject interviews showed persisted over time. In the postproject focus group, teachers recognized that challenges in research are primarily related to science and technology, not prior knowledge or time availability. Perceptions of the benefits of the TRPP for the classroom began with enthusiasm to translate elements of the project. After the TRPP, the enthusiasm remained, but teachers' plans evolved to pragmatic issues addressing how the translation would progress.

Teachers indicated that they wished to use this experience to "lead from a student perspective," be vulnerable, and use new tools in the classroom. One teacher hoped for "continuous change, a continuous collegial approach …" Teachers appeared to believe that they could directly replicate much of what they would learn during the project in the upcoming semester in their classrooms. After the experience, teachers hoped to maintain contact with their mentor, bring students to UNO, and/or bring new lab activities to their classroom. They also wanted to communicate to students that "failure is okay" and that "there is no right answer." Furthermore, teachers appreciated that they could "share that they are now a primary source for research to their classroom instead of just a consumer. …" Teachers identified a significant difference between the sophistication of the technology they had available and the need to scale back their modeling of the research process to be consistent with that technology.

Quotes supporting the emergent theme/node of confidence (see Figure 2) from the postparticipation focus groups included "I felt very confident in what I am doing," "my comfort zone," and "for all professional development for me it just gives me more confidence in science …" Other teachers said the following:

> [Regarding the impact of teacher confidence gains on youth] It has helped in their confidence level because they get frustrated when things don't work and when they know that that's authentic then I think that's helpful and I also think for them to know that the kind of research is happening in their local community I think that's been important.

> … because it was kind of scary and frightening, but I think what my experience did because it was so directly applicable to what I'm doing here at [school] that it enlightened me in ways that I can truly let kids ask their own questions and design their own experiments to engage them to understand a standard or a science concept.

> It's been a long time since I used lab equipment but it was kind of like riding a bike … like the pH and testing, … mass, I hadn't done in a long time, so I think that it gave me a lot more confidence in that too.

Responses to three of the focus group questions indicated that the project had a major impact on teachers' confidence in conducting scientific research, particularly related to their interaction with technology. Prior to the project, teachers expressed enthusiasm for learning new and different practices and strategies in science, inquiry, and data analysis and implementing their experiences in the classroom. Some shared concerns about working "outside my comfort zone" or needing to "look up words and see what things mean." There was really no mention of technology in their comments. Following the project, teachers' comments indicated a gain of confidence. They described situations in which time was spent with little productivity and errors occurred and had to be addressed—sometimes with differing opinions on how to address specific issues. They frequently indicated a significant "learning curve" for the laboratory technology or the computer analysis process for the data, but they had learned in those areas and spent time with the instrumentation.

Increase in perceptions of the process of science (including technological proficiency)

Teachers reported gains in their perceptions of the process of science. Quotes supporting the emergent themes/node of perception (see Figure 2) included "… research work is like an ocean you can never finish and it keeps on going because new things will come up and I don't even know the old things so there's a lot to do." Other teachers said the following:

> … for me it was truly the first time to work in I guess what I would call a real lab setting, I mean I did college lab settings and that's numerous people in one room and they're more cookie cutter so I think it was my first experience to do that myself which definitely changes your perception.

> … this was the result you're supposed to get and if you did not get that answer you did something wrong and so we knew the expected answer so this really opened my eyes to really open ended inquiry and how a lot of science is getting it wrong and going through the problem solving process is okay if something went wrong, where did it go wrong, these aren't the results we expected, why is that the case? So I think it really opened my eyes to different types [of inquiry] …

Moreover, during the process, teachers reported that their technological experience was enhanced via the use of scientific instruments and technologies (e.g., pH meters, water turbidity instruments, thermocyclers, bioinformatics databases and tools, coding) and that using such tools added to their technological proficiency and comfort.

The enhanced understanding of the scientific process among teachers was captured during the evaluation of the scientific posters at the end of the program poster session as well. Specifically, the maximum possible combined score on poster evaluations (among the six evaluators) was 96 points. Total scores ranged from 60 to 92 points, with a median score of 79 points. High-scoring posters (≥90 points) received comments like "This poster was exceptionally well done, it is akin to what I have seen at professional conferences." Low-scoring posters (≤70 points) received comments ranging from general questions/suggestions to positive impressions overall but typically lacked clarity and/or depth in one or more individual categories. The maximum score on individual evaluations was 16 points. Individual evaluation scores ranged from 7 to 16 points, with an overall average of 13.01 points. Mentors and teachers assigned similar scores overall (mentor average = 12.9, teacher average = 13.1, p = .41). The breakdown of scores for each question is reported in the Supplemental Material.

Taken together, the data indicated that teachers developed a strong sense of the role of research and process in science. Prior to the project, teachers' definitions of scientific research were generally brief, broad terms or comments related to data collection/analysis, methodology, goals, ethics, writing/publication, and funding. There was little mention of technology of any type and no recognition of the role technology might play in data collection and analysis. After the project, teachers realized that scientific research is a search for answers and includes frustrations, collaboration, sharing, and presenting results. Teachers also mentioned the challenges of learning, calibrating, and using laboratory equipment or other technology-related elements. A deeper understanding of science also emerged from the focus group question about the impact of the project on classroom instruction.

Impact of the TRPP as a professional development experience

During the postparticipation interviews conducted 4 months after the experience (as outlined previously), participants provided Likert scale ratings of five areas related to their professional development. These are described in Table 2. Teachers reported the authentic research experience and interaction with a research team as most positive for their professional development.

Surveys of teachers after the TRPP showed important support for the research and mentor interaction aspects of the project as professional development opportunities. Although the journal club and symposium aspects were also seen as positive, that support was less consistent. Results gleaned from focus groups were supported and emphasized by quantitative analysis of postresearch interviews.

Teachers reported improved confidence, perceptions of the scientific process, and scientific content knowledge in the qualitative data. Moreover, the results of the quantitative studies supported these findings, with nearly all teachers reporting that journal clubs and interactions with the laboratory faculty mentor and laboratory staff added significantly to their professional development. From these convergent data, we observed that teachers gained confidence as they gained in their understanding of the scientific process, inclusive of content knowledge as well.

The relationship between the research pairs was mutually beneficial, and many mentors and teachers maintained contact after the summer research period. Mentor follow-up included visiting the cooperating teacher's classroom, hosting the cooperating teacher's students in a visit to his or her research lab at UNO, and/or providing supplies and guidance for developing and implementing new laboratory activities in the teacher's

Table 2. Results of quantitative data collection of ratings of Likert items from transcribed postexperience interviews.

Likert item	Likert scale rating				
	1	2	3	4	5
Rate the benefit to your professional development of conducting an authentic research experience.	1	0	2	2	8
Rate the interaction with your mentor and research group on your professional development.	1	0	10	11	
Rate the benefit of the weekly journal clubs to your professional development.	0	5	1	2	5
Rate the benefit of formally presenting your research in the symposium to your professional development.	0	1	3[a]	5	4
Rate the benefit of participating in the poster evaluation as part of your professional development.	1	1	2	5[a]	4

Note. The frequency of reporting for each Likert item is reported.
[a]When participants responded with a decimal instead of an integer, we rounded up (n = 2 participants on two of the Likert items).

classroom. Some teachers later collaborated and shared lab experiences with one another for reciprocal use in their classrooms. This was through avenues such as collaborative projects, science fairs, and/or journal clubs being deployed with a cohort of in-service science teachers.

General challenges reported by teachers

When addressing the challenges they might face, teachers initially expected challenges related to developing a project and poster within the allotted time, defining the scope of the project, performing/understanding statistical analyses, and making errors. Challenges with the technology of the scientific equipment were generally not mentioned, with the exception that several teachers were concerned with "breaking something." Teachers were both nervous and excited to begin the project, work with a new or repeat mentor, and "play with higher grade science toys." Nervousness was generally related to confidence in one's ability to learn/perform above one's level of comfort or experience. Technology was not seen as a challenging element and was only mentioned in the context of "playing" with the equipment.

Following the project, teachers reported challenges that included inadequate sample size, time constraints, technology issues, lack of background knowledge or level of understanding (steep learning curve), difficulty with statistics, and coordinating time with mentor(s). There was frequent mention of equipment and technology and the significant efforts that both the teacher and the mentor made with it while doing research. Teachers did not mention nervousness in postproject focus groups. Rather, they communicated excitement, challenges, gains, project ownership, and frustrations related to their research. They also said that they had learned within a very "dynamic" laboratory environment with significant work with laboratory technology and data analysis.

Mentoring strategies and perceived effectiveness

The specific strategies that TRPP faculty deployed with their mentees to complete the project are included in Table 1. Most research mentors (50%) reported using a guided approach, followed by allowing the mentee to experiment on his or her own, including hitting roadblocks and then providing additional guidance. In all, 71% of mentors reported that this guided trial-and-error approach worked well in their laboratories at least 75% of the time (n = 12; see Table 2). Although university faculty commonly mentor undergraduate and graduate students in their research laboratories or with various technologies, when they were polled to compare the mentoring styles that they used with undergraduate or graduates students and teacher-researcher mentees, there was no consensus. Finally, a strong majority (79%) indicated that they planned to participate in the program again, with 14% undecided at the time of polling.

Discussion

Calls for infusing inquiry in the form of authentic research experiences into science education are clear and sustained (American Association for the Advancement of Science, 2011, 2015). Responses have been slow but steady among undergraduate programs, but surprisingly little attention has been focused on K–12. We admit that a multitude of constraints make authentic research more challenging in the K–12 curriculum, but few of these challenges can be overcome if teachers do not possess the confidence, experience, and expertise to lead their students in an authentic research project. Although undergraduate science programs are in a good position to extend their reach to preservice science teachers, there is a clear and present need to change the culture of K–12 science teaching sooner rather than later. Thus, the impetus for establishing the TRPP was the recognition that in-service teachers represent a cohort that can have an immediate positive impact while preparing the ground for the next generation of science teachers.

Our goals for the TRPP are multifaceted and ambitious. At the core is our desire to provide in-service teachers with an inspiring science research experience that translates to their classrooms. The partnership between UNO and OPS in the design and development stages of the TRPP was invaluable in meeting that goal. But beyond the research experience itself, we sought to conduct a study on the impact of the TRPP on the way in which teachers define and approach scientific research. Our findings, from both qualitative and quantitative measures, show significant gains in teachers' content knowledge, confidence, and perception. In addition, our results point very strongly to the role of genuine inquiry during an authentic research experience.

In-service teachers, like preservice teachers, typically need a relatively focused programmatic effort and mentors to improve their skills while journeying through their educational program (Dawson, 2007; Hofer & Grandgenett, 2012). Considering the insights from this study, that even experienced K–12 science teachers do not anticipate a large role for technology in actually conducting scientific research, one could infer that preservice teachers most likely share this trait; to some degree, this has been documented in the literature as well (Neiss, 2005; Pierson, 2008). It would seem critical then that the training of preservice science teachers, like that of their more experienced colleagues, include the use of technologically advanced scientific instrumentation and tools. Furthermore, these instruments and tools should be explicitly connected to a research process. It is critical to include technologies such as environmental sensors, electronic scopes and testing equipment, global positioning systems, instrumentation for molecular analysis, bioinformatics algorithms, and many others in the training of preservice science teachers as well as their more experienced in-service colleagues. If teacher preparation programs are trying to integrate real-life science experiences into their programs, then to some degree the technologies that scientists commonly use or a reasonable representation of such technologies must be integrated as well. Otherwise such programs run the risk of training science teachers who will have a context of the scientific inquiry of the past rather than the present and future, thereby limiting their students.

It is important to note that overall the STEM disciplines are undergoing a significant revolution of interdisciplinary content work (National Academies of Sciences, Engineering, and Medicine, 2016; National Research Council, 2011, 2012) that is bringing about new ways of working in, thinking about, and teaching in these content areas. Our TRPP project may now evolve to engage interdisciplinary teams of scientists and teachers, rather than just individual teachers and individual scientists, to represent the interdisciplinary nature of the STEM content areas. Researchers interested in STEM-related efforts will themselves want to continue to evolve to consider the increasingly interdisciplinary nature of the STEM content in this important educational research approach. Simultaneously, scientists and university faculty will need to consider the importance of training new teachers, and perhaps even new scientists, through infusing inquiry-based approaches into their professional development opportunities. Active engagement of future professionals, and especially future teachers, is critical to effective instruction in the STEM disciplines and interrelated areas of technology, pedagogy, and content.

Despite observing major gains in content knowledge, understanding of science processes, and confidence among participating science teachers, we also observed a side discovery related to the use of technology to study and address scientific problems. For example, the comments and reflections of the teachers before the experience mentioned how little they expected that the scientists themselves would be using technology. The focus groups were particularly enlightening in this regard, and the teachers seemed surprised at the number of hours the scientists spent using technology in various elements of the scientific process. Although research involving another theory, technological pedagogical content knowledge, has certainly documented that teachers at any level can often have a relatively low awareness of how technology is actually used within a particular profession (Agyei & Voogt, 2012; Grable, Molyneaux, Dixon, & Holbert, 2011; Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Mansour, 2009), it was particularly surprising in the TRPP project because many of these teachers were relatively experienced science teachers. Thus, it was somewhat odd to see them surprised at the significant role technology plays in actual science today. It may well be that building an understanding of the use and importance of technology in real-life science or in other STEM professions can be a very important contribution of immersive projects like the TRPP in which teachers and professionals work together.

To be consistent with a truly inquiry-based professional development experience, mentors were expected to actively involve teachers in the use of scientific equipment (technology), engage actively with them in scientific inquiry (pedagogy), and to help these teachers to engage deeply in the content knowledge of their scientific discipline (content). Mentors were asked to take the time to help the teachers use applicable scientific equipment effectively and safely, regardless of previous teacher experience or exposure to the equipment, rather than just operating the equipment for them. Mentors were asked to openly and carefully explain the scientific inquiry they had under way and to define and redefine scientific terms and concepts frequently for the teachers. Faculty members who did not provide a clear definition of their proposed mentoring in their program proposal, or who otherwise did not seem willing to take a patient and collaborative approach to the mentoring process, did not make the final proposal cut and were not invited to be a part of the project. Correspondingly, teachers were considered based on their willingness to be actively engaged in all technology, pedagogy, and content-related aspects of the TRPP effort and their willingness to be in a mentored environment.

Last, an additional component of the larger professional development experience that this cohort of teachers is receiving is through a grant and program run by OPS that meets Standard B, or learning to teach science through inquiry. Through the implementation of matches between the university and K–12, we create an ecosystem of support for teachers, thus enabling them to become lifelong inquirers and further construct professional development programs for inquiry-based learning and teaching. These programs are robust in supporting teachers through engaging in science with inquiry and providing them with the tools necessary to assist their students in inquiry-based learning.

Evolving challenges, limitations, and solutions

As was true for all 3 years of the program, the timing and balance of experience/expertise within the research pairs were the most common challenges associated with the TRPP. Teachers were often involved in other activities during the summer research period (such as teaching summer school), so despite having an adequate number of available hours, many found it difficult to coordinate their schedules with their faculty partner. Once the summer research period began, some faculty found it challenging to get their mentee up to speed quickly to perform the necessary tasks for the proposed experiment. Those mentors reported that in the future they would attempt to minimize these issues by providing background materials earlier; frontloading the schedule with more guidance; and setting more frequent goals, such as daily versus weekly objectives to be accomplished. The mentors who applied this approach during TRPP 2016 reported less frustration with orienting their mentee. TRPP program leaders (five principal investigators and one grant coordinator) also revised the TRPP 2017 proposal guidelines to include a timeline and staggered the mentor and teacher applications to further improve our ability to match teachers and mentors with mutual interests. Leaders also encouraged mentors to contact their mentees as early as possible.

Other challenges associated with the TRPP projects were issues related to technology and/or instrumentation and the goal of the TRPP to actively engage teachers in the technologies that scientists use. These endeavors often involved steep learning curves for the operation or use of software programs and computer-based equipment, including interactions with algorithms, programming, instrument calibrations, and the like. However, upon receiving proper training on the equipment and repeated practice, teachers' confidence in using the technologies improved.

Overall, despite encountering challenges along the way, both mentors and teachers reported positive impacts of the TRPP on their professional development. Mentors were able to provide genuine, immersive research experiences for their cooperating teachers. Mentors also gained insights into how they could impact students at an earlier age through interactions with teachers in the discipline. Inquiry-based approaches engage the learner in processes that include metacognition and application—far beyond the traditional hands-on definition in more of a hands-on, minds-on approach.

Conclusion

In this study, quantitative and qualitative results were analyzed by well-documented integration protocols to steadily reveal a holistic picture of the program (Creswell & Plano Clark, 2011). Our research question was as follows: How do teachers define and approach scientific research before and after a genuine research experience? We observed that teachers gained deeper knowledge about scientific research, improved their perceived confidence in science, and gained a deeper appreciation of the research process.

Summary

Finally, integration of the results from this mixed-methods study indicated significant benefit to participants, particularly related to gains in science content knowledge, confidence levels, and perceptions of the process of scientific research. Moreover, when asked to assess very specific components of the project, teacher-researchers indicated that the presentation of their work in a research symposium and evaluation of peers' posters positively impacted their professional development. Teacher-researchers rated the interaction with their mentor and research group as having the greatest impact on professional development. Following integration of these findings, we suggest that the relationship between the scientific researcher and the science teacher is the most impactful on professional development for K–12 science teachers.

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Appendix: Supporting Materials and Details Regarding Data Collection and Analysis

Preproject Focus Group Questions (Week 1)

First participants were asked to write down their own unique ideas behind each of the questions on the list (for approximately 5 min), and then a focus group discussion followed, with information gathered from all participants (faculty and teachers were in separate focus group rooms from each other). Worksheets were collected from each participant at the end, and a stenographer took notes throughout the discussion for emergent themes.

1. Written/focus: What would you define as scientific research?
2. Written/focus: What do you expect to learn during this shared research experience with your faculty mentor?
3. Written/focus: What challenges do you expect to have during this shared research experience?
4. Written/focus: How do you hope to have this impact your classroom instruction?
5. Written only: Do you serve as a “Science Matters” representative from your school?
   a. If you indicated yes, have you already engaged in with UNO through a prior event such as a workshop at Glacier Creek or NASA workshop?
6. Written only: Please rank the following disciplines by your comfort level, with “1” being most comfortable, and “10” being least comfortable.
   __ Science Education/Discipline-Based Education Research (DBER)
   __ Molecular Sciences
   __ Organismal Sciences
   __ Engineering
   __ Space Science
   __ Geography/Geology
   __ Physics
   __ Chemistry
   __ Sustainability/Community Impact STEM
   __ Statistical Analysis Strategies
7. Written only: What role to date has your science coach played in your education?
8. Written only: Which topics of significant professional development (a day or more) have you completed within the last three years (workshop, class, community of practice, etc.)?
9. Written/focus: What is a definition of immersion activities? What (if any) immersion activities have you done with your students?
10. Focus only: Any final comments? *[Once around the table]*

Postproject Focus Group Questions (Week 4)

1. Written/focus: What would you now define as "scientific research"? *[We will compare to faculty]*
2. Written/focus: What did you learn during this shared research experience with your faculty mentor?
3. Written/focus: What challenges did you have during this shared research experience?
4. Written/focus: How do you hope to have this impact your classroom instruction?
5. Written/focus: What is your current definition of immersion activities
6. Written/focus: Any final comments? *[Once around the table]*

Postproject Interview Questions (Month 4)

1. Did your TRPP experience change your perception of, or attitude about, authentic scientific research? If yes, in what ways? If no, why do you think that is the case?
2. Did your TRPP experience change your level of confidence in conducting authentic scientific research? If yes: Describe the impact. After the response, ask: On a scale of 1–5 with 5 most confident and 1 least confident, rate your level confidence both before and after the TRPP experience in conducting authentic scientific research.
3. Did your TRPP experience have any impact on your content knowledge in science? If yes, give an example. If no, why is that so? (Were you given or did you pick a project already in your area of expertise?)
4. Have you used your TRPP experience in your classroom or your role in OPS? If yes: Give an example. If no: Do you have plans to do so in the future? Why or why not?
5. Have you used or referenced any content material discovered during TRPP in your classroom or your role in OPS? If yes: Give an example. If no: Do you have plans to do so in the future? Why or why not?
6. Have you used any information or process from TRPP Journal club in your classroom or role in OPS? If yes: Give an example. If no: Do you have plans to do so in the future? Why or why not?
7. Have you communicated with your mentor since TRPP ended? If yes, describe the interaction. If no: Do you have plans to do so?
8. If given the opportunity, would you participate in TRPP again? Explain the reasons for your choice.
9. If you participated in TRPP again, would you choose the same mentor or seek a new mentor? Explain the reasons for your choice.
10. On a scale of 1–5 with 5 best, rate the benefit to your professional development of the following aspects of TRPP: conducting authentic research, interacting with a research mentor and research group, participating in journal club, formally presenting research (poster), evaluating research posters of peers.

Online Poster Assessment Rubric

Scored on a scale from 1 to 4, where 1 = strongly disagree, 2 = disagree, 3 = agree, 4 = strongly agree. Assessment also included the submission of open-ended comments justifying scores for each question and the submission of open-ended overall comments.

1. The objective/hypothesis was communicated effectively.
2. The methods that supported the study were appropriate and clearly described.
3. The major results and/or significant take-home messages of the study were clearly described.
4. The summary of the summer work was clearly articulated.
5. The major strengths of the study were adequately identified and discussed.
6. The major limitations of the study were adequately identified and discussed.
7. Future questions and/or next steps based on this study were clearly addressed.
8. This poster was effective at communicating science.

Likert Item Type Rating Collection

During one-on-one exit interviews, past participants were asked to provide a Likert-style rating to five Likert items. We aimed to collect quantitative data about (a) the perceived programmatic benefit to teachers as well as (b) the likelihood of participating in the future. These data are included as the quantitative analyses from this study in the Results section.

Note. UNO = University of Nebraska at Omaha; NASA = National Aeronautics and Space Administration; STEM = science, technology, engineering, and mathematics; TRPP = Teacher-Researcher Partnership Program; OPS = Omaha Public Schools.