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Enhancing the STEM Ecosystem through Teacher-Researcher Partnerships

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Abstract

STEM faculty at the University of Nebraska at Omaha (UNO) have partnered with teachers and administrators in the Omaha Public Schools (OPS) to implement a Teacher-Researcher Partnership Program. This program establishes resources and infrastructure that engage K-12 science teachers in scientific research experiences. In the first implementation of this program, eleven UNO faculty mentors, drawn from several STEM disciplines, were matched with eleven OPS teachers to conduct genuine research projects in support of their teaching.

Introduction

Science, technology, engineering, and mathematics (STEM) education is a national priority for good reason. According to a 2014 report from the U.S. Bureau of Labor Statistics, the number of jobs in STEM areas will increase by about 1 million from 2012-2022 (Bureau of Labor Statistics, 2014). At the same time, only 37% of U.S. high school students are ready for college-level science (American College Testing, 2014) and U.S. high school students rank 23rd in science readiness and 30th in mathematics readiness among industrialized nations (National Center for Education Statistics, 2012). Obviously, the gap between STEM educational preparation and career opportunities in the U.S. is alarming.

The State of Nebraska mirrors national statistics and highlights the persistent challenges for STEM educational pathways and STEM careers. An estimated 102,000 STEM positions will be available in the state of Nebraska by 2024 (Alliance for Science and Technology Research in America, 2015) while students in the Nebraska public education system have continually been outpaced in terms of their academic performance in science and mathematics. Currently, only 49% of K-12 students in Nebraska are proficient in science (American College Testing, 2014), only 42% of graduating seniors are ready for college science (American College Testing, 2014) and students from low socioeconomic households and those of migratory families show alarmingly low proficiencies of only 13% (Nebraska Department of Education, 2013).

While the statewide statistics cause considerable concern, the challenges in Omaha are even more significant. The Omaha Public Schools (OPS) district is by far the largest and most diverse school district in Nebraska with a total enrollment of over 50,000 students. Of these, 66.4% are minorities and 74% receive free and reduced lunch (Nebraska Department of Education, 2013). The district represents approximately 20% of the state's overall student population. In this highly urban district, more than one hundred different languages or individual dialects are spoken by students attending 7 high schools, 11 middle schools, and 63 elementary schools. When considering students within OPS, the proficiency rate in science drops to 46% (Nebraska Department of Education, 2013). The statistics are even more troubling for students who are eligible to receive school lunch at a free or reduced cost. Across the district, less than 31% of these students are tested as proficient in science. At a time when the number of low-income students in OPS is increasing by 2–3% per year, students receiving free or reduced lunch score 5–20 percentiles lower in mathematics and science standardized tests than students not in this program. Proficiencies are even lower for black and Hispanic minority groups; disaggregated achievement data from the standardized tests indicate that, compared to their white peers, African-Americans generally score 10–20 percentiles lower, and Hispanic students score 10–30 percentiles lower in standardized success measures in both mathematics and science (Nebraska Department of Education, 2013). These numbers indicate a clear and immediate need to improve STEM education and opportunities in STEM for all Nebraska students, particularly within OPS.

OPS and UNO are already very closely linked in the STEM learning pipelines. More than two-thirds of all UNO students come from the Omaha metropolitan area, and of those, 34% are graduates of OPS (University of Nebraska at Omaha, 2015). Nearly 60% of the secondary STEM teachers in OPS have received their degree from UNO. Thus, by working collaboratively with OPS on STEM initiatives, UNO has the opportunity to catalyze STEM reform that engages the entire K-16 educational system. Since UNO is not unique in this kind of relationship to partnering school districts in their local area, interventions at this metropolitan university that successfully address STEM educational pathways and related needs in a diverse urban context will serve as a model for replication on a national scale.

To advance the OPS-UNO partnership, enhance the STEM ecosystem in the metropolitan area, and provide genuine research experiences for teachers and youth in Omaha, faculty at UNO have developed an innovative approach called the Teacher-Researcher Partnership Program (TRPP). The TRPP is firmly grounded in Discipline-Based Education Research (DBER) evidence showing that STEM learning is greatly enhanced by implementing inquiry-based strategies into the classroom, and authentic research experiences are among the most effective of these strategies (American Association for the Advancement of Science, 2013). It is important to note that the TRPP is complementary to an aggressive and comprehensive OPS program called the K-12 Comprehensive Science Teaching and Learning Project. The OPS project has private funding to support a cohort of K-12 science coaches who assist science teachers as they synthesize professional learning opportunities into useable teaching tools, strategies, and lessons. The OPS project participating teachers engage in intensive professional development that includes graduate coursework, research immersion experiences, and other individualized professional learning opportunities. The TRPP led by UNO is an exemplar of a scientific research experience for OPS teachers as they benefited from systemic and programmatic support from both the TRPP research experience and the OPS project. This provides an environment of professional development synergy that increases the likelihood of positive change in the classroom.

The OPS Comprehensive Science Teaching and Learning Project is a project in which scientific inquiry meets K-12 teachers' professional development. The OPS project has a long list of objectives, two of which are increasing student achievement in science and increasing teacher effectiveness. Another major goal of the initiative is enabling students to conduct authentic scientific research. After less than a year of implementation, the project has eight active science coaches (the majority of whom participated in DBER research at UNO during the first half of 2015), thirteen teachers that completed a graduate-level UNO course in scientific research methods and eleven teachers that completed the summer TRPP. There are currently 52 OPS teachers who have signed up to work with coaches on their individual classroom plans and to enhance their science instruction.

This paper describes the overall organization, implementation and assessment of the TRPP. As mentioned, in the first implementation year of this program, eleven UNO faculty mentors, drawn from a variety of STEM disciplines, were matched with eleven OPS teachers to conduct genuine research projects in a 4-6 week summer session. These projects were supplemented by graduate level courses at UNO, journal clubs involving all teachers and faculty mentors, and a capstone research symposium where teachers presented the results of their research, and were scored according to a common rubric (by three anonymous participating teachers and three anonymous faculty mentors).

Results of the TRPP, which are described in detail below, were extremely encouraging. For example, pre and post program focus group sessions of teachers suggested learning gains in the understanding of the scientific method and of scientific research, and post project surveys of teachers and mentors showed that the vast majority of participants intended to apply for the TRPP next year. We also observed an increase in confidence in science and in scientific research by teachers that participated in the genuine research experience as reported by the focus groups. Moreover, many teachers stated that they have chosen to implement lessons learned from the summer research experiences into their courses (whether that be a class-led project or working with smaller groups of students toward projects at the Nebraska Junior Academy of Science or local science fairs). In some cases, teachers and mentors are continuing to work side-by-side to implement lessons into the teachers' classroom. Overall, our Year 1 results suggested that the TRPP is a useful strategy for empowering teachers by giving them the tools, resources, and personal confidence needed to conduct authentic research projects with youth in OPS. This contributes to the growing STEM ecosystem in the Omaha Metropolitan area by actively promoting authentic scientific inquiry into earlier K-12 stages of the STEM pathways. We hypothesize that these experiences will encourage students to be more interested and persistent in later stages when scientific inquiry is experienced at the university level.

TRPP Implementation

The TRPP was developed as an integral component of the UNO-OPS partnership supporting the OPS K-12 Comprehensive Science Teaching and Learning Project. This project began in January of 2015 with the selection of the first cohort of K-12 Science Coaches and enrollment of K-12 teachers in a special graduate level course called Discipline-Based Education Research Methods hosted by the UNO Biology Department. With this backdrop, the TRPP recruited mentors and teachers for the summer research program. Students in the graduate course and OPS Science Coaches were informed of the TRPP summer program and encouraged to contact the TRPP leadership team to express their interest in applying. After learning about goals and requirements of the TRPP, eleven teachers applied, were accepted and committed to participate.

For this initial implementation of the TRPP, UNO faculty mentors were recruited by contacting potential candidates from all STEM disciplines, and explaining the goals and requirements of the program. Eleven faculty mentors were identified. Faculty mentors submitted an abstract of the research problem that teachers would address in their summer program and these abstracts were posted online. Teachers were asked to review the abstracts and to submit a prioritized list of three potential mentors that they would like to work with in a collaborative scientific research effort. Given the teachers' requests, the TRPP leadership team matched teachers and mentors, doing their best to respect the teachers' top choice. After completing the matches, mentors reached out to teachers to establish initial communication, arrange preliminary meetings, discuss scientific interests and provide background readings and resources. Teachers and mentors signed a joint memorandum of understanding that articulated expectations for both partners.

The summer TRPP program commenced with an orientation session involving both teachers and mentors. At this orientation, expectations of the program were explained and reiterated. The orientation for teachers included sessions on ethics, scientific misconduct and laboratory safety as required of other graduate students that participate in research at the university. The orientation sessions also provided opportunities for completing personnel paperwork, obtaining campus identification cards, distributing keys and discussing parking strategies. Finally, a pre-project focus group was completed for both teachers and mentors at the end of the orientation.

After completing the orientation, each teacher began their research project, and began the minimum 20-hour per week schedule that was pre-arranged with their mentor. A research community involving all teachers and mentors was maintained in required once-per-week journal club meetings for both teachers and faculty. For the journal club, teacher-mentor pairs took turns finding and presenting a research paper and leading the discussion. The summer research project required a minimum of four weeks. The journal club continued for six weeks.

Teachers were provided full tuition remission for any summer courses in-discipline in which they enrolled, including an “Independent Research” course (BIOL 8020 at UNO) at the graduate level. This opportunity helped to fulfill content requirements needed for any teachers pursuing master’s degree in a STEM field or interested in eventually qualifying to teach dual enrollment coursework within the sciences.

The summer program culminated with a virtual capstone research symposium reminiscent of the platforms used today by major scientific research societies-- again emphasizing the translation of the work to a broader audience. This opportunity provides a “full-circle” approach to scientific research for the teachers by authentically sharing their work professionally as a scientist. This symposium was a poster session. Teachers were responsible for developing their posters with mentor input and were provided with a template that identified major topics areas. Posters were posted online and made available for viewing, posting comments and evaluation. Each poster was formally evaluated by three teachers and three mentors, who were each selected randomly. Mentors were excluded from evaluating their own teacher partner. All evaluations followed a common rubric developed collaboratively by the faculty principle investigators on this project. Reviewers were asked to assign a score of “0” (not present), “1” (present; not well-described), or “2” (well-described/effectively communicated) on each of eight questions. Questions included: 1) was the objective/hypothesis communicated clearly?, 2) Were the methods that supported the hypothesis clearly articulated?, 3) Were the major results or significant take home messages of the study clearly described?, 4) Was the summary of the summer work conducted clearly articulated?, 5) What was (were) the major strength(s) of the study?, 6) What was (were) the major limitation(s) of the study?, 7) What would a future question based on this study be?/What would next steps be for this project?, and 8) Was this poster effective at communicating science? We used a generalized linear model (with binomial family with log link) to compare the consistency in scores among questions from evaluation rubrics of the research symposium. Due to the low prevalence of “0” scores (n=34), we lumped scores of “0” and “1” in the same category and compared the probability of those responses with the probability of 2’s among questions. Similarly, “intermediate” responses of “1.5” (n=4) were rounded to “2” for all analyses except for calculation and comparisons of total score. Rubrics with missing values on ≥1 questions (n = 9) were not included in the total score comparison. Analyses were performed using the program JMP (Version 10.0.2, SAS Institute, Inc., Cary, NC).

We also asked mentors to provide information about what type of a mentoring strategy they used in the program with their mentee. Specifically, faculty were asked, i.) “Describe your mentoring style, ii.) Demonstrate how effective this method of mentorship was with your mentee, iii.) Do you intend to apply to this program in subsequent summers?, and iv.) Were you able to mentor your teacher mentee in a fashion similar to your approach for mentoring undergraduate and/or graduate students?” Responses from faculty mentors are summarized in the results section.

A post-project focus group was conducted separately with each of the teacher and the mentor groups. For the most part, the questions for the post-project focus group sessions were the same as the questions for the pre-project focus group sessions. Small changes in the questions were necessary for a few questions. For example, the question "What do you expect to learn" in pre-project focus group was changed to "What did you learn" in post project focus group".

Results

The recruiting and matching program implemented by the TRPP leadership team produced a diverse array of STEM research experiences for teachers. It also assembled a multi-disciplinary cohort of faculty and teacher colleagues for journal club discussions and capstone symposium participation. Table 1 shows teacher-faculty matches, research area disciplines, and titles of projects. As indicated in the table, a number of STEM disciplines were represented. The diversity of projects within disciplines further expanded the breadth of scientific experiences for teachers.

Table 1

TRPP Participants and Projects. Summary of mentored projects completed by teachers in the program.

Table Overview: Summary of projects completed by teacher-researcher pairs through the Teacher-Researcher Partnership Program. Projects mentioned below were all performed during the inaugural year of the program. This summary shows the diversity of disciplines and projects available to teachers in the program.		
Science Teacher Level	**STEM Discipline/Department of Faculty Mentor**	**Project Keyword**
Middle School Science	Biology	STEM Education
High School Science	Biology	Insect Immunity
High School Science	Biology	Rain Gardens
Middle School Science	Biology	Prairie Mass
High School Science	Chemistry	Enzyme Kinetics
High School Science	Geology	Mineralogy
Middle School Science	Bioinformatics	Genome Analysis
High School Science	Biology	Native Bees
High School Science	Biology	Viral Genomes
High School Science	Biology	Bat Ecology
Middle School Science	Biology	Cancer Biology

Since this was the first year of a three-year project to provide opportunities for teachers within OPS to participate in genuine research experiences advised by University faculty, the findings reported herein are based solely on this pilot year. However, the results for this first year were quite encouraging. Specifically, we observed significant gains from the teachers in terms of content knowledge, ability and confidence in discussing science, and in their understanding of the scientific process as detailed by the four major findings presented below.

Firstly, we observed increased teacher voice and comfort in discussing science and pedagogical problems through the weekly journal club context. Specifically, the journal club included methods papers for scientific protocols, discussion of the National Academies Press STEM calls to action series "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" (Committee on Prospering in the Global Economy of the 21st Century

2007, 1-30) and discipline-based education research articles focusing on integrating active learning strategies and authentic research experiences for both K-12 and undergraduate students in the sciences. Candid observations of what worked and didn't work in their scientific research endeavors and instructional efforts were openly discussed by both mentors and mentees. There were also several spontaneous brainstorming sessions on how to further research certain topics of particular interest, discussions of how to effectively frame a research question, and how to translate information accrued through the research experience back to the K-12 classroom and for research experiences for youth. Each weekly journal club was well attended and mentors and mentees alike commented on the positive and supportive atmosphere for sharing science and the ability to learn more through reading peer-reviewed, primary literature articles in various STEM disciplines.

Secondly, through the virtual research symposium, teacher mentees were provided the guided opportunity to share their findings via the poster presentation. In almost every case, this was the first time that the mentee had created a research poster presentation and shared it with others. As part of the learning process, both mentors and mentees alike scored the posters. The common scoring rubric contained eight questions and evaluative comments were encouraged. A perfect score for the rubric questions was 16. The overall total score mean was 13.1. Interestingly, the mean score for mentor evaluators was higher than the mean score for teacher evaluators (13.6 vs. 12.5, $p = 0.03$). A summary of insights from evaluating three of the eight questions is shown in Table 2.

The probability of a high score ranged from 59% to 81% but was not statistically significant (Likelihood ratio test, $X^2 = 13.14$, df = 7, $p = 0.069$). Specifically, there was consistency in the distribution of scores for questions 1, 2, 3, 4, 6, and 8 ($p > 0.09$ for all, probability of "2" = 62-79%); however, scores of "2" were more likely on Q5 (ß = - 0.592 ± 0.30, L-R $X^2 = 4.43$, p = 0.035; probability of 2 = 81%) and less likely on Q7 (ß = 0.5043 ± 0.2512, L-R $X^2 = 4.0464$, p = 0.044; probability of 2 = 59%) compared to questions 1, 2, 3, 4, 6 and 8. In summary, mentors reported higher total scores than teachers (ANOVA, $F_{1,35} = 4.83$, $p = 0.035$). Out of 16 possible points, mean total scores reported were 13.6 (± 0.34) among mentors, and 12.5 (± 0.37) among teachers. However, ordinal logistic regression analysis revealed that distribution of scores was consistent among mentors and teachers within each question ($p > 0.05$), except Q5, where mentors were more likely to report higher scores than teachers (ß = -0.86, p = 0.036).

Table 2

Poster Scoring Insights. Summarized results from teacher and faculty scoring of the posters in the research symposium.

Table Overview: The following insights were found from analyzing rubric scoring and comments from evaluation of the research symposium posters. This summary reports insights from three of the eight rubric questions. These questions most closely address scientific communication.

Rubric Question	Score	# of times reported	Comment Summary
1.) Was the objective or hypothesis	2	47	Clearly written. Easy to identify. Thorough. Justified. Emphasized with special text formatting. Well Described. Understandable.

communicated effectively?			Differentiated between multiple objectives and/or personal/overall goals.
	1	16	Addressed indirectly or partially. Present but lacking in detail/required clarification. Objective(s) stated but reasoning insufficient. Objective(s) stated but inconsistent with results. Addressed but not well integrated/did not flow well within the text.
	0	3	Lack of clarity, understanding, inclusion, and/or development
2.) Were the methods that supported this study clearly articulated?	2	52	Clear. Easy to follow. Thorough. Descriptive. Supported by supplemental material. Few or no items missing/lacking in detail. Reviewers suggest some changes in format, protocol, legend, flow, citation of references, and/or description of analysis. (*Note: two reported values of "1.5" are included in this summary)
	1	14	Present but brief, unclear, incomplete, and/or lacking in detail or reasoning. Ineffective presentation. Terminology not defined or clarified. Quantities and/or description of materials lacked sufficient detail.
	0	0	N/A
3.) Were the major results or significant take home messages of the study clearly described?	2	47	Clearly articulated. Well explained. Well communicated with figure(s) and text. Sufficient detail & explanations. Figure informative, legends complete. Results easily understood & significance described. Addressed both scientific results and personal impact. Few if any questions unanswered. (*Note: one reported value of "1.5" is included in this summary)
	1	18	Present but lacked data, support, detail, strength, and/or left questions unanswered. Project incomplete, so this topic was lacking. Figure(s)/table(s) helpful but significance unclear, and/or more needed. Take-home was identifiable but not emphasized. Not well understood.
	0	0	N/A
	None	1	Focused on challenges more than discussion of results, but basic take-home was clear.

Thirdly, when we analyzed the specific type of mentoring taking place through the TRPP by faculty survey, we observed that guided mentoring and apprenticeship style mentoring were used. Specifically, the majority of mentors reported using a guided mentoring experience (71.43%; Figure 1A) wherein they gave some background information, demonstrated how to do the science first, then let the mentee progress in the experiment until a roadblock occurred. The majority of mentors reported that this guided mentoring approach worked well the majority of the time (Figure 1B). Most faculty indicated that they planned to apply for the program again in subsequent summers (Figure 1C). Lastly, just under half of mentors reported that they used the same level of mentoring for teacher mentees as they did for undergraduate students, but not graduate students (42.86%). A total of 28.57% of mentors reported that they used the same mentoring strategies for their teacher mentee as they do for both undergraduate and graduate students (Figure 1D).

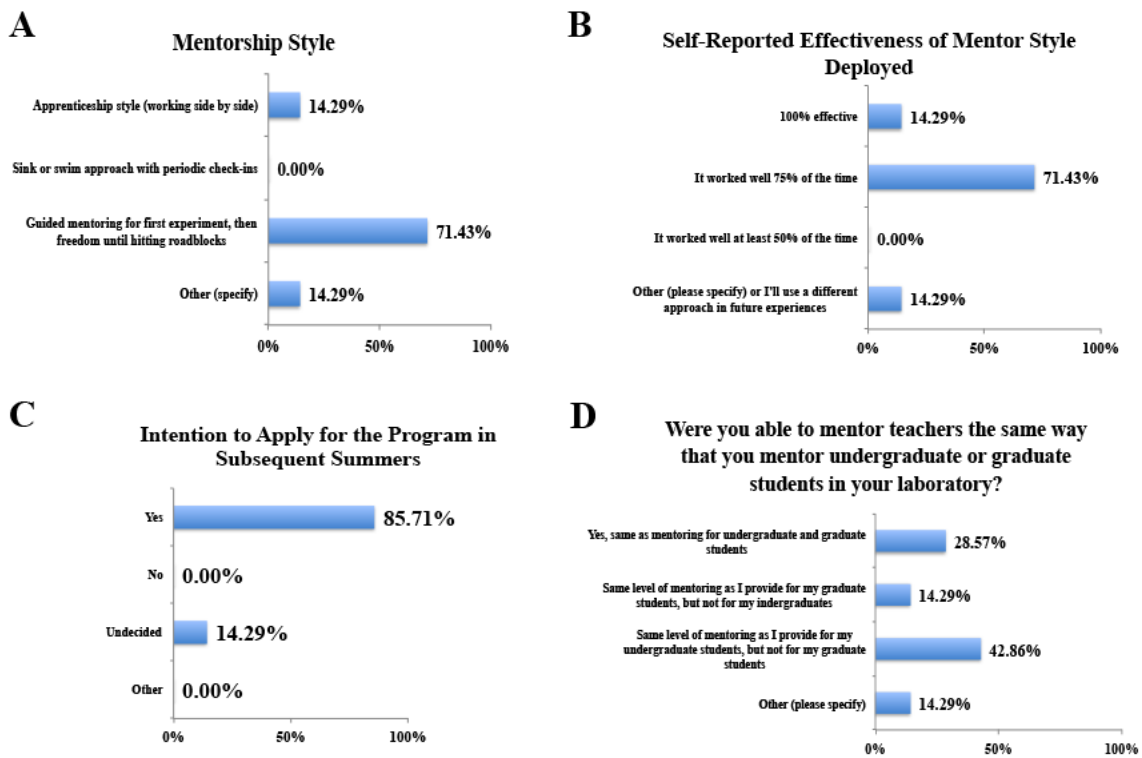

Figure 1. Faculty responses regarding their usual mentorship style and subsequent mentoring strategy. (A) Faculty mentors were surveyed to determine the type of mentorship style they conducted with their mentee. (B) Faculty mentors were surveyed to determine their perceived effectiveness of their mentorship style/methodology that was deployed. (C) Faculty mentors were surveyed to determine, at this time, how many are considering applying to participate in this program again in subsequent years. (D) Faculty mentors were surveyed to compare how they mentored teacher researchers as compared with undergraduate and graduate students in their laboratories.

Lastly, we analyzed the transcripts of post-participation focus groups of mentors and mentees as compared with that of the pre-participation focus groups. The salient findings of these transcripts are described in Table 3. Specifically, the insights gained across all focus group responses during the post-participation discussion included the fact that teachers found scientific research to be much more collaborative and involved than expected prior to the experience. Moreover, teacher mentees gained an understanding of data collection and error considerations in great depth through the experience and commented on the importance of following protocols and taking accurate measurements so that the data are reproducible. Other major findings included the recognition of the sheer amount of time that scientific research takes—many participants acknowledged the fact that it's quite difficult to adequately address an authentic research question in just 4-6 weeks. Faculty mentors commonly reported gains in the confidence of their mentees and increased communication with them as they appeared to become more comfortable with the collaborative research process—often recognizing that there may not exist a "correct" answer in the research process. Mentees ultimately recognized the need to strengthen scientific inquiry across the grade levels to involve youth in more authentic research experiences. Table 3 provides a summary of the pre and post focus group insights from both teacher mentees and faculty mentors.

Table 3

Focus Group Insights. Summarized results from teacher mentee and faculty mentor focus groups.

<table>
<tr><th colspan="2">Focus Groups Insights (Teacher and Faculty Participants)</th></tr>
<tr><td colspan="2"><u>Table Overview</u>: The following insights were found from four focus groups, one with Teacher Mentees before and after the TRPP process, and one with Mentor Faculty before and after the TRPP process. The focus groups were done separately. The questions were slightly differently in the focus group prior to the experience. For example, "What did you learn?" on the post focus group question set was stated as "What did you expect to learn?" on the pre-focus group questions.</td></tr>
<tr><th>Focus Group Questions (Post)</th><th>Insights Gained Across the Four Focus Group Responses</th></tr>
<tr><td><u>Question 1</u>.
Teachers: What would you define as "scientific research"?

Faculty: What would you define as "scientific research"?</td><td>• [Teacher Pre] In the pre-project responses, teachers appeared to nearly "quote" from their science texts, stating the "scientific method" steps, and "the importance of making careful observations".
• [Teacher Post] In the post-responses, which varied significantly from the pre-responses, teachers talked more about that the research process being "collaborative", "contributing to deeper scientific understandings", "depending on replication", and "involving careful field work". Teachers also emphasized the time needed "to do research right", "avoid errors" and "taking time to allow for reasoning of results and interpretation".
• [Faculty Pre and Post] In contrast, the faculty mentor responses varied relatively little from their pre to post responses, and emphasized "collaboration", "following scientific methodology and protocols", and "ultimately answering focused questions, and solving problems".</td></tr>
<tr><td><u>Question 2</u>.
Teachers: What did you learn during this shared research experience with your faculty mentor?

Faculty: What do you expect that your mentee teacher will learn during this</td><td>• [Teacher Pre] In the initial focus group, teachers generally expected to learn very generalized skills, that again seemed to be drawn somewhat from a textbook statement, such as "how to collect data", "how to do a lab journal", "how the scientific method is used", and "how technology is used".
• [Teacher Post] In the later focus group, teacher responses were much more personalized, and included thoughts that seemed to imply a more experiential perspective, including thoughts such as "it is difficult to do viable research in a short time", "setbacks are common but contribute to understanding", "introspection on errors is important", and the need to "move away from cookie cutter labs" with</td></tr>
</table>

shared research experience with you?	their own students. • [Faculty Pre] In the initial focus group for faculty, there was an expectation that teachers would hopefully "gain confidence and deeper insights into the complexity of research", and also eventually "better model actual research" in their classes. • [Faculty Post] In post focus groups, faculty mentioned that they saw both the "comfort level and communication" of their mentee teachers increase, as well as their "general interests in the research being undertaken", and a more "careful consideration of error".
Question 3. Teachers: What challenges did you have during this shared research experience? Faculty: What challenges did you have during this shared research experience?	• [Teacher Pre] Teachers entered the summer TRPP very nervous, and mentioned that they "felt out of their league", they were worried about "disappointing the faculty", or perhaps making the faculty member "babysit" them during the research process. • [Teacher Post] Post summer focus group comments from teachers suggested a much higher comfort level in pairing with faculty. Challenges centered more directly on logistical considerations, such as challenges in "scheduling", "weather", "pictures", and "computer skills". • [Faculty Pre and Post] Faculty expected and noted challenges relatively consistently between pre and post focus groups including: "short time duration", "getting the teacher up to speed", and generally a lack of an opportunities to involve teachers in "developing the project". Shared terminology use between the faculty and teacher was also mentioned as a challenge in collaboratively conducting the research.
Question 4. Teachers: How do you hope to have this impact your classroom instruction? Faculty: How do you hope to have this impact the teacher's classroom instruction?	• [Teacher Pre] Teachers in the initial focus group generally mentioned somewhat holistic or "big picture" impacts in their classroom in "being able to share the science experience with students", "bringing passion to the science classroom", and having more "credibility with students". Very little was mentioned about teacher expectations for refining the scientific process itself or the scientific process for their students. • [Teacher Post] In the focus group after their TRPP experiences, teachers tended to more clearly discuss refining the scientific process in their classroom, including "having students read scientific articles", using "different methodologies", "moving away from cookie cutter labs", and "helping students to formulate and develop good questions". • [Faculty Pre and Post] Faculty were again relatively consistent from pre-TRPP to post-TRPP focus group comments. They hoped that teachers would "be able to confidently teach and guide" their students and other teachers, "provide a direct link to hands-on curriculum", "give better laboratory experiences" and "teach from a point of view of enjoying the discipline", as well as having a "stronger belief in inquiry" in their classrooms.
Question 5. *(Post Only)* Teachers: How did your confidence improve through the research process?	• [Teachers Post] This question was only asked after the TRPP experiences, and teachers in the post focus group talked quite a bit about how their confidence had increased including related to: "math/stats involved in research", "doing it myself", "equipment handling", "understanding professional literature", "scientific rigor", "preparing students for college science", and ultimately, "teaching inquiry in a real way" with students.

Faculty: Did it seem like your mentee became more confident through the process? What evidence do you have to support that?	• [Faculty Post] Faculty agreed that teacher confidence greatly improved over the TRPP summer activities. Faculty mentioned that they saw confidence improve in: "presenting scientific work", "trouble-shooting", "instrumentation", "discussing scientific work", "communication". In general, they felt that the teachers became much more confident in discussing the research and "answering questions" about the research process.
Question 6. Teachers: Any final comments? Faculty: Any final comments?	• [Teacher Pre] The final "round the table" comments in the teacher focus group prior to the TRPP experiences showed again that the teachers were very worried about the upcoming research experiences, and that generally felt somewhat "stressful", with nearly all comments focused on that feeling. • [Teacher Post] In contrast, open ended final comments by teachers after the TRPP never resurfaced any comments on stress or nerves, and instead reinforced the overall contributions of the project in numerous areas, including: "being more comfortable in lab settings", "presenting data", "bringing in scientific literature", "the power of collaboration in science", "letting students know that no one is perfect", "the need to strengthen science inquiry", "the need to reevaluate others work", and "having a deeper understanding of actual science". • [Faculty Pre] Final comments in the initial faculty focus groups before the TRPP experience did not mention nerves or concerns of any kind, and instead simply mentioned that they were excited to get started. • [Faculty Post] Faculty comments in their final open-ended period of the focus group were very positive, and mentioned that for the first TRPP go around "they were really pleased", "they really liked communicating with the mentee", and that "talking about teaching approaches was beneficial with my mentee". Faculty also mentioned a desire to further contribute to the K12 classroom, and wondered "how do we help them get the resources to do real science?", "keep the connection going", and insights such as "understanding the limits of public education was eye-opening". Finally faculty reinforced in several different comments that that TRPP project "has shown its value".

Conclusion

As described, our results show that the first year of the TRPP was a successful effort that brought K-12 teachers and university scientists together for an authentic collaborative research experience. The immersive discipline specific coursework and research experiences of the TRPP provide a level of professional development that would seem critical for K-12 teachers for enhancing STEM pathways as described in the introduction of this article and the national reports cited. By experiencing authentic research, teachers in the TRPP developed a working understanding of scientific research and the related inquiry that they did not display at the beginning of the program. Most importantly, teachers in the TRPP began to adapt their research project into an experience that they could replicate with students in their own classrooms. The participation in journal clubs also led to a candid, thoughtful and positive discourse commonly practiced by scientists and added to the teachers' confidence and camaraderie within a context similar to that of a scientific community. Through a guided mentoring approach, as noted in the focus group comments, teachers were better able to take ownership of their project, consider the accuracy of their measurements and data, make interpretations and share results, while having the ongoing support and encouragement of a university scientist, thereby increasing their confidence in the ability to complete the research project and to lead more authentic research experiences in their own classroom. By engaging K-12 teachers in such authentic research that can be translated to their classroom, the TRPP enhances STEM capabilities of teachers while also providing opportunities for K-12 youth to experience STEM research. Evidence shows that such experiences improve understanding of science and the scientific method, including the importance of iteration and that failure can be an acceptable and at times required step in the scientific process (American Association for the Advancement of Science, 2013). Early introduction of authentic research experiences will enable students to become more interested and persistent in the educational pathways that might lead to a STEM career.

The program we have developed seeks to enhance the teachers' ability to provide the most effective and realistic STEM experiences to their students. While our focus is on teachers, the true test of program impact will be the success of students. The collaboration that links the UNO-based TRPP to the OPS-based Comprehensive Science Teaching and Learning Project has established a basis for sustained evaluation of these interventions and their influence on student preparedness. The overall goal for both UNO and OPS is improvement in student success. We will provide ongoing analysis of student preparedness as part of the UNO-OPS collaboration. In the end, evidence that our goals have been achieved will be provided by the achievement testing conducted by statewide agencies such as the Nebraska Department of Education and national organizations such as American College Testing and ultimately the interest and success of these students going into STEM educational pathways and careers. We also expect to see an increase in inquiry-based instruction in OPS science classrooms as identified by the evaluation measures of the Comprehensive Teaching and Learning grant.

We fully recognize the importance of local actions to address the national imperative in the United States to provide more experiential, hands-on learning opportunities in science, technology, engineering, and mathematics. STEM concepts and competencies can be infused in the classroom through genuine research experiences across K-16. These inquiry-based approaches are essential for understanding how scientific research works, to build confidence in participants in STEM fields, and to better understand major concepts. While this is the first year of this project and results will be more robust as the program is sustained, we are increasingly enthusiastic that this program will lead to major gains for the teachers involved in the project and the youth that the teachers serve. Through projects such as the TRPP, we are building a STEM ecosystem amongst university faculty and K-12 that contributes to the effectiveness of the STEM pathways that will hopefully lead to the increased number of STEM professionals that are so critically needed by our country.

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