Reflections from the First Year of a National Science Foundation Research Experience for Teachers in Civil Engineering

Beena Ajmera
Iowa State University

Sarah Crary
North Dakota State University

Abstract

Through funding from the National Science Foundation to create a Research Experience for Teachers site at North Dakota State University, the authors provided summer research experiences to current secondary (6th to 12th grade) educators to improve their understanding of the civil engineering field and develop new curriculum modules for their classrooms. Reflection of the first summer program in 2021 highlighted several modifications that could be made to improve the quality of the program and curriculum developed, increase the accessibility to underserved and/or underrepresented populations and to better utilize the limited resources available. This paper summarizes the successes of the RET program and provides several concrete recommendations for future programs. Specifically, recruiting of both teachers and faculty could be more effective when personal communications through known contacts are used. Flexibility in the approach without compromising rigor and expectations allows for a more inclusive program that supports underserved and marginalized populations.

Keywords: National Science Foundation, Research Experience for Teachers, Secondary education, STEM curriculum, civil engineering, lessons learned

Introduction

The National Science Foundation's (NSF) Research Experience for Teachers (RET) program is designed to help current educators secondary (6th to 12th grade) gain a deeper understanding of the engineering field by creating a RET site at North Dakota State University (NDSU). In the funded (NSF Award #1953102) program, the PI and Co-PI (RET team) created a summer program with the objective to deepen participant knowledge on how civil engineering can be used to mitigate natural disasters in the region and globally. The activities participants engaged in allowed them to bridge research experiences to improve content knowledge which will translate to improved secondary STEM education in their classrooms (Farrell 1992; Dubner et al. 2001; Silverstein et al. 2009). The RET team had two goals to help accomplish the objective: (1) to provide a deeper understanding of civil engineering with tangible hands-on curriculum; and (2) to develop better abilities among middle and high school (secondary education) teachers in North Dakota to prepare their students to become future leaders in Science, Technology, Engineering and Mathematics (STEM) fields. An indirect goal was also to create ongoing partnerships between NDSU and area teachers for field trips, guest speakers and other opportunities for collaboration.

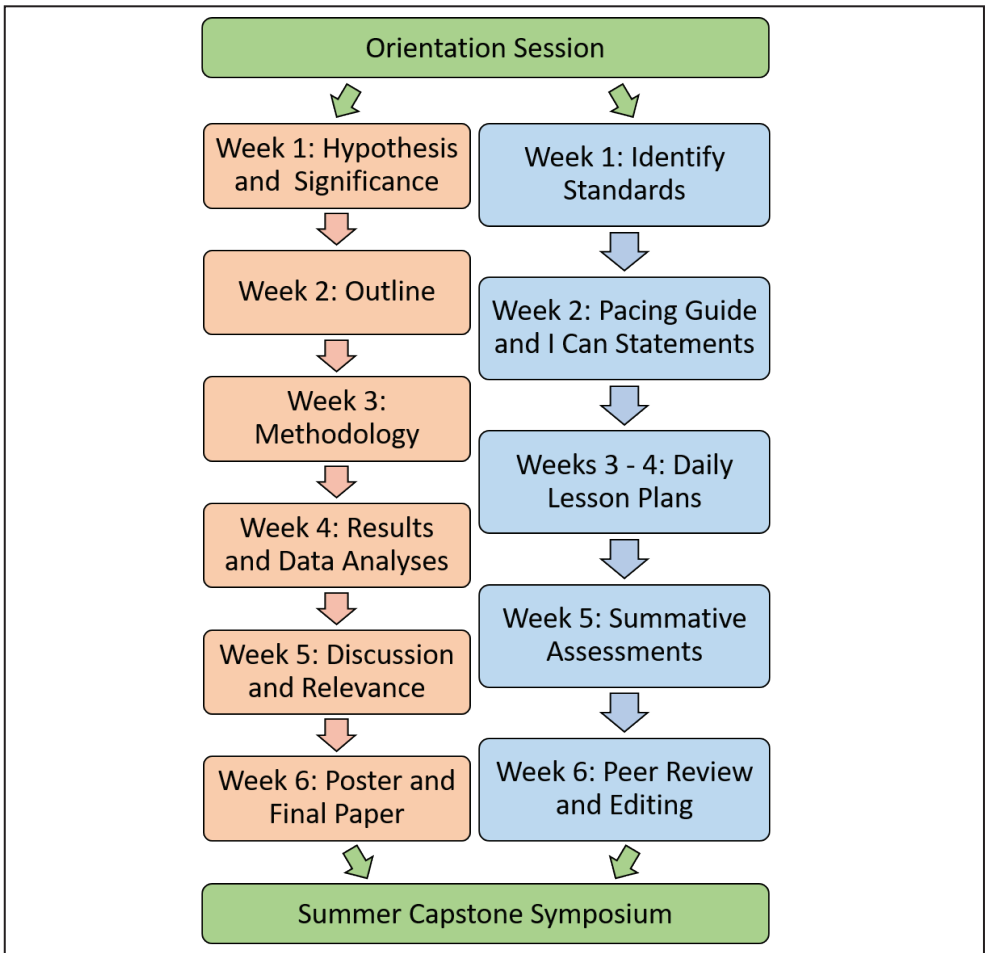

Figure 1. Overview of the RET Summer Program Academic and Research Workshops

The RET program in Year 1 spanned over six weeks in summer. During this time, the participants were expected to spend 20-30 hours per week conducting hands-on research in faculty laboratories and 10-20 hours per week attending research and academic workshops, going on field trips and doing their weekly assignments. The weekly assignments were focused around the discussion of the workshops and intended to help the participants complete the deliverables for the summer capstone symposium at the end of the summer program. A brief overview of the weekly workshops is shown in Figure 1.

The research team focused on teacher recruitment of secondary teachers (grades 6-12) who taught in a district within a commuting distance of NDSU, where the research would be conducted. The targeted schools served a large population of underserved and underrepresented groups including females, Hispanics, African Americans and Native American students. The teachers were required to teach in a STEM-related field in order to be able to connect the research in an authentic way to their curriculum. Pre-service teachers in STEM fields from NDSU's School of Education were also encouraged to apply and paired with current teachers in a research group for two reasons. First,

approximately half of teachers leave the field of education within their first five years (Johnson et al. 2005) so the RET team intentionally built a mentorship relationship by pairing to provide support for the pre-service teachers. Second, the pairings provided a classroom for the pre-service teacher to teach the curriculum they created.

Potential faculty mentors in the NDSU Department of Civil and Environmental Engineering (now, the Department of Civil, Construction and Environmental Engineering or CCEE) were requested to submit a short abstract with details regarding the roles and responsibilities of the teachers to be mentored in the project. The abstract indicated how the research project was connected to the theme of "Mitigating Natural Disasters." The selected projects and faculty mentors represented a diverse population and a variety of disciplines within civil engineering. Three of the five projects selected for the site had a female faculty co-mentor.

The research team paired the participants with the faculty mentors. To create these pairings, the research team carefully reviewed the application materials submitted by the teachers and created teacher teams based on the schools at which they work, the classes and subjects they will be teaching, and years of teaching experience. Some teachers invited colleagues to apply to the program and indicated on their application their desire to be paired together, which was honored by the research team. Each teacher team was then assigned to a faculty mentor and the associated research project. These assignments were based on the ranking of the projects as provided by the teachers in their applications. These decisions were further facilitated by considering the connection between the faculty mentor's research with the courses taught by the teacher team.

The RET team focused on creating a cohort dynamic among the participants. They began building the group dynamics from the first day through team building activities and discussion time that included participants, graduate students and faculty mentors. It was continued through weekly lunches held with the participants to discuss the research they were conducting as well as any questions they may have on the curriculum they were developing. In addition, group field trips with industry partners fostered discussions on how this information could be embedded within different curriculums. The RET team believed it was important to provide coffee and snacks in a central workroom throughout the day to provide a place for organic relationship building and networking. The depth of the cohort relationship was clear during the capstone presentations through encouragement and collective sharing of ideas.

Current literature related to experiences from RET sites focuses on the outcomes of the program, the effectiveness in achieving quality STEM curriculum for classroom implementations, improvements to teacher preparedness to teach STEM subjects and the impact of the curriculum on the students in their learning (Melear et al. 2000; Dubner et al. 2001; Westerlund et al. 2002; Hemler and Repine 2006; Blanchard et al. 2008; Grove et al. 2009; Silverstein et al. 2009; Kapila 2010; Laffey et al. 2013; Saka 2013; Zhu et al. 2018; among others) However, there is little information regarding the programmatic details of RET sites available forcing future sites to re-invent and individually discover best practices for such programs. The authors believe that this wealth of knowledge, summarized in Table 1, would allow future RET sites a springboard to build programs that are more effective and efficient, thereby increasing the quality of STEM curriculum developed and the preparedness of secondary educators in their implementation. Thus, to meet this need, this paper focuses on the experiences of the authors from the first year of this RET program at NDSU.

Measurement and Assessment Tools

Given the small population sample, this paper relies on observations, interactions between the research team and the participants as well as the experiences of the research team in the first year of the RET program at NDSU. While this approach may lack the rigor of surveys and other assessments, it offers valuable insights into the dynamics and organization of this program as well as the associated outcomes. The authors acknowledge that this methodology may not yield statistically generalizable results. However, this case study allows the authors to capture nuanced aspects of the RET program that cannot be captured through standardized assessments. Specifically, it allows the authors to share their experiences in establishing an RET site and provide recommendations on improvements that can be made bettering future RET programs and thus, the resulting impacts on K-12 STEM education in the future.

Reflection on Teacher Application and Selection Process

The RET team first reflected on how to improve the program for future years by revising the teacher application and selection processes. The initial email contained useful information that teachers needed to determine if they were interested. Word of mouth dissemination about the program resulted in several teachers sharing the email with colleagues, who then applied.

Several school superintendents and other district administrators forwarded the email to their teachers regarding this opportunity. However, based on answers in the application on how participants heard about the RET program, in larger school districts, the superintendent's office is often not in the building and does not have a first name connection with many of the teachers. The team realized that reaching out to the principals as well as teachers in STEM departments was more effective in garnering interest. On the other hand, for smaller school districts, having the superintendent send the email worked well.

The RET team found several interested applicants were unable to participate due to being overcommitted, having young children and also being burned out from the COVID-19 pandemic (Crary, Huseth-Zosel and Hill UR). Therefore, based on the authors' experiences, RET site coordinators are encouraged to revise the summer program schedule to be more inclusive of these teachers as they represent an underserved population that is being further marginalized. Future schedules will be created to allow for more flexibility in the activities.

Some examples of strategies that can be used to increase the flexibility for the program include the following:

1. Host part of the program asynchronously online allowing teachers to complete tasks at their own pace over a given amount of time.
2. Organize all of the workshops and assignment times to have hybrid options that encourage in-person participation to facilitate cohort building while allowing teachers to be remote, if needed.
3. Allow teachers flexibility to create their own schedules for the in-person research activities. These schedules should be approved by the faculty mentors to ensure research activities are completed in a timely manner. In addition, these schedules should be shared with the RET research team to allow them to interact with the teachers while they are on-campus.
4. Offer remote participation options that allow teachers to do hands-on research from their own homes. This will allow teachers from distant communities to participate in the program without forcing them to be away from their families and lifestyles for an extended period of time.
5. Permit teachers (and faculty mentors) to bring young children to certain meetings and workshops reducing the burden of childcare. And,
6. Listen to the needs of the teachers during the program and make accommodations, as appropriate.

Reflection on Faculty Application and Selection Process

The email request for summer projects from faculty mentors in CCEE attracted a few emails from faculty stating that they would be interested in participating and would submit the documents at a later time before the given deadline. A couple of the contacted faculty stopped by the PI's office to express their interest and ask some questions. However, only one of the six interested projects that were submitted were a direct result of the email sent. The RET team had more success in receiving responses from faculty members through direct hallway and informal conversations in which the PI encouraged participa-

Category	Challenge	Mitigation Strategy
Teacher Application and Selection Process	Effective recruitment of teachers	• Disseminate call through principals or teachers in STEM departments at larger schools • Disseminate call through superintendent at small schools
	Accommodations for underserved populations	• Offer flexible scheduling options
Faculty Application and Selection Process	Effective recruitment of faculty mentors	• Announce call for applications during faculty meetings with a follow-up email containing instructions
	Time commitment in the mentoring role	• Allow co-supervision of teacher teams
	Strong collaborative faculty mentoring team	• Have conversations with faculty teams that establish primary contact, protocols when disagreements arise, task approval process, roles and responsibilities, and disbursement of funds
	Last minute faculty mentor dropouts	• Obtain written commitments • Have back-up faculty mentors to step-in for those that dropout
Summer Activities	Foster interactions between the faculty mentors, the graduate students and the teachers	• Plan social gatherings in advance • Send calendar invites to ensure attendance • Articulate importance of social gatherings
	Clarity of expectations of industry partners	• Require structure on field trips • Engage industry partners to RET activities
	Timely submission of program deliverables by the teachers	• Tie stipend payments to program deliverables
	Improve inclusivity of the experience	• Allow hybrid participation when feasible • Provide flexible scheduling options

Table 1. Summary of Lessons Learned and Suggested Mitigation Strategies

tion and emphasized the ease of submitting interest in the program, resulting in faculty submissions within a day. Based on the authors' experiences, it would be suggested that RET site coordinators should announce the call for applications during faculty meetings with a follow-up email with additional instructions to obtain better and quicker responses.

Conversations with faculty revealed concerns about time commitments associated with being a mentor in the program. In response, the RET team allowed faculty to submit their summer projects in teams. By allowing the faculty mentors to co-supervise teacher teams, more were able to participate in the program as several had other commitments during summer that would have prevented them from participation. Additionally, the faculty mentor teams provided several other benefits to the program participants and their research including the following:

1. The teachers involved in the RET program had access to two faculty mentors that could support them in their summer research activities as well as in their future classroom implementation of the curriculum modules.
2. The projects could be expanded to include more interdisciplinary and cross-disciplinary aspects that naturally stemmed from faculty mentor teams. Therefore, the projects were more widely applicable in the classroom and allowed the faculty to continue their on-going research having a greater impact on their outcomes and productivity.
3. Faculty teams tended to be a combination of experience levels allowing informal mentoring between the members as they interacted with each other and learned effective techniques to mentor research groups.

However, there were also drawbacks to the faculty mentor teams. The lack of effective, regular communication between the faculty mentors on a single project led to confusion among the teacher teams as well as the graduate students involved. RET sites that plan to allow faculty mentor teams should have conversations with those teams to establish an understanding of: (1) the primary contact for the teacher participants; (2) faculty mentor approval process for submissions to the program; (3) the roles and expectations for each faculty mentor; (4) disbursement of funds allocated to the faculty; and (5) protocols in the case of conflicting messages from the two faculty mentors. To help further address the conflicting messages, future RET sites could (a) encourage regular communication among the faculty mentors, (b) document communications over emails that include all individuals involved, (c) empower the teachers and graduate students to speak up with conflicting messaging occurs, and (d) establish a conflict resolution policy prior to the start of the program. A clear understanding and communication of these aspects will go a long way towards establishing a strong collaborative faculty team.

The RET team empowered the teachers and graduate students by creating an open and supportive environment by demonstrating that diverse perspectives are valued and respected, ensuring the individuals that they are free from retaliation when they voice their opinions and/or concerns, and encouraging an open door policy where they can approach the RET team without fear. The RET team also scheduled regular meetings with the teachers and graduate students involved in each project to discuss their progress, concerns and questions. Teachers and graduate students were encouraged to be open about their experiences and any conflicts that they might be facing. When necessary, the RET team would advise the teachers and graduate students to directly communicate with their faculty mentors providing guidance on how to frame their concerns respectfully and constructively. On occasion, the RET would reach out the faculty mentors on behalf of the teachers and graduate students to obtain clarity or would join them in their discussion with the faculty mentors. Finally, follow-up efforts were undertaken by the RET team to ensure that the situation was improving and to make sure that the teachers and graduate students felt supported in their research experiences.

A week before the start of the RET program, these authors faced an unexpected challenge. One of the faculty mentors that had committed backed out citing overcommitment of time during the summer requiring last minute changes to the program. The changes included changing pairings between teacher teams and research teams to ensure the research topics aligned to what the teachers taught, canceling contracts for the faculty mentor and his/her graduate student, finding, hiring and training a substitute faculty mentor and his/her graduate student and disseminating this information to all affected individuals. As a result, the RET team created contingencies to avoid such situations in the future. First, when notifying faculty mentors of their selection into the program, those faculty mentors whose projects were not selected will be asked if they wished to be contacted if someone is unable to participate. Second, the team relied on individual verbal communications with the faculty to ensure they would be available. In future years, the team will get written commitments from the faculty, which will hopefully serve as a deterrent to the last-minute changes.

Reflection on Summer Activities

The first cohort occurred in Summer 2021, amidst some ongoing restrictions from the COVID-19 pandemic. Most of the restrictions at NDSU had been lifted at this time, although social distancing, wearing a mask and other safety precautions were still recommended. Therefore, the authors would like to note that none of their planned activities during this summer were adversely affected by pandemic-induced restrictions.

As part of the scheduled summer activities, the RET team scheduled weekly research and curriculum development workshops for the participants. These workshops assisted the participants in how to disseminate their research and effectively implement their research in the classroom. While resources existed to support these workshops, the authors opted to develop their own content, such that it was streamlined to focus on the most relevant aspects for the RET program. This allowed time to be better allocated for the participants to work on their research and curriculum development requirements.

The RET team valued the cohort model in order to develop connections between the participants through cohort activities and paired research groups. While nearly all of the participants were white, the majority of the faculty mentors and all of the graduate students represented diverse, international backgrounds. Through the cohort activities, the teachers learned about the paths that brought the graduate students and faculty mentors to their current careers. This allowed for deeper connections between past experiences and research interests, while providing teachers with different perspectives on the trajectories of the students. Several teachers noted that they would like to invite the faculty mentors and graduate students to share their experiences with their students. The teachers felt that such interactions would allow their diverse students to see individuals that look like them overcome and succeed in their professional careers, which is not always an easy connection to make in Midwest schools.

While connections formed between the teachers and their research team during the summer program, the authors felt that the summer activities could be better organized to intentionally foster these interactions. At the start of the program, the RET team did not build in time for informal social interactions outside of the casual hallway conversations. However, within the first week, the authors realized that more intentional interactions were needed and organized several weekly social lunches with the teachers, the RET team and faculty mentors. This allowed the teachers to get to know each other and the faculty mentors in a more social setting forming deeper, more meaningful connections. While faculty mentors and graduate students were invited to these lunches, many did not attend due to the last minute additions to the summer schedule. In future years, the RET team will add these events as part of the summer schedule to allow faculty mentors and the graduate students to plan accordingly.

Faculty mentors and graduate students excelled at providing mentorship and guidance on the research aspects of the RET program. However, very few faculty mentors (less than 25%) and nearly none of the graduate students made an effort to be present at the social lunches, the Capstone presentations at the end of summer and other non-research activities organized for the RET program. In future RET summer programs, the authors will better articulate that the intent of these activities is to cre-

ate stronger bonds between the teachers and the research teams they are part of as well as to foster relationships between the university and the area schools.

Another area of improvement identified by the RET team related to the clarity of expectations for the industry partners. The field trips served the purpose of creating connections between teachers, industry partners, and related local projects. However, some of the trips appeared to present information in a haphazard manner while others were structured. From the comments received, it was evident that the structured trips were more beneficial to the teachers. In future trips, the RET team will provide clearer instructions on the structure needed during the field trips and will encourage the industry partners to build time for interactions. Additionally, the industry partners will be more frequently invited to RET summer activities to allow for greater interaction with the hopes of creating stronger ties between the local civil engineering industry and the secondary schools in the area.

An issue the authors faced with the teachers concerned the timely submission of deliverables for the program. The RET team felt that the stipend structure could be modified to allow better accountability and a clearer understanding of the requirements for the program. Rather than providing stipends based on the percentage of participation in the program, the authors recommend that the stipends be tied to deliverables. That is, in the current model, the teachers received 50% of their stipend when they completed 50% of the summer program and the remaining when they finished the program. However, it would be more beneficial to tie the stipends to major outcomes, for example, the completion of the research activities for the summer program, the submission of the curriculum modules developed and the successful implementation of the developed modules within the classrooms of the participants.

Finally, given the lessons learned from the COVID-19 pandemic, the RET team felt that they could have done a better job in providing a more accessible program to be more inclusive. Some examples of how the RET team could have improved the accessibility of the program were listed earlier this paper. Over the course of the next year, the authors will be evaluating the time commitments within different aspects of the program and looking at allowing hybrid participation. Through these modifications, the RET team feels that they could then be more accommodating to different scheduling demands (such as, allowing parents to participate in the activities of their kids).

Conclusions

Overall the research team felt that the RET program at NDSU was able to provide authentic hands-on research experiences and develop new curriculum modules. Yet through reflection, the authors identified ways to improve the program and quality of the STEM instruction that the teachers will bring to their classrooms. In particular, the RET team will be implementing the following changes:

1. Disseminate the call for participants through more recognizable contacts within their institution,
2. Solicit faculty mentors for the program through meetings and personal communications in addition to email,
3. Converse with faculty mentor teams to ensure clear understanding of roles and expectations of each member,
4. Develop contingency plans for changes in commitments from teachers and faculty,
5. Intentionally develop connections between teachers and the research team,
6. Better articulate that the role of non-research activities in creating stronger bonds, and
7. Revise the summer program to be more inclusive.

It is necessary to be reflective and constantly seek how to improve programs to ensure fidelity of funding received and to have the greatest impacts on K-12 education towards inspiring the next generation of scientists, mathematicians, and engineers.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant No. 1953102. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Beena Ajmera, Ph.D., P.E., is an Assistant Professor in the Department of Civil, Construction and Environmental Engineering at Iowa State University prior to which she held Assistant Professor positions at North Dakota State University and California State University, Fullerton (CSUF) . She is the PI for the NSF Research Experiences for Teachers grant. Her primary research interests lie in various areas of geotechnical engineering and engineering education. Beena earned her PhD in Civil (Geotechnical) Engineering from Virginia Polytechnic Institute and State University, and her MS and BS in Civil Engineering as well as BA in Applied Mathematics from CSUF.

Sarah Crary, Ph.D. is the Assistant Director and Online Programs Coordinator in the Office of Teaching and Learning at North Dakota State University (NDSU) prior to which she was an Assistant Professor in the NDSU School of Education. She is the Co-PI for the NSF Research Experience for Teachers grant. Sarah has a Ph.D. in K-12 Educational Leadership from the University of North Dakota, Master of Education in K-12 Educational Leadership, and a Bachelor of Science in Social Studies education both from Minnesota State University Moorhead.