Research Experiences for Teachers in Precision Agriculture and Sustainability for Solitary STEM Educators

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Abstract

Over the past two years, North Dakota State University (NDSU) has conducted a National Science Foundation sponsored *Research Experiences for Teachers* (RET) grant focused on Precision Agriculture and Sustainability. For six weeks in the summer, middle and high school math and science teachers engage in authentic research projects through the mechanical engineering and the electrical and computer engineering departments. The main goal of the program is for teachers to develop an understanding of research principles, engineering applications, and the engineering design process. By accompanying the research with professional learning sessions on effective pedagogy, active classroom environments, and student-centered learning strategies, these teachers are building capacity to increase student engagement. The intent is to create a shift in how the teacher approaches lesson plan design creating more meaningful, engaging, and authentic learning experiences for their students. Since the majority of the school systems in the upper Midwest are characterized as rural, a unique aspect of this program is the focus on this demographic of teacher. To create the largest possible impact in a rural educational community, this program selects participants who are the only math or science teacher in their school building. In addition, each in-service teacher works alongside a pre-service teacher in NDSU's mathematics education or science education program. This provides a valuable experience for both the in-service and pre-service teachers while engaging in a collaborative experience. Having completed two summers of the three-year grant period, data results show the program has been highly effective in transforming the teacher's approach to classroom practices that increase student engagement. Results also demonstrate a positive impact on the pre- and in-service teacher's shift in attitude towards general classroom practices and teaching pedagogy. This paper describes the program goals and outcomes, specifics of the summer experience, data collection, results, and the next steps for research and practice.

Introduction

The teachers recruited for this RET program are the only math or science teacher in their middle or high school grades. These teachers, referred to as "solitary STEM teachers", come from the upper Midwest region. This region is categorized as over 99% rural, and it is common for schools to be separated by 30-40 miles or more [1]. Therefore, teachers in these areas are typically the only teacher in their content area and lack the support, resources, and professional opportunities required to develop effective teaching strategies. However, these teachers have significant influence over the development of their students, since they may be the only mathematics or science teacher their students ever have while in that building. Many of these teachers have 5-7 different preparations of classes per day and only one planning period. When policies and assessment methods change, such as with Common Core and Next Generation Science Standards, these solitary STEM teachers may struggle to implement transformational classroom practices [2] – [4]. During the RET program, teachers connect to STEM education by working with a strength of the local region: agriculture. Our goal is to enhance STEM education for rural students and their teachers, including exposure to the engineering field through an agricultural framework. The RET includes follow-up activities and support for each cohort as

they translate the experience into their mathematics and science courses throughout their academic year.

Program Description

This program brings solitary STEM teachers together into a cohort to provide them resources to implement research-based approaches to student learning through engineering practices [5]. Due to participation in the RET site program, teachers have enhanced content knowledge through their engineering and scientific research experience [6] – [8]. They also develop an understanding of active learning strategies they implement in their classrooms the following year [9] – [11]. This research experience occurs over a six-week period during the summer and engages five in-service and five-pre-service teachers. Each in-service teacher, paired with a pre-service teacher in their same content area, conducts research in the College of Engineering's Mechanical Engineering Department and Electrical and Computer Engineering Department on the campus of [University]. The design team, engineering faculty members, and graduate student mentors from the College of Engineering interact with the participants throughout the program to enhance the knowledge and skills required for the teachers to fully benefit from the experience. This includes but is not limited to refresher courses in math and science content, pedagogical workshops, engineering design activities, lab work, and curriculum writing. In addition to the summer experience, four workshops throughout the year provide continuous support and follow-up to ensure successful transformation of classroom practices. The anticipated outcomes of the RET site program are as follows:

1. Teacher Outcomes
    a. Greater knowledge of content aligned with research activities in their field
    b. Transformation of classroom practices resulting in more frequent STEM and engineering education teaching techniques
    c. Long-term collaborative partnerships with university faculty and industry representatives
2. Student Outcomes (indirectly from their teacher's experiences)
    a. Students having more positive STEM influences which encourage them to pursue careers in these areas
    b. Students being more engaged in the classroom due to better developed authentic classroom activities

This year, it was also important to continue establishing a professional learning community for the in-service teachers. Since two cohorts have completed the program, an adequate amount of teacher resources has been developed that can be shared with all the past and current participants.

Methodology

The evaluation design uses Kirkpatrick and Kirkpatrick's four-level model for evaluating training programs, with measures collected to address key features of participants' training experience and learning [12]. Throughout the program, data is collected at appropriate times to assess: (Level 1) participants' reaction to the training and its content (reaction); (Level 2) the extent of participants' learning of the intended skills, knowledge, and dispositions from the

training (learning); (Level 3) the extent of participants' transfer of these new skills, knowledge, and dispositions into their own course design and classroom practices (behavior); and (Level 4) the extent of their students' achievement of desired educational results stemming from these enhanced educational practices (results). During the first two years of the project, data was collected to assess Level 1- 3 outcomes. During year 2, Level 4 outcomes were also evaluated to assess changes in student engagement levels in classes taught by program participants. This summer, ten participants, five in-service and five pre-service teachers, participated in the program. Two of the in-service teachers and two of the pre-service teacher participants in year one also participated in year two. Therefore, interviews that are more detailed were conducted with these participants to better understand the impact of the program on their classroom practices and student engagement. Data collected included the following measures:

- Pre- and Post-program classroom observation and lesson plan evaluation [13], [14]
- Post-program individual interview [15], [16]
- Mid-academic year interview
- Academic year classroom observations and lesson plan evaluation

During the final week of the summer program, an external evaluator conducted individual interviews with each of the in-service and pre-service teacher participants. Each interview lasted approximately 30 minutes and was semi-structured to ensure coverage of the essential topics while affording sufficient flexibility to probe individual experiences of the program. The in-service teachers were interviewed again near the end of their first semester following the summer program to capture information about how they have implemented new teaching practices in the classroom. In addition, the repeat participants were given a more in depth interview near the end of the summer to collect additional data on how participating another year has influenced their teaching philosophy.

Results

In-Service Teachers

From the pre- and post-program observations, it was evident the program influenced the teachers' thinking towards classroom practices. Through recorded classes and lesson plan evaluation, the teachers exhibited increased uses of the engineering design process and active learning strategies. Students were more engaged in collaboration and design oriented projects. The teachers also used more inquiry-based instruction for promoting higher thinking during class activities.

From the results of the interviews, we determined the participants' average teaching philosophy had undergone a pedagogical shift towards a more design process approach. Teachers self-reported an increase in using a design process and allowing the students to have more control over the learning process. The teachers reported an increased level in student interest and engagement with the classroom activities. Some of the comments from the interviews are as follows:

- "I now have new ideas about how to teach some biology lessons. I learned a better way to engage students with constructing protein models."
- "In the future I will give my students more freedom to direct their own learning."

- "I learned to ask my students much broader questions. This will allow my students to work through the different steps of the engineering design process without me giving them the answer."
- "The students loved the activity and seem to be engaged much more than usual."

These comments from the in-service teachers demonstrate the effectiveness of the program and how the research experience is fundamentally shifting their thinking about teaching practices. This is also evident in how all the in-service teachers submitted lessons to the *teachengineering.org* website. This database is a collection of classroom-tested activities that undergo a rigorous review process for engineering-based lessons.

Another theme that emerged from the data was how the repeat participants served as mentors or "coaches" to the new participants. This was incredibly valuable in helping the new participants understand how the experience gained in the summer can translate to increased student engagement during the school year. Some of the new participants commented about how, "It was helpful having previous participants in the program. This allows us to engage in the material more quickly and have a better understanding of the research process." Other comments were, "Previous participants helped me stay calm and understand that issues and goals would become clearer as the program progresses", and "having past participants helped us organize our time more efficiently."

Pre-Service Teachers

As part of the data collection, interviews with the pre-service teachers occurred during the last week of the program. A few of the common themes are listed below:

- The experience gave the pre-service teachers a perspective on student learning they have not been exposed to before.
- The experience will change the way they produce classroom assignment and create lesson plans when they do student teaching.
- Working with a practicing teacher was very rewarding. They were able to help the pre-service teachers understand what some of the ways engineering design and active learning may look like in the classroom.
- This experience opened up other opportunities for the pre-service teachers to engage with the local educational community. Two of the pre-service participants connected with a local middle school to offer weekly engineering design challenges for several classrooms.

Conclusions

The results indicate both the in-service and pre-service teachers are immersed in an extremely beneficial experience. They are gaining valuable knowledge about research and best practices in active learning. They are also learning about the practical applications of engineering and design, and how the research process can be used to deliver their existing content. In addition to gaining knowledge and skills, it is apparent the participants enjoyed the program and the collaborative learning environment it provided. The researchers will use existing data to re-evaluate the program and use participant comments to improve the experience over the last year of the grant period.

References

[1] United State Census Bureau. "2010 Census Urban and Rural Classification and Urban Area Criteria". Retrieved from https://www.census.gov/geo/reference/ua/urban-rural-2010.html on October 4, 2017.

[2] National Governors Association Center for Best Practices (NGACBP). "Common Core State Standards." Washington, DC: Author. Retrieved from http://www.corestandards.org on September 22, 2017.

[3] NGSS Lead States. (2013). Next generation science standards: For states, by states. Washington, DC: The National Academies Press.

[4] J. Ravitz, "Beyond Changing Culture in Small High Schools: Reform Models and Changing Instruction With Project-based Learning," *Peabody Journal of Education*, vol. 85, pp. 290-312, 2010.

[5] Ignite (formerly Industry Initiatives for Science and Math Education [IISME]). Retrieved from http://www.igniteducation.org/about/impact/ on October 27, 2017.

[6] J. Dubner, S. Silverstein, N. Carey, J. Frechtling, T. Busch-Johnsen, J. Han, G. Ordway, N. Hutchison, J. Lanza, J. Winter, J. Miller, P. Ohme, J. Rayford, K. Weisbaum, K. Storm, and E. Zounar, "Evaluating Science Research Experience For Teachers Programs and Their Effects on Student Interest and Academic Performance: A Preliminary Report of an Ongoing Collaborative Study by Eight Programs.", *MRS Proceedings*, 684, GG3.6 doi:10.1557/PROC-684-GG3.6, 2001.

[7] A. M. Farrell, "What Teachers Can Learn From Industry Internships." *Educational Leadership*, pp. 38-39, March 1992.

[8] S. Silverstein, J. Dubner, J. Miller, S. Glied, and J. Loike, "Teachers' Participation in Research Programs Improves Their Students' Achievement in Science," *Science*, vol. 326, pp. 440-442, 2009.

[9] B. D. Bowen, A. Kallmeyer, and H. Erickson, (2017). "Research Experiences for Teachers in Precision Agriculture and Sustainability," *National Science Foundation Engineering Education and Centers PI Conference, Arlington, VA, USA, October 29-31, 2017*. (Poster Presentation).

[10] B. D. Bowen, A. Kallmeyer, and H. Erickson, "Research Experiences for Teachers in Precision Agriculture and Sustainability," *Annual Proceedings of the American Society for Engineering Education, Columbus, OH, USA, June 25-28, 2017*. (Poster Presentation).

[11] B. D. Bowen, "Educators in Industry: Using Teacher Externships as a Professional Development Models in STEM Education," *Annual Proceedings of the American Society for Engineering Education, New Orleans, LA, USA, June 26-29, 2016*. (Poster Presentation).

[12] D. L. Kirkpatrick and J. D. Kirkpatrick, (2006). *Evaluating Training Programs: The Four Levels, 3rd ed*. San Francisco, CA: Berrett-Koehler Publishers, Inc., 2006.

[13] B. D. Bowen, "Measuring teacher effectiveness when comparing alternatively and traditionally licensed high school technology education teachers in North Carolina," *Journal of Technology Education*, vol. 25(1), pp. 80-98, 2013.

[14] G. K. Colvin, K. B. Flannery, G. Sugai, and J. Monegan, "Using observational data to provide performance feedback to teachers: A high school case study," *Preventing School Failure*, vol. 53(2), pp. 95-104, 2009.

[15] B. D. Bowen, “Teachers in Industry: Measuring the Impact of a K-12 Teacher Internship Program,” *Annual Proceedings of the American Society for Engineering Education, Atlanta, GA, USA, June 23-26, 2013.*
[16] B. D. Bowen, “K-12 Teacher Internships: Professional Development in the Engineering Design Process and STEM Learning,” *Annual Proceedings of the American Society for Engineering Education, Indianapolis, IN, USA, June 15-18, 2014*. (Poster Presentation).