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Research Experiences for Teachers in Precision Agriculture and Sustainability

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Research Experiences for Teachers: Engineering in Precision Agriculture and Sustainability for Rural STEM Educators

Abstract

Over the past year, 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, accompanied by several professional learning workshops throughout the school year, rural middle and high school mathematics and science teachers engage in a research program within the College of Engineering. The main goal of the program is for teachers to develop an in-depth understanding of how research principles, engineering applications, and the engineering design process (EDP) can enhance the delivery of instruction in their content area through standards-based instruction. The intent is to create a pedagogical shift in how the teacher approaches lesson plan design creating more meaningful, engaging, and authentic learning experiences for their students. A unique aspect of this program is the focus on rural teachers. In the upper Midwest, the majority of school systems have a rural classification. To create the largest possible impact in a rural community, this program selected teacher participants who were the only math or science teacher in their school building. In addition, pre-service teachers work alongside in-service teachers majoring in mathematics education or science education. This provides a valuable experience for both the in-service and pre-service teachers, as they can engage in the research process collaboratively, strengthening their knowledge and understanding of the learning outcomes. The research design includes both qualitative and quantitative methods to measure the impact of the program on the teachers' understanding of engineering design and any shifts in classroom practices. Having completed the first year of the program, the researchers have preliminary data to determine the effectiveness of the program as well as teacher-reported outcomes. Initial results show the program provided a valuable experience for the teachers' and provided significant knowledge and skills to improve their lesson plan design process. Evidence also suggests there was a positive impact to the pre-service teachers in regards to how they approach lesson planning and student teaching. This paper provides more detail about the program description, intended goals and outcomes, preliminary data and results, conclusions, and the next steps for program improvement.

Introduction

The teachers recruited for this RET program are referred to as "solitary STEM teachers" in rural North Dakota (ND) and western Minnesota (MN). This definition is due to these teachers being the only mathematics or science teacher in their school building. With 99.7% of the state categorized as rural, North Dakota has the fourth-largest percentage of rural area by state while Minnesota's western portion, consisting of the Northwest Valley and Southwest Corn Belt regions, is among the most rural of the state, consisting of only 8.6% of Minnesota's population[1]. It is common for schools to be separated by 30-40 miles or more across rural ND and MN. 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 significance 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 types of classes per day and only one prep 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[2,3,4]. During the RET program, teachers connect to STEM education by working with a strength of rural students, NDSU, and the 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 will include 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 will have enhanced content knowledge through their engineering and scientific research experience[6,7,8]. 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 on the campus of NDSU. The design team, engineering faculty members, and graduate student mentors from the College of Engineering interact with the participants throughout the course of 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 refreshers 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

Methodology

The evaluation design is based on Kirkpatrick and Kirkpatrick's four-level model for evaluating training programs, with measures being collected to address key features of participants' training experience and learning[9]. 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 year of the project, data was collected to assess Level 1- 3 outcomes. Level 4 outcomes will be developed and tracked in subsequent years to assess changes in student engagement and achievement levels in classes taught by program participants. Data collected included the following measures:

- Pre-program classroom observation and lesson plan evaluation[10,11]
- Pre-program online survey (Adapted from SWEPT and RET NSF Programs)
- End-of-program online survey (Adapted from SWEPT and RET NSF Programs)
- Post-program individual interview[12]
- Mid-academic year interview
- Academic year classroom observation and lesson plan evaluation (in progress)

Results

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. Some of the most common themes that emerged from the interviews with the in-service teachers are listed below:

- I really liked the engineering design process (EDP) exercise in week one and will plan to use something similar in my classroom (multiple comments).
- The importance of the mindset to always improve - no matter what you're doing, you can always do better.
- I want to incorporate more active learning strategies and project-based work to stimulate thinking and how to apply the concepts. Students will learn better if they are more engaged. It also decreases classroom management issues.
- I liked the problem solving and hands-on research. I want to let my students struggle more so they experience the joys and frustrations of the learning and discovery process.
- I have a renewed sense of the importance of the connection between learning and real life experiences, examples, and hands-on work.
- It was a challenge being immersed in the EDP, but I learned a lot from it. I am still trying to figure out how best to apply it in the classroom, but at least I now have some new ideas to test out.
- I learned to appreciate the process more and not just value successful results. I will give kids more credit to acknowledge the work they have done and the progress they have made.

- I will attempt to teach some things in larger chunks – integrating 5 or 6 related concepts – to show real world applications and provide more challenging problems that lead to deeper learning.
- I will use more active-learning concepts and not just focus on preparing students for standardized tests. This will help hold their attention and enable them to use their knowledge more effectively.
- We were exposed to many new technologies and resources that I would like to implement in the classroom (multiple comments). Some participants particularly liked the Kennedy Space Center chatroom and the teachengineering.org website.
- I will develop lessons that incorporate the EDP so students can develop skills that help them adapt to challenging problems and environments. Realizing that making mistakes, remaining patient, being persistent and seeking support are all part of the learning process.

As part of 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:

- This experience gave me a perspective on student learning that I have not been exposed to before
- This will change the way I will create lesson plans when I do my student teaching
- I was great working with a practicing teacher. They were able to help me understand what some of this may look like in the classroom

In addition to the interviews, surveys were administered to corroborate the results of the interviews in order to provide another measure for achievement of program outcomes. The pre-program survey measured self-reported frequencies of teacher practices from the previous year. This captures the participants' current teaching practices. The post-program survey measures self-reported frequencies of intended teacher behaviors for the upcoming school year. This captures what the teachers plan on doing in the upcoming school year. By taking the difference between the response of the pre- and post-survey, a value can be placed on the teacher's perceived value of the summer experience. Although there is not a sufficient sample size to conduct tests of statistical significance, the changes from pre- to post-test responses were substantial in the desired direction for the RET program's outcomes. The outcomes with the largest difference from the pre- and post-program surveys are reported in Tables 1 and 2. Table 1 reports on the teacher behavior and student structure in the classroom while Table 2 reports on lesson plan design focused on the engineering design process. A complete list of survey questions can be found in the research by Bowen[13]. The Likert scale for both tables is as follows: 1= never, 2 = 1-2 days a month, 3 = 3-4 days a month, 4 = 1-3 days a week, and 5 = almost every day.

Table 1.

Descriptive statistics comparing the pre- and post- online surveys for teacher behavior

Question	Pre-	Post-	Diff. (Post-Pre)
How often do you use (or plan to use) teacher-led lectures or discussion	4.40	3.80	-0.60[1]
How often do you use (or plan to use) student-led class discussions or presentations	2.20	3.20	1.00
How often do you use (or plan to use) inquiry-based activities	2.60	3.80	1.20
How often do you use (or plan to use) hands-on projects	2.80	3.60	0.80

[1]A negative value indicates a decrease in lecture, which aligns with program goals

Table 2.

Descriptive statistics comparing the pre- and post- online surveys for use of the engineering design process

Question	Pre-	Post-	Diff. (Post-Pre)
Have students defining a problem when given probable scenarios	2.60	3.60	1.00
Have students engage in various steps of the engineering design process	2.60	3.60	1.00
Have students communicate solutions to a problem in oral format	2.60	3.60	1.00
Have students communicate solutions to a problem by formal presentation	1.80	2.80	1.00
Have students reflect in a notebook or journal	1.80	3.00	1.20
Have students develop a design portfolio	1.20	2.40	1.20
Have students critique their own work	2.20	3.40	1.20
Have students critique other students' work	1.80	3.00	1.20
Have students rework solutions based on self or peer evaluation	1.40	3.40	2.00
Have students investigating possible career opportunities in your subject	1.40	2.40	1.00

The results from both tables show a substantial increase in the perceived importance of integrating student-focused active learning strategies and the engineering design process within classroom activities. The researchers felt that, considering a five point scale was used for this analysis, an increase of one point from pre- to post-surveys indicates the current RET program provides a significant benefit for the teachers.

Conclusions

The qualitative and quantitative data shows the participants are immersed in a research experience they feel is providing a substantial benefit for improving teaching effectiveness. The participants are gaining a significant amount of knowledge about engineering, research, and best practices in teaching that will allow them to create more impactful and transformative learning experiences for their students. Two of the most significant pieces of data that demonstrate the effectiveness of the program are the following teacher comments:

" I realized the importance of sustaining an ongoing commitment to incorporating these approaches in my classes by remaining engaged in a network of supportive colleagues, resources, and technologies that this project had enabled me to develop through NDSU, the RET program faculty, and my fellow program participants"

"I am already working with colleagues in my school district on expanding the use of these approaches in STEM education."

In addition to gaining knowledge and skills, it is apparent the participants enjoyed the program and the collaborative learning environment it provided. All of the participants said that, if possible, they would like to return to the program next year. The researchers will use existing data to re-evaluate the program and use participant comments to continuously improve the experience over the next two years of the grant period.

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