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Assessing the Need for Professional Development in Engineering Among Rural High School Science Teachers (Fundamental)

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Abstract

The Next Generation Science Standards (NGSS) for K-12 science instruction, released in 2013, were developed to address lagging student achievement and to improve scientific and technological literacy in the United States educational system. To accomplish this goal, the NGSS integrate standards on engineering design and application at an equal level with standards on scientific literacy.

So far, 18 states have formally adopted these standards, and others have begun to reevaluate existing standards in this light. The widespread adoption of the NGSS means that many science departments and teachers are now expected to develop and present instruction aligned to standards on engineering, a field in which most science teachers have minimal training.

To assess the possible need for engineering training in response to the NGSS, a survey was created and distributed to high school science teachers around the country. The first component of the survey asked about teachers' confidence in delivering engineering content, incorporating engineering applications, and answering students' engineering related questions in their classrooms. The second part asked how much teachers felt they would benefit from different aspects of professional development related to engineering.

Responses from 338 teachers indicated a general need and desire for engineering professional development, but this need was greater among teachers working in rural areas. Rural teachers expressed significantly less confidence in teaching engineering concepts and may perceive a greater benefit from professional development on engineering in the classroom. In addition, rural teachers indicated different priorities for professional development. Though teachers overall saw the greatest benefit from professional development on lesson plans that incorporate engineering, rural teachers indicated an even higher benefit just from having access to an expert teacher in engineering.

The lower confidence that we see may be indicative of the limited support, community, and resources available to teachers in rural areas who often have a more limited budget and fewer colleagues to collaborate with. These results make a strong case for the creation of a professional development program that targets science teachers in rural areas, helping them incorporate engineering into their classrooms and providing networking opportunities with trained engineering teachers.

Introduction

In recent years, there has been an increased national push to incorporate technology and engineering into math and science curricula. The National Academy of Engineering (NAE) (2010) recommended that relevant engineering learning goals be embedded within existing standards of other STEM disciplines rather than evolve as separate stand-alone engineering standards. The Framework for K-12 Science Education carefully articulated a framework for the integration called for by the NAE (National Research Council [NRC], 2012), by emphasizing the equal roles of scientific and engineering practices within the K-12 science classroom. Though the framework differentiates between the practice of engineering and that of science, it highlights the many similarities between the two and describes how the integration of both practices best prepares students for real life applications.

The Next Generation Science Standards (NGSS), developed between 2010 and 2013 (NGSS Lead States, 2013) built upon the NRC framework by describing specific expectations and competencies for each grade level that were developed to align with the framework. In the standards, engineering and technology are considered one of the four core ideas that the standards aim to cover. This means that engineering design is woven throughout the ensemble of standards on all scientific topics. So far, 18 states have formally adopted the NGSS into their educational system, and others have adopted new standards heavily based on the NGSS (National Association of State Boards of Education, 2016).

This inclusion of engineering into the standard science curriculum represents a new body of knowledge that has not typically been included in traditional K-12 education. Science educators in states that have adopted the NGSS now hold the responsibility of teaching their students to meet objectives in engineering design, while they themselves may have little to no training in the field. This creates a significant gap in content knowledge that concerns many science educators (Bybee, 2014). This knowledge gap creates an opportunity for professional development to aid teachers in building new expertise and curriculum that incorporates engineering concepts.

Many programs have been designed to provide this kind of professional development in the response to the new standards. For example, Custer, Ross and Daugherty (2014) worked with 21 science teachers to incorporate engineering concepts into science lessons. Moorhead, et. al. (2016) developed robotics activities aligned with the NGSS, and worked with math and science teachers to implement them in classrooms. Berry and DeRosa (2015) provided professional development in which teachers learned about engineering education and developed their own engineering curriculum aligned with the NGSS. Bowen (2014) described teacher internships that provide experience with the engineering design process, so that teachers bring more engineering knowledge to their science classrooms. These cases are just a sample of the programs that have been developed to help teachers integrate engineering into K-12 classrooms.

These programs have many positive effects, however there is a tendency to provide training primarily based on the need as subjectively perceived by academia or the researchers, rather than a thorough assessment of the need. Given the lack of clear standards for K-12 engineering education, Moore et al. (2009) developed a framework and set of principles for quality engineering education through extensive research. This framework is an important foundation, however as programs design training for educators, it is important to also assess the current abilities, confidence, and needs of potential participants in order to provide relevant and effective professional development.

Ames (2014) conducted research along these lines within the state of Utah to assess teacher preparedness for integrating engineering design into science curricula in response to the NGSS. This research found that science teachers did not feel prepared to teach engineering concepts, although they could easily recognize and differentiate science and engineering processes. Unfortunately, the implications for this work are limited since it only surveyed teachers within Utah, a state that did not adopt science standards with engineering concepts until 2015, after Ames' publication (Utah State Board of Education, 2015).

Not only is it important to directly understand the needs of educators, it is also important to recognize that professional development needs may significantly vary between teachers in different demographics. One such characteristic that has long influenced educational practice and research is the distinction between rural and urban schools. Rural schools face unique challenges because of their position within small and sometimes limited communities (Arnold, 2005). This has been a concern of educational researchers for decades as evidenced by the body of literature and practice focused on rural education (Sher, 1977), and continues to be a relevant consideration today.

This paper seeks to expand on the work done by Ames by presenting results from a similar study, while focusing on a particular demographic: secondary science teachers serving in rural communities. The authors surveyed over 300 secondary science educators across the country to assess their current confidence in presenting and addressing engineering related topics in their classroom, and the benefit they would anticipate from professional development in a variety of specific topics and categories. Responses were categorized by the population of the community around the respondent's school, and the responses of teachers in rural areas were compared with those in each other population category.

This research aims to contribute to the creation of targeted professional development programs that meet the expressed needs of secondary science educators as they prepare to implement engineering standards into their classrooms.

Methods

To better understand the need for professional development in engineering among science teachers, a survey was created based on the survey developed by Ames (2014), and made available to 2520 science teachers from 20 states around the US, including 7 states that have already adopted the NGSS. From this participant pool, 338 completed responses were received and analyzed.

Aside from a few introductory questions at the beginning and demographic questions at the end, the survey can be divided into 4 major sections. The first section (9 questions) asked about participants' confidence in delivering engineering related content in their science classrooms (e.g. "I feel confident being able to answer most of my student's engineering focused questions in a science class.") Participants responded on a 7-point Likert scale for 6 questions, and a 5-point Likert scale for the remaining 3 questions. Both scales ranged from “Disagree a great deal” to “Agree a great deal”, which was coded numerically as 1 through 7 respectively. Since the responses on the 5-point scale were embedded in the 7-point scale, the same numerical coding was used.

The second set of questions (9 questions) asked participants to rate aspects of professional development that they felt would benefit their ability to teach engineering concepts. This included aspects like “Training on the engineering design process” and “Content knowledge about engineering disciplines and the types of work they engage in.” Participants responded with a perceived level of benefit as either “none,” “low,” “medium,” or “high,” which was coded as 0 through 3, respectively.

The third section (17 questions) asked about teachers’ preparation and confidence to teach specific engineering concepts in their science classes. These questions were designed to target the principle of incorporating “important and developmentally appropriate mathematics, science, and technology knowledge and skills [in K-12 engineering education]” from *Engineering in K-12 Education* (NRC, 2009). These questions included concepts such as vector operations, equilibrium and Newton’s First Law, and elasticity and plasticity. Possible responses for each concept were “have no idea,” “confident,” or “prepared,” and were coded as 1, 2, and 3 respectively.

The final section of the survey (4 questions) asked about the benefit teachers felt they would receive from professional development in the specific engineering topics addressed in section three. Responses were either “low,” “medium,” or “high”, and were also coded as 1, 2, or 3.

Participants were categorized based on a self-report of the population of the area in which they teach. Four population brackets were used, based on standard US census categorization (United States Census Bureau, 2016), ranging from “Rural population area; < 2500 people” to “Urbanized area; 50,000 or more.” For the purposes of this paper, rural teachers are defined as those who teach in area with a permanent population less than 2500. In the current sample, 42 participants, or 12% of the total sample, are considered rural teachers.

All statistical analysis were performed in R.

Results

Confidence in Teaching Engineering

We first compare the responses of rural teachers to those in other population categories. On 25 out of the 26 questions in sections one and three that assess confidence to teach engineering related topics, rural teachers responded with significantly lower levels of confidence than any other population demographic. A total score for engineering confidence in section one was generated by averaging responses on all section one questions, and a t-test was performed. The test found that the mean response for rural teachers was significantly lower than that of non-rural teachers, $t(53) = 2.32$, $p = 0.024$, (see Figure 1) although a comparable test yielded no significance when singling out any other population category. The same testing process was performed on section three, and the difference was again found to be significant $t(51) = 2.40$, $p = 0.020$ again only when comparing rural and non-rural teachers.

Perceived benefit of professional development

Sections two and four asked 13 questions assessing the participants' level of potential benefit from professional development. Rural teachers responded with the highest levels of perceived benefit of any population group on 10 of these 13 questions. Responses from sections two and four were averaged for each section (see Figure 1), and analyzed with a t-test, but the means for rural teachers were not found to be significantly different from those of other teachers.

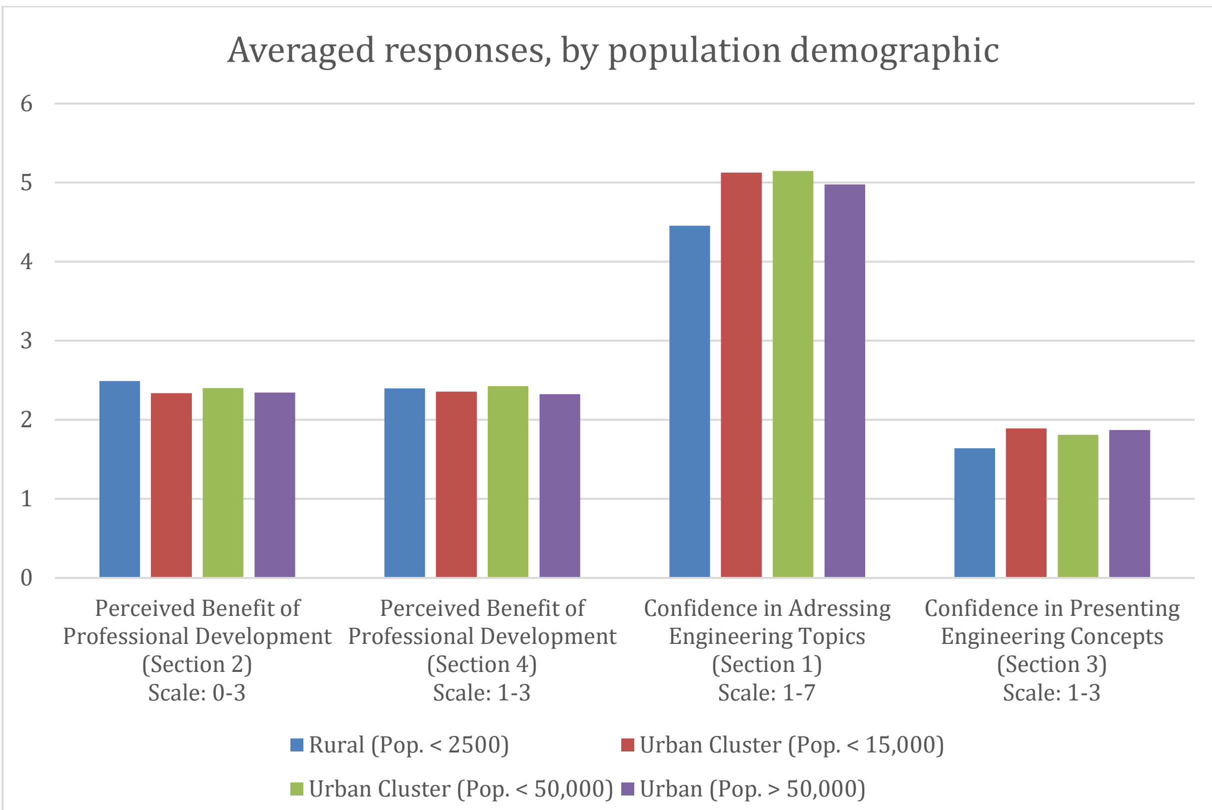

Figure 1 *- The blue bars on the left of each cluster represent teachers in rural areas, and show that they express significantly lower confidence in addressing engineering related ideas in their classroom, but anticipate a slightly greater benefit from professional development.*

Specific areas of need

Having established that teachers in rural settings have less confidence in their preparation to teach engineering, and may anticipate slightly greater benefits from receiving professional development in this area, it is clear that this is a worthwhile population to target for professional development programs. However, the question remains, how should those programs be tailored to best match the needs of teachers in rural areas? To answer this, we identify notable areas of low confidence and high benefit from responses of rural teachers to the survey.

From section one, the area of least confidence among rural teachers was their ability to implement the NGSS in their classrooms, as measured by agreement to the following statement: “I feel confident enough in my foundational engineering knowledge levels to be able to develop and deliver engineering content focused on applications that satisfy engineering standards in the Next Generation Science Standards (NGSS).” (M = 3.8 on a 7 point scale, centered at 4) This weakness was reflected across all demographic categories, but was most prominent among rural teachers.

The area of greatest benefit identified in section two was the opportunity to have ready access to one or more expert teachers in the field of engineering. The importance of this benefit was unique to rural teachers since it ranked as a near average benefit for respondents overall, and as the lowest benefit for teachers in urban settings, as can be seen in the data presented in Table 1. This may reflect the limited access to resources and industry involvement that constrain rural teachers.

	Benefit from access to expert engineering educators	**Average benefit from items in section 2**
Rural Area	2.63	2.49
Small Urban Cluster	2.32	2.34
Large Urban Cluster	2.43	2.40
Urbanized area	2.20	2.34
All responses	2.33	2.37

Table 1 *- The perceived benefit of having access to expert teachers in engineering by demographic category compared with the average benefit perceived for all items included in section two. Benefit is assessed on a three-point scale from one to three.*

In the third section, addressing specific concepts used in engineering, rural teachers showed the least confidence in teaching about the mechanics concepts of bending, shear, and the deflection of beams (M = 1.24 on a one to three point scale). This means that more than three quarters of rural science teachers indicated they had “no idea” how to develop or teach these engineering tools in their classes.

The final section asked about the benefit of professional development in engineering statics, mechanics, materials, and lesson planning. Rural teachers expressed a significantly higher benefit from professional development that taught engineering focused lesson planning than professional development focused on specific engineering concepts ($t(41) = 3.08$, $p = 0.004$).

Conclusions

The differences between the needs of rural and urban teachers described here motivate further research to understand what training will be most relevant and beneficial to each demographic of teachers preparing to incorporate engineering principles into their science classroom.

This research also lays the groundwork for the creation and improvement of professional development programs that serve rural science educators. The data suggest that the population of science teachers in rural communities are less confident and less prepared to teach their students about engineering design than their urban and suburban counterparts. This represents an opportunity for the engineering community to reach out and provide training, but it is important that the pillars of that training be grounded in the specific needs of those it serves.

For science teachers serving rural communities, their specific needs include practical resources in lesson planning to help them meet the new standards they are now faced with implementing. They also need access to experienced engineering educators who can serve as a reference as science teachers build up their own expertise around engineering in the science classroom. Finally, rural educators admit to having minimal knowledge about the engineering principles their students may be asked to apply, and recognize the benefit of increasing their content knowledge in engineering.

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