Changes in Teacher Self-Efficacy Through Engagement in an Engineering Professional Development Partnership (RTP)

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Abstract

K-12 teachers serve a critical role in their students' development of interest in engineering, especially as engineering content is emphasized in curriculum standards. However, teachers may not be comfortable teaching engineering in their classrooms as it can require a different set of skills from which they are trained. Professional development activities focused on engineering content can help teachers feel more comfortable teaching the subject in their classrooms and can increase their knowledge of engineering and thus their engineering teaching self-efficacy. There are many different types of professional development activities teachers might experience, each one with a set of established best practices.

VT PEERS (Virginia Tech Partnering with Educators and Engineers in Rural Communities) is a program designed to provide recurrent hands-on engineering activities to middle school students in or near rural Appalachia. The project partners middle school teachers, university affiliates, and local industry partners throughout the state region to develop and implement engineering activities that align with state defined standards of learning (SOLs). Throughout this partnership, teachers co-facilitate engineering activities in their classrooms throughout the year with the other partners, and teachers have the opportunity to participate in a two-day collaborative workshop every year. VT PEERS held a workshop during the summer of 2019, after the second year of the partnership, to discuss the successes and challenges experienced throughout the program. Three focus groups, one for each grade level involved (grades 6-8), were held during the summit for teachers and industry partners to discuss their experiences. None of the teachers involved in the partnership have formal training in engineering. The transcripts of these focus groups were the focus of the exploratory qualitative data analyses to answer the following research question:

> How do middle-school teachers develop teaching engineering self-efficacy through professional development activities?

Deductive coding of the focus group transcripts was completed using the four sources of self-efficacy: mastery experience, vicarious experience, verbal persuasion and physiological states. The analysis revealed that vicarious experiences can be particularly valuable to increasing teachers' teaching engineering self-efficacy. For example, teachers valued the ability to play the role of a student in an engineering lesson and being able to share ideas about teaching engineering lessons with other teachers. This information can be useful to develop engineering-focused professional development activities for teachers. Additionally, as teachers gather information from their teaching engineering vicarious experiences, they can inform their own teaching practices and practice reflective teaching as they teach lessons.

Introduction

Within the last decade, there has been a push for engineering to be taught in the K-12 school system. Integrating engineering into the classroom is especially important due to the expressed need for engineers from organizations such as the National Academy of Engineering and from reports like PCAST that predicted a need for one million more STEM professionals by 2020 [1], [2]. In addition to this expressed need, research shows that students begin making career choices as early as, if not before, high school, so it is important they gain an understanding of different career fields [3]. The engineering field is sometimes perceived to be particularly challenging, especially without any exposure to engineering. Various curricula and learning experiences have been encouraged nationally to help students transition to engineers. In a 2010 report from the National Academy of Engineering, the integration of engineering into existing educational math and science standards was encouraged rather than creating a new, separate engineering curricula [1]. For example, the Next Generation Science Standards focus on students understanding science and engineering practices [4]. There are also many programs that focus on engineering in K-12, such as Project Lead the Way, that allow students to experience the engineering design process and learn more about the field [5].

In order to successfully achieve this integration, it is important that K-12 teachers are able and prepared to teach engineering. However, engineering may not be a subject teachers are comfortable teaching in their classrooms because it requires a different set of skills from which they may be trained [5]. Professional development focused on engineering has been identified as being critical to increase teachers' teaching-engineering self-efficacy and overall comfort with teaching engineering in their classrooms [5], [6]. Professional development is defined in many ways, ranging from anything that can increase teacher performance to communities of learning among teachers [7]. Some research suggests that professional development should have five critical features: content focus, active learning, coherence, duration, and collective participation [7]. Therefore, it is imperative that teachers who are new to teaching engineering are involved in on-going professional development to help them develop their skills and self-efficacy. Through professional development, self-efficacy can change over time and can develop from different sources, however, not many studies focus on how the sources of self-efficacy form, develop, and change over-time [8]. The purpose of this qualitative study is to understand how teachers develop teaching engineering self-efficacy over-time through professional development using the self-efficacy framework as proposed by Bandura [8].

Theoretical Framework

Self-efficacy as described by Bandura was chosen as the framework for this study. Self-efficacy, a construct of Social Cognitive Theory, is based on the idea that performing certain procedures creates and strengthens expectations of personal efficacy [9], [10]. The four sources of self-efficacy have been defined as mastery experiences, vicarious experience, verbal persuasion, and physiological states [9], [11].

Table 1. Definitions of the sources of self-efficacy as provided by Bandura (1977).

Source	**Definition**
Mastery experience	Self-efficacy based on success completing a task
Vicarious experience	Expectations of success based on observing others completing tasks
Verbal persuasion	Belief in the ability to be successful based on suggestion from others
Physiological states	The physical reaction to an experience influencing the perception of ability to be successful

Many studies in engineering education have used self-efficacy as a framework. Those studies with a focus on K-12 teachers include the development of a scale to measure self-efficacy the examination of engineering teacher self-efficacy of K-12 teachers, and the effects of teacher involvement in different programs on their engineering-teaching self-efficacy [6], [11]–[13].

Literature Review

Self-efficacy in engineering education has been used to study engineering students and teachers at various education levels. In K-12, there have been a number of instruments developed to measure teacher self-efficacy. One of the first instruments developed by Riggs and Enochs [8] was said to "lead to further understanding of teacher behavior" and a deeper understanding of science teaching efficacy (p. 633). This understanding of teacher behavior can help create strategies for in-service professional development for elementary school teachers [12]. This first content-specific measure of self-efficacy led to the development of other content-specific self-efficacy instruments for subjects such as math and chemistry for K-12 teachers [13]. More recently, an instrument for measuring teaching engineering self-efficacy was developed to contribute to the understanding of teachers' behavior in classes where they teach engineering [13].

These scales can help those who work with teachers understand teacher behavior, particularly if teachers have low self-efficacy which can often be the case when they teach engineering. Teachers may have a high personal teaching efficacy meaning that they believe they can implement any lesson or module in their classrooms [14]. However, when it comes to teaching engineering, some researchers have found that teachers have low engineering self-efficacy and low engineering teacher efficacy [15]. This low engineering self-efficacy could be due to the discomfort teachers have when teaching the subject because it is not the subject in which they are formally trained [16], [17].

To increase teachers' engineering teaching self-efficacy, various experiences and professional development around engineering have been shown to be effective for teachers who teach various grade levels. There are 5 principles of professional development that define the effectiveness of the program: content focus, active learning, coherence, duration, and collective participation [7].

For example, professional development for elementary school teachers has been shown to increase their teaching engineering self-efficacy as well as their understanding of the field of engineering [18]. Additionally, a professional development model where the pre-service teachers got to play the role of the students in an engineering lesson increased other forms of teacher self-efficacy such as engineering pedagogical content knowledge and engineering engagement, which led to an overall increase in teaching engineering self-efficacy [19]. Other studies have also found that the integration of robotics projects into various disciplines increased the involved teachers' self-efficacy around the use of robotics into middle school curriculum [20]. Immersing teachers in laboratory settings and research experiences has also been effective at increasing high school teachers' self-efficacy in content areas such as nanotechnology [21], as well as shifting their perceptions of engineering as a field [22]. These examples of professional development activities embody the five principles of professional development and ultimately demonstrated the effectiveness of professional development at increasing teachers' engineering teaching self-efficacy.

Many of these studies mentioned relied on quantitative analysis, and few of them were longitudinal, capturing the change in teacher self-efficacy at one moment in time. Additionally, many of these studies focus primarily on different types of self-efficacy (e.g. engineering pedagogical content knowledge) but not necessarily the experiences of the sources of these types of self-efficacy.

Methods

Context

VT PEERS (Virginia Tech Partnering with Educators and Engineers in Rural Communities) is a program designed to "provide recurrent hands-on engineering activities to middle school students in rural communities in or near Appalachia" [23]. The project partners middle school teachers, university affiliates, and local industry partners throughout the state region to develop and implement engineering activities that align with state defined standards of learning (SOLs). Throughout this partnership, teachers co-facilitate engineering activities in their classrooms throughout the year with the other partners, and teachers have the opportunity to participate in a two-day collaborative workshop every year. VT PEERS held a workshop during the summer of 2019, after the second year of the partnership, to discuss the successes and challenges experienced throughout the program.

Data Collection

Data for this analysis was collected from focus groups, each lasting about one hour, with the teachers and industry partners involved in the VT PEERS partnership. There were three focus groups, totaling 16 teachers, for each grade level of teachers involved: 6^{th}, 7^{th}, and 8^{th}. Though each focus group was defined this way, it is possible that participants participated in a focus group based on their own position in teaching (i.e. they taught one grade level in the previous year but are now teaching a different grade level, or they teach multiple grade levels). The focus groups were led by members of the VT PEERS team and the conversations were recorded and later transcribed.

Questions asked in the focus groups were primarily focused on the experiences teachers and industry partners had while teaching engineering. For example, questions asking who the key players in the partnership were and why, and what worked well and what didn't were used to start conversations among the groups. The interviewers followed-up on responses where appropriate. While the questions were not necessarily centered on self-efficacy, many teachers talked about experiences related to self-efficacy and how they felt their engineering-teaching self-efficacy changed during their participation in the partnership.

Participants

Participants for this study were middle school science teachers (6^{th}, 7^{th}, and 8^{th} grade) at rural schools in Southwest Virginia. The teachers were active partners in the program, with a range of teaching experience from one to 42 years. At the time of the 2019 summit, the 6^{th} grade teachers had been involved in the partnership for two years, while the 7^{th} grade teachers had been involved for one and the 8^{th} grade teachers were just entering the partnership. Though the 8^{th} grade teachers were new to the partnership, their perspectives and contributions were important, and this experience was part of their integration into the VT PEERS community. The majority of the teachers had no formal engineering training.

Data Analysis

Focus group transcripts, specifically the responses from the teachers, were analyzed qualitatively using the four sources of self-efficacy as codes in a first round of deductive coding: mastery experience, vicarious experience, verbal persuasion and physiological arousal [23]. After this first round, the coded portions were then grouped into common themes [24]. Microsoft Excel was used to code portions of the transcripts. For the purposes of this paper, the codes for vicarious experience and the corresponding themes will be presented and discussed.

Research Quality

To ensure quality of the data analysis, we used interrater agreement [24] where researchers worked together to come to a consensus on the initial coded portions of each transcript. This was done to mitigate the effects of bias in the interpretation of the transcripts, and also to ensure that the process of coding was regularly discussed and reviewed by the coders [25]. A common file was used to document final codes. Additionally, as the transcripts were coded, updates were shared with other researchers involved in the project for feedback and assistance with interpretation. Having multiple focus groups transcripts from the same program also allows for data validity through triangulation of data.

Results

As previously stated, the focus of the results and discussion will be on the portions of the transcripts coded for vicarious experience and the corresponding themes. Vicarious experience was chosen as the focus for this paper because of how teachers seemed to express the importance of vicarious experiences and how these experiences contributed to their comfort with teaching engineering activities. The table below describes the themes for vicarious experiences and provides an example of a quote for that theme.

Table 2. Themes for units of data coded as vicarious experience.

Theme	Description
New Ideas	Talking to other teachers or partners for ideas to bring into the classroom
Need for experiences	Expressing a need for more demonstrations
Support	Receiving support from other partners
Student roles	Taking on the role of students learning something new
Seeing others	Observing other people do engineering activities

New Ideas

This theme was common across all grade levels' transcripts. The primary focus of this theme is to capture the experiences teachers had when they spoke to other teachers or partners to get new ideas for engineering activities they could also use in their classrooms. For example, one teacher expressed how rejuvenating it was to get new ideas in their classroom from participating in this partnership and having VT PEERS as a resource:

> "After you've been teaching so long, sometimes you lose track of bringing in new ideas. So, this has been rejuvenating fact for me to make me look at, "Oh hey, I need to do more this and more ideas." That's been a great part for me, because it brings me back to life a little bit."

Another teacher expressed the value in various moments where they were able to get new ideas:

> "To me, I'll just say that these informal, formal moments where we're actually making connections with other people who are not necessarily the same five people in our department or in our school and we're able to hear other people's ideas, I think that's where the value really is."

This theme in the data captures teachers sharing new ideas with each other, and also getting ideas from the VT PEERS team, which they found to invigorate and bring excitement into their classrooms. Additionally, hearing new ideas from other teachers and hearing about the success other teachers had as they discussed ideas gave them the confidence that they could try new things in their classrooms. Bringing these new ideas into their classrooms was also perhaps made easier by the support of other teachers and the partnership.

Need for Experience

This sub-code was only identified in the 7th grade teachers' transcripts. Many of the teachers expressed a need to see the engineering activity performed ahead of time for them to fully understand it. For example, one teacher succinctly said, "We just want to know how the activity goes, what we have to look out for." This teacher then expressed that they can figure out the logistics of their classroom and which SOLs will be covered, but having the initial demonstration can help them prepare for the activity. The need for demonstration from the experts is something that these teachers felt was important to them and possibly the development of their self-efficacy regarding teaching engineering, but was something they felt was lacking in their initial introduction to the VT PEERS program.

Support

This sub-code was also only identified in the 7th grade teachers' transcripts. In this specific instance, the teachers were discussing how helpful it was to have support from some of the VT PEERS team. For example, one teacher indicated being confused initially by the lesson plan for an engineering activity and indicated that It looked very complicated. However, they gained a better understanding of the lesson after a VT PEERS team member taught one of the engineering lessons: "But when you came in and you did it, it was like oh, okay. I know what I'm doing now." This indication of confidence through getting help and seeing the lesson is an indicator of the development of self-efficacy through vicarious experience.

Student Roles

This sub-code was identified in all grade levels' transcripts. One teacher indicated the rarity of being able to be the in the role of a student as a teacher:

> "[…] and it gave me a chance to watch without having to do at the same time. I got to be the observer and make my notes, as well as the kids enjoying the project. You don't get that very often in teaching, to be the observer."

This sort of experience of playing the role of a student while learning how to teach an engineering lesson supports the idea that self-efficacy is built through watching the example of others and learning. For teachers to develop self-efficacy, they must reverse their roles and become students.

Seeing Others

This sub-code was identified only in the 6th grade teachers' transcripts. One teacher discussed their motivation to join the partnership based on observing an engineering activity happening across the cafeteria:

> "I was jealous because the first year, they were next to me. They had all these people and you all went into the cafeteria and called us over and stuff. I had the 6th grades, next time I saw them, they loved it. There was no prompting on my part."

This teacher was able to see that others were successfully leading engineering activities and that their students loved it.

Discussion

The purpose of this analysis is to understand how teachers develop teaching engineering self-efficacy over-time through professional development. One important source of teaching engineering self-efficacy is vicarious experience, which is developed through seeing others completing a task. Additionally, vicarious experience aligns with the principles of professional development as discussed by Desimone [7], particularly the principles of content focus, active learning, and collective participation. When teachers had vicarious experiences, they thought they were incredibly valuable and influential to getting them to try new things in their classrooms but felt like they suffered when they were not able to play the role of a student and observe an engineering lesson. They also found that having support from other teachers, either within their grade level, school, or through the partnership was incredibly valuable. Additionally, different types of self-efficacy sources are needed at different stages of self-efficacy development. Specifically, vicarious experiences are important early on in the development of engineering teaching self-efficacy, which was something discussed more by 7th grade teachers who had only been involved for one year of the partnership. These findings about vicarious experience as a source of teaching engineering self-efficacy also align with the previously discussed research about experiences that allow teachers to be students when participating in professional development [11].

Identifying the sources of self-efficacy in professional development as teachers develop their teaching engineering self-efficacy is particularly beneficial for understanding how the sources may interact. These results suggest that vicarious experiences can be a pre-cursor to the other sources, such as mastery experiences, and can help mitigate the effects of negative physiological feedback, such as stress about not knowing what to do when leading an engineering lesson or activity. Understanding this development can help increase teachers' teaching engineering self-efficacy, which can ultimately benefit their students and may even encourage some students to pursue engineering.

Implications for Practice and Building Teacher Expertise

For anyone involved in engineering professional development for K-12 teachers, this research is particularly important for understanding how to develop effective professional development. Firstly, understanding that teachers of all levels of experience have different levels of self-efficacy is important. It is important to also recognize that a teacher's teaching engineering self-efficacy may not be as high as their personal teaching self-efficacy, and professional development specifically focused on engineering content can help increase their teaching engineering self-efficacy. It is also important to understand the sources of self-efficacy and how these sources can interact to build self-efficacy. While it may be assumed that mastery experiences should be the focus of professional development, giving teachers the ability to first be students and watch someone else lead an activity can be a valuable experience, particularly because many teachers may not be trained in engineering nor comfortable with teaching engineering [5].

Aligned with developing teachers' teaching engineering self-efficacy through focusing on vicarious experience in professional development is the concept of reflective teaching [25]. As teachers hear about or see the experiences of other teachers teaching engineering, or as they become students experiencing an engineering lesson, they are able to gather information that can ultimately inform their own practices of teaching engineering [26]. While teachers might have a high personal teaching self-efficacy which allows them to draw on information about their students and their classroom, having information and knowledge as shared by other teachers can be extremely valuable, particularly as they have to make quick decisions in their classrooms to lead an engineering lesson [14], [26]. Being able to reflect in the moment and make these decisions based on their self-efficacy as it develops from vicarious experiences may then also help build a log of mastery experiences, which will continue to build their teaching engineering self-efficacy. This log of experiences ultimately builds teachers' expertise not only as teachers, but as teachers who teach engineering. Emphasizing reflective practice in engineering related professional development, which is likely something teachers already do, can help them continue to build their teaching engineering self-efficacy and build their expertise as teachers.

Limitations and Future Research

Some limitations of this research are directly related to the data collection. For example, because there are multiple people involved in a focus group, there are many voices. Sometimes some voices can dominate a conversation and not all participants get a chance to contribute. Having many people involved also limits the depth to which the facilitators can follow a participant's response because they are trying to elicit many responses. Finally, the questions asked in these focus groups were not necessarily asked with self-efficacy in mind. However, having transcripts from multiple focus groups all discussing the same program provided an ability to triangulate our data and increase our data validity. Though this exploratory qualitative study was not approached with teacher self-efficacy as a primary focus, salient self-efficacy data were provided by the participants, allowing an opportunity to understand middle school teacher's teaching engineering self-efficacy, and how it developed over the course of this partnership.

Future research in this area of teaching engineering self-efficacy should continue and examine the longitudinal development of self-efficacy as teachers continue to teach engineering. Future research should also continue to explore the different sources of self-efficacy and how these sources interact as teachers participate in VT PEERS activities.

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