

A Blended Professional Development Model for Teachers to Learn, Implement, and Reflect on NGSS Practices

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Abstract

In this paper we describe a professional development project with secondary physics and physical science teachers. This professional development supported fifteen teachers in learning the newly adopted Next Generation Science Standards (NGSS) through integrating physical science content with engineering and engineering practices. Our professional development utilized best practices in both face-to-face and virtual meetings to engage teachers in learning, implementing, and reflecting on their practice through discussion, video sharing, and micro-teaching. This paper provides details of our approach, along with insights from the teacher participants. We also suggest improvements for future practice in professional development experiences similar to this one. This article may be of use to anyone in NGSS or NGSS-like states working with either pre- or in-service science teachers.

Introduction

The incorporation of engineering into science instruction is a vehicle to provide a real-world context for learning science and mathematics, which can help to make “school science” more relatable. Common arguments for the inclusion of engineering education in K-12 settings include providing and promoting: a real-world context for learning mathematics and science content, a context for developing problem-solving skills, the development of communication skills and teamwork, and a fun and hands-on setting to improve students’ attitudes toward STEM fields (Brophy, Klein, Portsmore, & Rogers, 2008; Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007; Koszalka, Wu, & Davidson, 2007). These arguments illustrate the potential for engineering education to make a significant and unique contribution to student learning, particularly for women and minorities (Brophy, Klein, Portsmore, & Rogers, 2008; National Research Council [NRC], 2012). The Next Generation Science Standards (NGSS) highlight the importance of incorporating K-12 engineering practices and performance expectations into science standards (NGSS Lead States, 2013). Integration of engineering into science standards requires a shift in current educational practices, as the majority of K-12 science teachers lack knowledge and experience of engineering and engineering education (Banilower et al., 2013; Cunningham & Carlsen, 2014).

As more states continue to adopt the NGSS and other standards that incorporate engineering into K-12 education, there is a critical need to provide practicing teachers with professional development. These professional development experiences must not only

support teachers' understanding of these standards, but also focus on changes in practice that are required in order to implement them (Cunningham & Carlsen, 2014). Calls through national reform documents highlight the integration of engineering into K-12 science standards as a mechanism to both improve the future of the STEM workforce and increase STEM literacy for all (NRC, 2012). Teachers in states like Michigan, which has recently adopted the performance expectations of the NGSS, require professional development in order to learn these new standards and develop a fundamental understanding of the field of engineering. This will allow teachers to help students relate science concepts to real-world issues using engineering.

The professional development described here was part of a state-funded grant to support and deepen in-service science teachers' content knowledge and pedagogical practices. At the time of funding, Michigan had recently adopted the NGSS performance expectations, which highlighted the need to support teachers in making a shift in their practice. Specifically, our work helped secondary physical science and physics teachers improve their understanding and use of inquiry-based and engineering-integrated instruction. The timing of this program was critical in helping our teachers transition from the previous state science standards to the NGSS. This transition is important, as these teachers will soon be expected to bring engineering practices into their science classrooms, but may lack knowledge related to engineering. Through our 18-month long professional development, we equipped teachers with tools and examples of engineering in physical science classrooms, focusing on the integration of these two areas. The work shared here describes our approach to addressing these issues in hopes of providing a framework for others to use in similar settings.

Description of Professional Development

Participants

A total of fifteen middle and high school teachers participated in our professional development over the course of eighteen months as part of a Michigan Title IIA(3) grant. These teachers from across the state applied for the professional development, and spots were filled on a first-come, first-served basis. All but one of these teachers taught a physical science or physics course at the time of the professional development; this last teacher was an industrial technology teacher, who had previously worked as a mechanical engineer. All fifteen teachers were instructing their students in the areas of energy, work, force, and motion, which we advertised as the science content focus of the professional development. Five of our teachers were currently teaching middle school, seven taught high school, and three taught across K-12 grades as the sole science teacher in their rural school. Generally, these teachers were experienced in the classroom; three had been teaching between 0-5 years, five between 5-10 years, 3 between 10-15 years, and three over 15 years of experience. These teachers came from eleven schools across ten school districts, four of which were considered high needs as determined by Michigan Department of Education. The majority of these districts represented rural schools with 50-75% of students eligible for

free and reduced lunch and less than 25% of the students were considered minority. For many of our teachers who taught in rural communities, they were either the only science teacher in their school or taught a wide variety of subjects due to the school's needs. Table 1 provides additional details about each of the districts' demographics.

Table 1 (Click on image to enlarge)

School Demographics from Eleven Partner Schools

School	District	Grades Taught	Size	% FRL	% Minority	Student Population
1	A	9-12	Rural	65.1%	15.1%	66
2	B**	9-12	Rural	46.7%	13.6%	315
3	C	6-8	Town	26.7%	15.6%	667
4*	D**	9-12	Suburb	54.9%	75.0%	557
5*	D**	6-8	Suburb	72.9%	76.4%	424
6	E	K-12	Rural	55.9%	3.7%	136
7	F	9-12	Town	63.0%	42.5%	381
8	G	7-12	Rural	60.0%	6.8%	219
9*	H	K-12	Rural	91.0%	71.1%	166
10*	I	K-12	Rural	56.2%	18.1%	276
11	J**	6-8	Town	42.1%	15.4%	492

* Indicates three teachers from this school participated
 ** Indicates high needs district
 * Indicates charter school

Professional Development Framework

Our approach to this professional development was guided by both Michigan's Title IIA(3) grant guidelines and our past experiences in working with physics and physical science teachers new to engineering (Dare, Ellis, & Roehrig, 2014). As teachers new to engineering often struggle to meaningfully integrate between science content and an engineering design challenge, we suggested three core components be included in professional development (Dare et al., 2014):

1. Ascertain knowledge about teacher beliefs related to engineering integration prior to the professional development
2. Foster discussions about what engineering integration in the classroom would look like
3. Spend time modeling the creation of instructional goals that include both physics and engineering content

These three components framed our overall approach to the professional development in addition to known best practices (e.g., Banilower, Heck, & Weiss et al., 2007; Capps, Crawford, & Conostas, 2012; Supovitz & Turner, 2000) to actively engage teachers in hands-on, engineering-integrated instruction. For instance, the literature on teacher learning and professional development calls for professional development to be sustained over time, as the duration of professional development is related to the depth of teacher change (Banilower, Heck, & Weiss, 2007; Supovitz & Turner, 2000). This is important for creating broad changes in overall classroom culture as opposed to small-scale changes in practice (Supovitz & Turner, 2000). For our project, we provided over 90 contact hours of professional development (a requirement of the Title IIA(3) guidelines) over the course of 18 months. Not only is the total number of contact hours important, but also the time span of the professional development experience (i.e. the number of months across which professional hours occur)

to allow for multiple cycles of presentation and reflection on practice (Blumenfeld, Soloway, Marx, Guzdial, & Palincsar, 1991; Garet, Porter, Desimone, Birman, & Yoon, 2001; Kubitskey, 2006).

Overview

We provided two one-week summer workshops and sustained support during the school year by creating a blended professional development program that utilized both face-to-face and online meetings (Table 2). As facilitators, we were concerned that the large geographical distances (up for 10 hours away) between ourselves and our teachers would make sustained professional development challenging, particularly once our teachers returned to their classrooms. To mitigate this, we provided academic year support virtually. This blended form of professional development has been gaining traction with other researchers and teacher educators as the ability to communicate virtually is becoming more user-friendly (Community for Advancing Discovery Research in Education, 2017). We designed the course of the project as follows: a one-week summer institute in Year 1 led by project staff, academic year follow-up in the form of virtual monthly group and individual coaching meetings, and another one-week summer institute in Year 2, in which teachers led the bulk of the activities. We started with learning the basics of engineering and engineering integration by engaging in example activities and lessons, which were scaffolded in complexity over our week-long workshop. This was followed by academic year coaching to help teachers reflect on their practice in a group setting. Additionally, individual meetings helped teachers reflect on a specific lesson or unit that they implemented and receive feedback from project staff. The second summer allowed for further practice and reflection, focusing on opportunities for teachers to gather feedback from peers and project staff. The following sections describe how each of these components provided our teachers with 18 months of sustained professional development.

Table 2 (Click on image to enlarge)

Outline of Overall PD Structure

	Summary	Goals
Summer 1 (40 hours)	1-week summer professional development led by project staff.	• Learn in-depth content related to physics and physical science • Learn about the engineering design process • Develop lessons to implement in the school year
Academic Year (10 hours)	Teachers implemented activities and lessons in their classrooms. Monthly and individual coaching meetings.	• Implement new activities and lessons in classrooms • Receive feedback from professional development facilitators • Develop reflective practice skills
Summer 2	1-week summer professional development primarily led by teacher participants.	• Reflect on experiences from the classroom with peers • Build on knowledge gained during the academic year • Continue to develop lessons and units for classroom use

Summer Year 1 Activities

The main focus of the first summer workshop was to provide our teachers with an understanding of engineering through integrated physical science and engineering activities in order to engage all students in authentic scientific and engineering practices. Our three main goals were for our teachers to: 1) learn in-depth content related to forces and motion, 2) learn about the engineering design process, and 3) develop lessons to implement in the following school year. Research identifies professional development that focuses on science content and how children learn as important in changing teaching practice (Corcoran, 1995), particularly when the goal is the implementation of inquiry-based instruction designed to improve students' conceptual understanding (Fennema et al., 1996). This guided us to create an experience that was interactive with teachers' own teaching practice. As the facilitators, we modeled instructional practices during the professional development, provided authentic learning experiences to allow teachers to truly experience the role of the learner in an inquiry setting, and supported teacher development of conceptual understanding of the physical science content. By allowing teachers to learn about the engineering design process using hands-on engineering activities in the context of physical science, teachers developed ideas and plans for how to bring engineering to their classrooms. We provided our teachers with a variety of engineering design process models (e.g., Engineering is Elementary, NGSS, PictureSTEM), feeling that it was important that they chose a model that they felt would work best with their students. In addition to modeling integration strategies, we built in time to discuss each activity to assist teachers in thinking about the activity from both a teacher and a student perspective. Figure 1 shows the typical progression when introducing a new activity.

Figure 1 (Click on image to enlarge). Outline of a typical progression when introducing new activities in summer year 1.



We introduced a variety of topics and engineering design challenges as we scaffolded the complexity of the activities with either more content or new instructional strategies. With each activity that we introduced, we attempted to focus on something new each time (for example, emphasizing teamwork or using data analysis to make design decisions). We frequently moved teachers around and arranged them in different groups, using a variety of means to group them to model different strategies for use in their own classrooms. We discussed how to come up with learning goals/targets that aligned with both science and engineering practices; starting on Day 2, we never shared an activity that did not include both physical science content and engineering standards. This was a strong emphasis throughout the professional development, as we frequently asked questions such as, “What made you decide on that design? What evidence do you have? What standard does this address?” We shared various assessment approaches, focusing on performance assessment. Table 3

describes the core activities that shaped this one-week institute, along with the NGSS standards that were addressed. When appropriate, we discussed safety measures in the classroom, building off of our teacher’s own knowledge of safety in the science classroom.

Table 3 (Click on image to enlarge)

Summary of Year 1 Core Activities

Day	Short Description of Core Activities	Standards Addressed
1	Crash Course (Vomir) - This activity made use of Vomir LabQuest with the motion detector probe. This lab was a modification of the lab found in the Vomir lab. Our activity, however, provided a contextualized problem to get students to understand motion. The problem was to determine who was at fault for a sliding accident. We provided teachers with two graphs that used different scales to determine who was at fault for a sliding accident. Teachers had to understand how to interpret the (distance vs. time) graphs in order to justify their decisions. Builder of Force and Motion - As an introduction to force and motion, this activity utilized a chain to allow students to understand the factors that relate to force. By pulling chains at different strengths and with different loads, students are able to come up with relationships between force, velocity, mass, and acceleration in a qualitative manner.	MS-ETS1-4, MS-P2-2, MS-P3-1, MS-P3-5, HS-P2-1
2	Engineering concept maps - To get teachers thinking about engineering and for us to assess their current understanding, teachers drew concept maps of what they thought engineering was. This was done first individually and then shared across the group, where participants noted similarities and differences in their maps. This led to discussion about engineering design processes and their varied nature. Tabletop Hovercraft - After a quick review of balanced and unbalanced forces, we tasked teachers to work in pairs to design, build, and test, tabletop hovercrafts to complete a challenge. They had glue, straws, and balloons. We provided other items as well, more past experience showed us that in order for the hovercraft to balance, sometimes teachers used index cards. We encouraged “competitive espionage” here where teams could walk around and “spy” on what others were doing. A formal share-out of designs through an Engineer’s Journal was also part of the process before final designs were created and tested. During the final testing, each pair was asked to assess their design and justify whether or not it met the challenge. Paint Cars - We adapted this activity from Angle (2011) to make use of various types of uncooled paint. For this activity, we introduced effective teamwork through cooperative learning and more team encouraged cooperative espionage. In this activity, we asked the teachers to come up with a design challenge using the NGSS standards as a guide to determine both the scientific content as well as the engineering design practices. We encouraged through brainstorming and sketching of designs, challenging teachers to consider whether or not another team could build their design based on their labeled sketches.	MS-ETS1-2, MS-ETS1-3, MS-ETS1-4, MS-P2-1, MS-P2-5, HS-P2-1
3	Paint Cars Revisited - In the morning, we finished the paint cars from Day 2 before talking about assessment and providing sample rubrics of assessing student learning in performance assessment. We revisited the Paint Car Challenge, but instead of providing teachers with a specific challenge, we tasked them with first coming up with a challenge that they thought all their students to do. This meant that they needed to come up with standards and a way to assess; they then had to give this assignment to another group, which provided an opportunity for feedback from their peers (which was expected since this was a mutual task).	MS-ETS1-2, MS-P2-1, MS-P3-1, MS-P3-2, MS-P3-5, HS-P3-1, HS-P3-2, 3
4	Save the Penguins - The activity that we shared with our teachers was an abbreviated version of (Schickel, 2009) in which the engineering design challenge is to create a well-suited habitat for penguins. In going through some of the pre-course activities to understand standards and best practice, we introduced the concept of storyboarding as a way to assess student thinking. This includes multiple modes of representation including pictures, symbols, words, and data. Wind Turbines - Using the Vomir KitWind Wind Turbines kit, we engaged teachers in designing a blade and blade management that would generate the most power. We provided a variety of materials and teachers could have anywhere from 1-2 turbine blades. This activity started with first testing controlled variables to create class means of options, but then groups made decisions based on this data set to create their own design. The emphasis on this was placed on determining a best solution through data analysis. Because of time constraints, this activity was completed in the morning on Day 5.	MS-ETS1-1, 2, 3, 4, MS-P3-4, HS-ETS1-1, 2, 3, HS-P3-4
5	Runway Trials - This culminating activity was one that the first two authors had previously designed (Ellis, Davis, Voigt, & Roeding, 2017) and centered on building the class and group that is so often used in physics classes. For this culminating activity, teachers were asked to first select standards, identify the core content being used by unpacking the standards, and develop an activity with their team. Teachers then used their own guidelines to design, build, and test their creations.	MS-ETS1-1, 2, 3, 4, MS-P2-1, MS-P2-5, HS-ETS1-2, 3, HS-P2-2, 3

Beyond the core activities, we administered a pre/post content assessment (based on the Force Concept Inventory), an instructional practice survey required by the Michigan Department of Education, and a self-efficacy survey (described below); discussed the nuances of the new NGSS compared to previous state standards through “unpacking the standards” activities; and formatively evaluated the previous day’s learning. We also guided teachers through using both Google Drive (where they were expected to later upload lesson plans and classroom videos) and the Google Site we created for them, where we shared all of our professional development materials (i.e., slides, handouts, materials lists, readings, etc.) and quick links to Google Drive. Throughout the week, we provided teachers with ample time to write lesson plans for their classrooms in the coming academic year, encouraging sharing between peers and facilitators for feedback. On the last day, we supplied teachers with recording equipment (video camera, tripod, and lapel microphone) to record engineering-integrated lesson in their classrooms and discussed what we were looking for in the academic year.

Year 1 Teacher Feedback

As part of our formative evaluation, we provided teachers with a brief course evaluation at the end of the week. This evaluation showed that teachers received the course positively, but most importantly, they felt that our strategies were helpful to their learning. For instance one teacher noted, “One of the best aspects was the instructors didn’t act like this was the best and/or only way to teach this material. Discussions abounded with many alternative ideas.” Teachers appreciated our modeling strategy such that, “The literal hands-on approach made a huge difference in my comprehension of the material. I also felt that by utilizing an open-forum approach we were able to feel more comfortable for invaluable discussion.” Further, “Hands on opportunities to learn from a student’s perspective and reflect from the teacher

perspective,” were seen as beneficial. The biggest failure in this first year was that the course was not long enough: “This could be a 2 week class with more emphasis on other standards in the 2nd week,” including, “More time for teacher discussions.” This feedback helped us design the workshop in summer Year 2, where we emphasized a greater focus on teacher-led activities and discussions.

One teacher commented that, “I sent a note to my principal telling him a couple of our teachers [who were not a part of the professional development] could have benefited from the class, too.” It was clear that teachers valued the work they did over the summer. These teachers left feeling confident about the upcoming year, armed with new tools in their teacher tool belts to bring engineering and the NGSS to their classrooms. In particular, “I had such an amazing week and feel so much more prepared to create engineering challenge lessons for my students. The instructors shared great ideas with us and empowered us to come up with our own amazing ideas.” By allowing teachers to struggle with engineering hands-on they felt prepared to add engineering to their instruction.

Academic Year Coaching

In order to support our goal of sustained professional development during the academic year (Garet et al., 2001; Richardson, 2003; Supovitz & Turner, 2000), we provided time for teachers to try out new instructional techniques, obtain feedback, and reflect. Facilitators of professional development should provide opportunities for teachers to reflect critically on their practice and to fashion new knowledge and beliefs about content, pedagogy, and learners (Darling-Hammond, 2005). During the academic year, we set goals for our project in which our teachers would: 1) implement new activities and lessons in their classrooms, 2) receive feedback from professional development facilitators, and 3) develop reflective practice skills. While teachers were expected to implement and video-record engineering-integrated lessons into their instruction during the school year, they were also expected to meet with project staff in monthly group coaching meetings as well as less frequent individual coaching meetings. Individual meetings provided teachers with opportunities to meet one-on-one with project staff and engage in conversations about their individual practice. These intentional conversations provide one of the most powerful forms of reflection (Ortmann, 2015; York-Barr, Sommers, Ghere & Montie, 2006), as “awareness of one’s own intuitive thinking usually grows out of practice in articulating it to others” (Schön, 1983, p. 243). When the conversation partner is a coach or mentor, this practice of reflection is non-evaluative and seeks to deepen the teacher’s reflective practice (York-Barr et al., 2006). This type of coaching has been used in science and mathematics classrooms to effectively expand teachers’ content knowledge and pedagogy (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Further, coaching in STEM (science, technology, engineering, and mathematics) classrooms has the potential to drive success in K-12 STEM education in addition to increasing teacher self-efficacy (Cantrell & Hughes, 2008; Ortmann, 2015).

Monthly group coaching. We scheduled two online meetings each month using Google Hangout; each of the two monthly meetings covered the same topics and were scheduled so that half of the group would meet during the first meeting and the other half would attend the second meeting. Meeting times were determined simply by polling teachers using a Google Form; one meeting was at the end of the school day and one was at a later evening hour. During these group meetings, teachers shared what was going on in their classrooms and elicited help from facilitators and colleagues. The topics of each month were guided by teachers' interest in topics, which they shared with us at the end of each meeting. As the months continued on, we changed our strategy to make sure that the coaching sessions better met our teachers' needs. In this, we ended up going through three phases of meeting type.

Discussion and topic driven. For the first meeting, the first author emailed a Google Form to teachers to indicate topics that they would like to address in the first meeting. A short list of specific topics was provided in the form, but respondents were also able to add in their own suggestions. From the responses, we determined that the first topic would be a continuation of a discussion about creating motivating and engaging contexts for student learning. The first four meetings (September to December) followed a similar format that began with a welcome and general check-in with teachers, a short interactive PowerPoint presentation to ground the conversation, whole group discussion and sharing, and a closing. At the end of each meeting, we asked teachers to contribute to a table in Google Doc to note the following: "I'm planning to implement...", "I'm excited to try...", and "I'm still wondering about...". This third item led us to determine the topic for each subsequent monthly meeting, which covered assessment strategies, formative assessment, and planning ahead for Summer 2.

A focus on classroom practice. After the winter break, we adjusted our approach to the monthly meetings. We incorporated breakout sessions in which the meeting would start as a large group, then we would create small breakout groups on the fly in Google Hangouts, and the whole group would finally come back together for the last 10 or so minutes. We created separate Google Hangout links ahead of time and emailed the small groups when it was time for these small group discussions; because we never knew who was attending which meeting, this second part was done in the moment. As the facilitators, we would "drop into" these meetings using those links, much like a teacher would check in with a small group in a classroom setting. During these two sessions, teachers discussed issues, challenges, and/or successes in their classroom (January) and then identified a particular area that they wanted to work on to improve (February). This latter topic helped us in planning ahead for the Year 2 summer institute. In particular, teachers voiced their struggle with classroom management and creating performance assessments, and were proud of their success in increasing student engagement in their classrooms.

Video work. Our original plan was to engage teachers in video reflection during Summer 2, so we shifted our focus in March to prepare teachers for watching their peers' classroom video to provide feedback. We first introduced teachers to VideoAnt, a free online tool for video annotations, and asked them to view a video from the Engineering is Elementary video collection. Specifically, we asked teachers to annotate 3 things they found interesting, 2 things they would ask the teacher if s/he were present, and 1 implication for their future engineering-integrated instruction. In April, we continued this discussion by encouraging teachers to comment on all of the annotations from the previous meeting. We used this experience to help our teachers generate ideas via a Google Form to establish guidelines/norms for sharing video clips during the summer. The teachers worked together to define the following guidelines, which were implemented in the summer Year 2:

1. Teachers can share strategies or elicit feedback on specific aspects of instruction
2. Viewers can help solve a problem
3. Anyone can ask probing questions
4. You can give advice related to your own instruction
5. Everyone will recognize that not all classrooms are the same
6. No high-fiving or being negative – constructive criticism only!

By May, we realized that a week full of video clips and feedback might be monotonous for this group of teachers who thrived on variety, so we opened up the summer session to include a micro-teaching option. In this option, teachers would be able to showcase or pilot an activity they wanted to receive peer feedback on. This required that we discuss what this meant during our May meeting.

Individual coaching. During the school year, teachers implemented activities and lessons in their classroom that focused on engineering integration (many of which reflected slightly-altered versions of activities shared in the Year 1 institute). In addition to the monthly group meetings, they also engaged in individual coaching meetings. Because of the large distance between the project team and the teachers, teachers video-recorded lessons in their classrooms and shared the recording digitally via a shared Google Drive folder; these were only shared with the project staff, not all of the teachers. The first author then watched these recordings in order to prepare for a one-on-one virtual meeting with the individual to discuss the lesson. During this meeting, the first author used a coaching approach to learn more about the teacher's experience in implementing the lesson of focus and to inquire about future practice, providing an opportunity for the teacher to reflect on their current practice. Although some specific questions were drafted ahead of time, typically these meetings were organic. Meetings often started with a broad question such as, "How do you think your implementation went?" From here, the first author would elicit not only the teachers' concerns, but also their successes. These discussions were often centered on student learning and engagement, as teachers were most concerned about this aspect of their instruction. While the project only required one of these meetings, a handful of teachers took advantage of this external support and engaged in multiple conversations.

Summer Year 2 Activities

The original plan for Year 2 was to have teachers share segments of their recorded classroom video, but as the monthly meetings progressed during the school year, we realized that sharing video may limit the activities. Because of this, we altered our plan slightly. We knew from the group meetings that teachers were interested in what their peers were doing in their classrooms, so instead of watching video clips for the entire week, we added the option for teachers to micro-teach a lesson. Teachers could share either what they had implemented in their classrooms or something that they were thinking about implementing (i.e. a pilot). The first author sent out a Google Form to elicit responses and to assure that each teacher signed up for either micro-teaching or video share. We made it clear to our participants that this second workshop would be extremely different from the first, as we would provide very little new information. Similar to professional learning communities, our aim was to continue to allow these teachers to build their knowledge from one another as they continued to develop ideas for classroom use.

This second summer institute followed a similar format each day, where the goals were for teachers to: 1) reflect on experiences from the classroom with peers, 2) build on knowledge gained during the academic year, and 3) continue to develop lessons and units for classroom use. In order to reduce the stress of having a teacher lead a discussion on the very first day, the first author led the group through an engineering design challenge related to forces and buoyancy (Dare, Rafferty, Scheidel, & Roehrig, 2017). This final engineering design challenge – design and build a watercraft for use in floods – was revisited at the end of the week. Each day included video scenarios, two rounds of micro-teaching, and an Engineering with an Engineer segment (described below) or time for lesson development.

Video scenarios. Teachers who elected to share classroom video were asked to select a video clip no longer than 10 minutes to share; this was done prior to the week-long summer meeting and with support from us. Teachers were expected to not only share the video clip, but to ask for specific feedback from their peers. During the professional development we shared the video clips either in a large group or two small groups. After watching the clip, the group engaged in discussion, led by the focus teacher, where others followed the previously established viewing guidelines and constructive feedback norms.

Micro-teaching. Teachers who chose this option provided the first author with a list of materials needed to complete the activity and were asked to prepare any handouts necessary to implement it in the classroom. Teachers were provided approximately 45 minutes to introduce and lead the activity as they would in their classroom; while this meant that a multi-day lesson may not have been fully implemented, this activity provided teachers an opportunity to share enough to receive feedback from their peers. Afterward, the group debriefed the activity, where the teacher asked his/her peers for specific feedback and suggestions for improvement.

Engineering with an engineer. To encourage teachers' growth in their understanding of engineering, the third author (a doctoral student in Civil and Environmental Engineering) led activities to share more about what real engineers do, using real engineering practices and situating them within an activity. For instance, engineers make informed decisions using a systematic process; this is reflected in NGSS standard MS-ETS1-2. In one activity, teachers were asked to consider how they make decisions while evaluating three different roofing materials. Teachers used a decision matrix (Figure 2) to identify criteria and constraints based on their roof project needs, wants, and overall budget. Once teachers individually documented their ideas, they paired up and shared their decision matrix with a colleague. Each teacher team reached a consensus, agreed on their top three decision criteria, and selected one roofing material. While no physical product was created as a result of this decision-making activity, this exercise is one example of how real-world engineers work in a team, using an objective process to make decisions by prioritizing facts, importance, and values. As part of this process, teachers practiced discussing trade-offs, used the matrix as supporting evidence to determine the best design solution, and enacted engineering practices that they could take back to their classroom.

Figure 2 (Click on image to enlarge). Example template for a decision matrix used in summer year 2.

Decision Criteria	Importance value (%)	Roof Material Solutions					
		Shingle		Metal (screw-down)		Metal (standing-seam)	
		Score	Rating	Score	Rating	Score	Rating
1.							
2.							
3.							
Totals	100 %	-		-		-	

Lesson development. In order to encourage continued collaboration within the group, we incorporated time for teachers to brainstorm and write activities and lesson plans. This was similar to the summer workshop in Year 1, but by this point, teachers had been exposed to multiple ideas. Teachers worked both individually and in groups to write down ideas and possible activities for their classroom. As part of this, all lesson plans and handouts from the micro-teaching were shared digitally on our course Google Site.

Year 2 Teacher Feedback

Evaluations from both summers indicated that teachers were positive about their experiences with this professional development approach, emphasized by the fact that they asked when they could work with us next. Specifically, in this second summer, teachers were positive about the video shares and the micro-teaching. They noted, “The time to collaborate with other Science Professionals at all levels was so helpful to view ideas/lessons/concepts from multiple perspectives. This time allowed for troubleshooting, idea formulating, and just plain professional discussion that benefited all.” The collaborative aspect of this second summer appeared to be fulfilling: “The amount of collaboration between teachers was astronomical and really accelerated my understanding of the different sciences and how they are taught.” The micro-teaching enabled teachers to get more ideas of activities to use in their classroom: “Having numerous hands on activities that can be applied directly to class. I also liked talking with others about activities that worked.” It appeared that this sharing of ideas benefited our teachers.

When asked to comment on improvements for us to think about future professional development offerings, most responses were similar to, “None that I can think of,” however, “I think the biggest drawback to this class was the time. It was great to talk with other teachers and how we use stuff in our classes-ideas, ideas, ideas. This class could have easily gone two weeks both summers. There was more than enough useful material.” Teachers appreciated their colleagues and commented, “I know everyone has been suggesting it, but, honestly, a continuation so that our strong network of teachers can meet again.” Without being prompted, our teachers thanked us for providing them with this opportunity:

I just want to thank you for treating us like professionals, allowing us the time to interact in fun and engaging ways that we can apply directly to our classrooms, and for providing this opportunity to connect with other science teachers facing similar issues.

Similarly, teachers felt that this opportunity, “...has helped me improve as a teacher and make my classes better for my students,” and helped gain confidence in understanding the new NGSS standards such that, “I feel much more confident in teaching NGSS after this workshop, thank you for allowing me to be a part of this.” Our format clearly impacted teachers who were hungry to learn more about engineering and to connect with others outside of their schools.

Other Measures of Success

As part of our reporting measures, we administered the Teaching Engineering Self-Efficacy Scale (Yoon, Miles, & Strobel, 2013) as an assessment to measure the impact of our professional development workshop on teacher’s self-efficacy; the first assessment occurred at the beginning of the first summer workshop and the second at the end of the second. The TESS uses a 6-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (6). The survey measures four constructs (Yoon et al., 2012): Engineering Pedagogical Content Knowledge Self-Efficacy (KS), Engineering Engagement Self-Efficacy (ES), Disciplinary Self-Efficacy (DS), and Outcome Expectancy (OE). According to Yoon et al. (2013), analysis of

the Teaching Engineering Self-Efficacy Scale (TESS) can be done by examining the average score of each of the four constructs and also by looking at the overall score for self-efficacy by summing these averages. This was done for all participants for their pre and post surveys. We used a paired t-test to analyze the significance of any gains (Table 4). Teachers' self-efficacy significantly increased in two of the four different constructs, as well as overall, using a cutoff of $p < 0.05$. Although teachers rated their Engineering self-efficacy fairly high in the beginning of our time with them, we can confidently say that this professional development helped to build that self-efficacy even more.

Table 4 (Click on Image to enlarge)

Teacher TESS Results (Likert 1-6 scale)

TESS Construct	M(SD) _{pre}	M(SD) _{post}	p-value
Engineering Pedagogical Content Knowledge Self-Efficacy (KS)	4.25(0.6)	5.07(0.55)	0.002**
Engineering Engagement Self-Efficacy (ES)	4.95(0.78)	5.52(0.71)	0.034*
Disciplinary Self-Efficacy (DS)	4.41(0.97)	4.76(0.88)	0.152
Outcome Expectancy (OE)	4.13(0.66)	4.59(0.88)	0.053-
Overall Teaching Engineering Self-Efficacy (TES)	17.74(2.25)	19.93(2.29)	0.011*

-p<.1, *p<.05, **p<.01, ***p<.001

Discussion

As noted by teacher feedback in both Years 1 and 2, teachers felt that the professional development helped them understand the new NGSS-like standards, which would help them to develop activities and lessons for their classroom. Additionally, teachers successfully implemented lessons in their classroom and received feedback from project personnel and peers; this feedback helped teachers reflect on their development. While further study would shed light on aspects of classroom practice, it was clear to us as facilitators that this project was a success. It is also evident to us how important it was for teachers to work through learning about engineering and the NGSS with their peers. While we provided a foundation for their learning, most of their growth appeared to be a result of collaboration with their peers.

Although we had not explicitly planned for it, we believe that one of the most successful aspects of this project was the development of collegiality between the teacher participants; this collegiality was unlike any seen by us. We attribute this success in part to the sustained contact throughout the school year. The inclusion of monthly group meetings allowed teachers to remain connected not only with project staff, but with each other. Additionally, we designed these virtual group meetings to fulfill the needs of these teachers by asking what they wanted to work on and encouraged responses from their peers.

This success also came from our participants. We were extremely fortunate to work with teachers who were eager and willing to learn and push themselves outside of their comfort zone. Their written feedback showed us that our model worked for them and that they built their own learning community within this project. This encourages us to consider improvements to any future professional development opportunities we offer. Many of our

teachers asked to keep the video recording equipment that they used during the academic year to continue their growth as educators. This is something we plan to include in our future work to expand the use of video reflection. Unexpectedly, few teachers implemented integrated lessons early in the school year; the majority of them chose to wait until the last month or two. Anecdotally, our prior work in similar engineering-focused professional developments showed similar patterns. We suspect that this is due to teachers viewing engineering as something “new,” meaning there is no time in the school year except at the end; a formal study is necessary to more fully understand this phenomenon. This limited our ability to engage teachers in much meaningful video reflection throughout the academic year; however, during the professional development in Year 2, we felt that teachers began to notice the value of video sharing. It was perhaps an error of ours to attempt to fit so much into summer Year 1, as we missed some opportunities to showcase the benefits of video reflection before teachers returned to their classrooms. This is parallel to teachers’ comments about the need for more time in each of the summer workshops.

Another successful piece of this project was the inclusion of micro-teaching in Year 2. For an activity that we had not originally planned for, teachers rated it as one of their favorite activities on course evaluations. This practice, which is more often used in pre-service teacher preparation, clearly has uses for in-service teacher education as well. This may be an imperative addition when in-service teachers are learning new skills; they need opportunities to engage in new practices in a low-stakes environment, reflect on those practices, and receive feedback from their peers. The lessons that teachers did implement in their classrooms between the two summers tended to be modifications of the activities we shared in Year 1. For teachers new to engineering and engineering integration, this may help to build confidence. At the end of summer Year 2, it was clear to us that teachers were going back to their classrooms with new ideas from their peers, in addition to what we shared with them as facilitators. Further study with these teachers may allow us to understand how these teachers continue to grow with respect to engineering integration once they were equipped with the tools and increased their confidence in understanding the NGSS. If we were able to expand this work and focus on developing high-quality curriculum for classroom use, we believe that we would have seen more novel engineering activities in these classrooms in a second year of implementation. Beginning experiences like these are necessary for teachers who are now expected to bring engineering and NGSS to their classrooms.

Our model used here can be successful outside of rural and remote settings. While we had some bumps along the way, the model of professional development that we used helped teachers develop their practice over time while creating a small community with their peers. We still receive emails from our participants about accomplishments (such as being successful in securing grant money to purchase equipment for their classrooms or participating in professional conferences). We have been fortunate enough to invite these participants to join other projects we are conducting, and we hope to continue working with

these amazing individuals over the years. A model of professional development such as the one described here may be beneficial for pre-service teachers, school-wide or district-wide reform, or long-distance professional development opportunities.

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