Evaluation of Engineering Problem-Framing Professional Development for K12 Science Teachers (Evaluation)

Abstract

As the importance to integrate engineering into K12 curricula grows so does the need to develop teachers' engineering teaching capabilities and knowledge. One method that has been used to aid this development is engineering professional development programs. This evaluation paper presents the successes and challenges of an engineering professional development program for teachers focused around the use of engineering problem-framing design activities in high school science classrooms. These activities were designed to incorporate the cross-cutting ideas published in the Next Generation Science Standards (NGSS) and draw on best practices for instructional design of problem-framing activities from research on design and model-eliciting activities (MEAs). The professional development (PD) was designed to include the following researched-based effective PD key elements: (1) is content focused, (2) incorporates active learning, (3) supports collaboration, (4) uses models of effective practice, (5) provides coaching and expert support, (6) offers feedback and reflection, and (7) is of sustained duration.

The engineering PD, including in-classroom deployment of activities and data collection, was designed as an iterative process to be conducted over a three-year period. This will allow for improvement and refinement of our approach. The first iteration, reported in this paper, consisted of seven high school science teachers who have agreed to participate in the PD, implement the problem-framing activities, and collect student data over a period of one year. The PD itself consisted of the teachers comparing science and engineering, participating in problem-framing training and activities, and developing a design challenge scenario for their own courses.

The participating teachers completed a survey at the end of the PD that will be used to inform enhancement of the PD and our efforts to recruit additional participants in the following year. The qualitative survey consisted of open-ended questions asking for the most valuable takeaways from the PD, their reasoning for joining the PD, reasons they would or would not recommend the PD, and, in their opinion, what would inspire their colleagues to attend the PD. The responses to the survey along with observations from the team presenting the PD were analyzed to identify lessons learned and future steps for the following iteration of the PD. From the data, three themes emerged: Development of PD, Teacher Motivation, and Teacher Experience.

Introduction

The need for integrating engineering education programs in K12 classrooms has increased as the Next Generation Science Standards (NGSS) have included engineering as part of their guidelines [1]. Because of this, K12 teachers need training on how to integrate engineering into their classrooms. Many K12 teachers lack engineering content knowledge and pedagogy needed to teach engineering and thus require more training [2]. Engineering professional development (PD) programs are one type of educational intervention that aid in increasing teacher engineering teaching knowledge. Various engineering PD programs have different foci including increasing teachers' preparedness to undertake teaching engineering [3] and effective learning experiences that support the development of professional practice [4].

There is a special need to provide tools for K12 programs to fold STEM content into existing math and science courses and to develop a means by which those activities may be connected to a common learning progression across otherwise perceived disparate areas of the curriculum. While many programs adopt a full-scale replacement of existing courses – in the model of Project Lead the Way [5] or engineering magnet programs – this requires extensive resources (time, money, and knowledge) and cannot feasibly be provided to all students in the nation. The introduction of problem formulation activities linked to NGSS materials provides a particularly low resource means to address this need, as they do not involve extensive prototyping and testing or the associated equipment and materials.

Problem formulation and its purpose in problem solving has been studied extensively by theorists, practitioners, and experimentalists specializing in management, decision making, and design, because it is critical in effective design and strategic decision making [6]–[9]. Problem formulation is especially important when solving ill-defined and open-ended problems, which require problem solvers to work under specific constraints [10]–[15], to acquire relevant information from all available information [15], to work within a context [13], [14], [16]–[18], and to work towards meeting a client's needs [10], [15], [19], [20]. This relationship between successful problem framing and successful problem solutions – and the difficulty in conducting problem framing in complex contexts – necessitates development of students' problem-framing skills, a skill seen as critical to the development of future engineers [21], [22].

The overarching goal of our project is to strengthen high school science education by (1) developing educational curricula to foster and evaluate engineering problem-framing skill development (engineering problem-framing focused design activities (EPDAs)) in high school students; (2) providing educators with guidance, professional development (PD), and support for deploying such EPDAs; and (3) classroom testing and refining the EPDAs and teacher training/support materials in three phases. This evidence-based practice paper discusses the evaluation and lessons learned from the first iteration of the developed engineering PD.

Professional Development Implementation

The PD participants consisted of seven high school science teachers (two female and five male), with focuses including biology (four participants), chemistry (two participants), and physics (one participant). The teachers represented four different high schools, all suburban with one being a Title 1 school. The courses they teach follow a traditional science curriculum built around the state adopted NGSS. The participants were recruited through the professional network of a member of the research team. Each participant received a stipend for their participation in the PD and their integration of the engineering problem-framing activities throughout one school year. The PD took place over three days during the summer. The teacher PD, in-classroom deployment, data collection, and its analysis and feedback integration has been designed as an iterative process taking place over three years and is intended to improve and refine our approach. The PD was designed to include the research-based key features of effective professional development. These features include (1) being content focused, (2) incorporating active learning, (3) supporting collaboration, (4) using models of effective practice, (5) providing coaching and expert support, (6) offering feedback and reflection, and (7) being of sustained duration [23]. The PD sequence is illustrated in Figure 1.

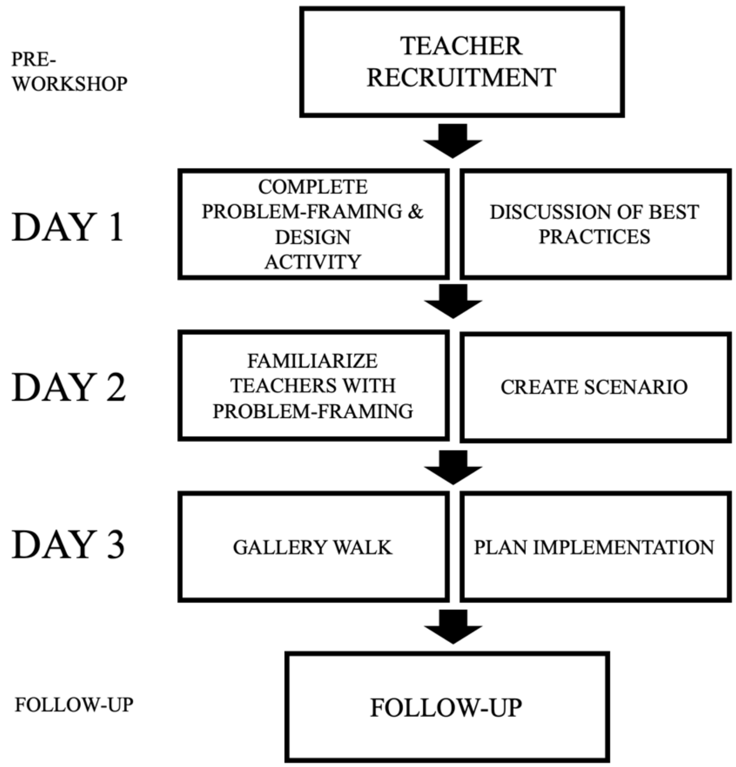

Figure 1: Engineering Professional Development Sequence

The first day consisted of the participants completing an activity intended to help students understand the similarities and differences of engineering and science. An engineering design experience was also included that consisted of the participants following the engineering design process based on a given scenario. It entailed the participants practicing problem-framing, planning a solution, and developing a prototype of their design. This allowed them to take on the student perspective of the type of lesson they will be teaching. A discussion of best practices for facilitating this kind of experience concluded the first day. The second day was dedicated to the familiarization of the problem-framing activities developed by the research team and the development of engineering design experience scenarios. The participants completed each of the activities and reviewed all of the materials, including presentations, for the activities. Discussions of facilitation methods were held throughout this portion of the PD. Each participant was then asked to create a scenario for an engineering design experience that aligned with a topic from the courses that they teach. These scenarios consisted of the general context, curricular links, stakeholders, stakeholder needs, and design specifications. On the third day, a gallery walk of the created scenarios was held with a debrief of the characteristics of the scenarios that would aid and/or inhibit implementation of it as a design experience in the classroom. Finally, the implementation expectations for the following school year was discussed and participants created plans for their individual implementation. Each participant was expected to implement two of the provided activities during the first semester and one provided activity and an original engineering design experience during the second semester.

Professional Development Evaluation and Results

The participating teachers completed a feedback survey at the end of the PD that will be used to inform enhancement of the PD and our efforts to recruit additional participants in the following year. The survey consisted of open-ended questions asking for the most valuable takeaways from the PD, their reasoning for joining the PD, reasons they would or would not recommend the PD, and, in their opinion, what would inspire their colleagues to attend the PD. Additionally, throughout the PD, one research team member collected observations about the facilitation of the PD.

Thematic analysis was used to identify patterns within the data, both the qualitative survey responses and the research team notes. A top-down analysis approach was implemented, meaning that the analysis is driven by the goal of evaluating the PD [24]. This approach was chosen because it allowed the data analysis to focus on the experiences of the participants and the research team who conducted it. The analysis began with becoming familiar with the data sets through multiple readings of each. Initial codes were then generated to describe the different experiences of the PD from the participants' and the research team's perspectives. From the list of codes, three themes were derived that will be used to inform future iteration of the PD.

The three themes are Development of PD, Teacher Motivation, and Teacher Experience. Development of PD was derived from the PD observations and includes deviation from originally scheduled activities, existing teacher perceptions of engineering that affected the flow of the PD, and changes that should be made to the problem-framing activities developed by the research team. While a detailed schedule of the PD was created, some of the planned activities took longer than expected or did not happen as smoothly as the team would have liked. For example, during the PD some teachers vocalized their perceptions of engineering as being "more guess and test while science analyzes data and creates models" and "tinkering until you get something that works." This prompted a more in-depth discussion of the comparison of engineering and science that was not originally planned. The increased amount of time spent on those activities and discussions decreased the amount of time spent on subsequent activities. The engineering design experience completed on the first day ended without testable prototypes due to problems with the materials we provided for prototyping. The adhesive material provided was not strong enough to hold the prototypes together. We recognize the need to plan extra time during each day for unplanned occurrences and to test alternative activity materials for the next iteration of the PD. Observations of the problem-framing activity materials discussed during the PD led to a list of changes that would need to be made before their implementation by participants. Some of the items were recognized through the presentation of the material while others were suggested by the participants such that they would be easier for them to implement. This aided our recognition of the yearly PD as a time to gain insights into changes to our activities that would benefit teachers implementing them and student learning.

The theme Teacher Motivation was derived from the participant feedback survey responses discussing why the teachers chose to participate in the PD and why they would or would not recommend it to their peers. This theme describes the motivating factors, as described by the participants, of joining our PD including professional improvement, desire to give students engineering experiences, and direct personal benefits to themselves. Participants were motivated by the potential for professional improvement such as wanting to improve their ability to teach engineering. When asked why they joined the PD, one participant stated, “I was inspired because I will be switching teaching assignments next year that are heavily centered in engineering and I know very little about engineering. I needed help in learning how to put it into my classroom.” Many of the participants recognized integrating engineering into their science classrooms as being important for their students and cited the desire to give their students engineering experiences as their motivation for attending the PD. A participant described integrating engineering as being “essential for our students to get a grasp of [a] huge career field and develop the skills that engineers employ on a daily basis.” While this may be compelling motivation for some, other participants discussed direct personal benefits, such as college credit, money, and teaching support, as being what motivates teachers to join engineering PD. These motivating factors described by the participants will be used to aid our recruitment for the next iteration of our PD. We will highlight the key motivational factors, as described by the participants, in the recruitment documents sent to potential participants.

The theme Teacher Experience was also derived from the participant feedback survey. The participants’ responses to why or why not they would recommend the PD to their peers cited development of confidence, the provided activities, and the differences from other PD available to them. Participants described the PD as aiding in their development of confidence in teaching engineering. A participant stated, “I feel more comfortable in trying [EPDAs] in my classroom and know the thought process. Even though I am not an expert, hopefully, I will be more comfortable using this in my class and it will help me become a better teacher.” Similarly, some participants discussed the EPDAs (provided activities) as being valuable takeaways from the PD. Participants expressed excitement about implementation of the activities and described them as “direct scenarios [we] can apply in [our] classrooms immediately.” The participants also discussed how our PD was positively different than others available to them. They described our PD as being “better than the normal in-service which is mostly stuff that never gets used” and being helpful because they have “no district-wide PD on incorporating engineering into science courses.” These experiences led us to believe that we are providing professional content that is unique and wanted by teachers. Because of this we will continue to center our PD around content and activities that allow for smooth and confident integration of engineering into science classrooms.

Conclusions and Recommendations

The engineering PD evaluated was developed to train teachers on integration of engineering problem-framing activities in response to the growing need for K12 teacher engineering education. A feedback survey provided insights into the participants’ experience of our PD. These insights combined with observations of the facilitation of the PD were used to inform future iterations of the PD and communicate lessons learned. In the next iteration of the PD we have included extra time during each day for unplanned occurrences and have edited the engineering design experience to allow for successful completion in the time allotted. The recruitment effort for the next iteration has also been updated to include the key motivational factors described by our previous participants.

Based on the lessons learned, we recommend the following for those developing engineering professional development programs for K12 teachers.

- Allow sufficient time to design and deliver at least one complete engineering design challenge as part of the PD
- Include an activity to compare and contrast science and engineering that allows for open discussion of their understanding of engineering concepts
- Establish agreements with school districts well in advance about the scheduled contact time with the teachers in order to maintain a continuous mentoring approach

Since many high school science teachers have no experience with engineering design processes, this can aid in the development of their confidence when coaching students on any subset of engineering design process skills. It is important that teachers understand they are only expected to build engineering literacy skills, not become engineers themselves when attending engineering PD. Many teachers feel overwhelmed by the belief that they are not engineers and therefore cannot teach engineering. Researchers and engineering teacher PD providers must explore and address these types of fears in order to have teachers improve their levels of confidence and realistic learning goals from the teacher engineering PD. While not being part of the three main themes discussed previously, we've also learned a good deal about how important up-front agreements with school district administrators are with respect to locking in PD time and, by extension, being able to successfully implement activities during the school year. A continuous mentoring approach is critical to getting teachers ready to facilitate the activities. Without the district on board to allow that access, we end up playing second fiddle and lose out on implementation opportunities.

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