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Integrated STEM Professional Development: Utilizing Best Practices in an Online Format

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Abstract

Online professional development (PD) can reach teachers from widespread areas. Here, we describe PD activities that are part of a project focused on integrated science, technology, engineering, and mathematics (iSTEM) teaching self-efficacy and effectiveness among early-career elementary teachers. Toward our objective of building a community of elementary teachers focused on improving their iSTEM teaching, we are conducting online PD institutes over four summers. These PD institutes are designed using Desimone's five critical features of effective PD: content focus, active learning, coherence, duration, and collective participation. Our institutes engage teachers in an initial synchronous online session, which is followed by independent work time to put their learning into practice. It concludes with a final synchronous online session where teachers share their asynchronous work, receive feedback, and identify the next steps in enacting their learning in the classroom. Below we describe the first year's PD activities.

Keywords: *professional development, science education, elementary, STEM*

Project Background and Literature Base

Elementary teachers are often uncomfortable teaching science, mathematics, and engineering as independent subjects [1], and integrated science, technology, engineering, and mathematics (iSTEM) poses new challenges. To address these challenges, we are conducting a five-year research project focused on elementary teachers' self-efficacy and effectiveness teaching iSTEM. One aim is to create a community of practice – a group of teachers who are connected by what they are doing and learning. To that end, we are inviting participants from our larger project to virtual PD, held over four summers of a five-year project. Because our participants are from geographically diverse regions of the United States, we chose an online PD format.

Researchers have found that online PD can have a widespread reach versus face-to face PD [2]. Fostering a rich, interactive, community of learners is a critical factor related to successful PD [3], and this type of community is possible through online PD [4]. Sometimes referred to as professional learning communities (PLCs) these are groups of teachers working collaboratively to improve student outcomes. The members of these PLCs are connected through their common activities and experiences [5], and participation in PLCs can increase science teaching self-efficacy among elementary teachers [6]. Additionally, the active responsiveness of the instructor can also serve to enhance the collective learning pursuits of the online PLC [7].

Our PD institutes are designed using Desimone's [8] five critical features of effective PD: content focus, active learning, coherence, duration, and collective participation. When included in PD planning and activities, these features contribute to an increase in perceived teacher preparedness [9]. Desimone [8] argued that content focus may be the most influential element in PD experiences. Indeed, there is ample evidence that increased teacher knowledge is connected to increased student achievement [10]. Our PD *content focus* is fostered by inviting content experts to deliver key PD sessions, which are described in more detail below.

According to Wong et. al. [11], effective online PD should be designed around Bandura's [12] proposed sources of self-efficacy. Connecting with Desimone's [8] model, we built *active learning* based on the proposed sources of self-efficacy: mastery experiences, vicarious experiences, verbal persuasion, and emotional arousal. For example, mastery experiences may include teaching rehearsals, whereas vicarious experiences may include video analysis. The foci of PD institutes vary each year but maintain *coherence* through their connection to participant classroom observation data using a STEM observation protocol [STEM-OP; 13] and the daily demands of elementary teachers. We frame our PD activities around the protocol items that need the most support based on a needs assessment during the PD registration process.

Duration includes the number of PD hours and the time span of the program. Desimone asserts that PD that is spread over time and includes 20 hours or more of contact time is optimal [8]. Our PD institutes engage teachers in an initial synchronous online PD session, which is followed by independent or small group work time over the next week to put their learning into practice. It concludes with a final synchronous online PD session where teachers share their asynchronous work, receive feedback, and identify the next steps in enacting their learning in the classroom. In addition, the PD institutes are held annually, providing long-term engagement. This strategy concurs with the findings of Bragg et. al. [14], who found that participant engagement is a key factor in PD experiences.

C*ollective participation* is fostered through the strategic use of online breakout rooms, collaborative activities, peer feedback, and a shared Canvas page that provides space for participants to share iSTEM teaching resources and provide ongoing support. These structures allow for authentic discourse, learning, and encouragement among teachers. Below, we describe our 2023 PD institute that was offered to elementary teachers.

Description of Online PD

Two of the three PD days were synchronous and included hands-on, inquiry-based activities that integrated science and engineering, with the goal of developing both content and pedagogical knowledge. Between the two synchronous sessions, one day of asynchronous activities was included. Inquiry-based strategies were modeled using the learning cycle format. Participants were presented with an engaging, participatory, and interactive learning environment throughout the experience [15, 16].

Day One

Following introductions, the PD opening provided context for aligning to the National Science Teaching Association elementary school science position statement [17]. STEM pedagogical knowledge was applied through open-ended problems embedded in the activities. For example, participants were engaged in a structure-building activity organized according to the 5E inquiry instructional model (Engage, Explore, Explain, Evaluate, and Elaborate) modified from the lesson *Build-Up* from the Picture-Perfect STEM K-2 curriculum guide [18]. To *engage* and pique learner interests, we used the picture book *Dreaming Up* by Christy Hale. We also discussed global workforce needs, STEM careers, and the accomplishments of women scientists. We asked participants to list as many STEM careers as they could think of in one minute, then discussed STEM careers and representation in STEM fields, sharing the story of the renowned Iraqi architect, Zaha Hadid. We emphasized that this female STEM role model exhibited both creativity and perseverance throughout her career. To provide hands-on experiences to *explore*, participants sketched a building that they would build with everyday materials they had collected. They built the structures and measured the height of their designs. To *explain*, participants shared their buildings with each other. We introduced related science and engineering concepts through discourse and discussed iconic buildings throughout the world. To *evaluate*, participants considered modifications to their designs. Finally, to *elaborate*, participants reflected on their learning, the 5E components of the activity, and how the activity might be adapted for classroom use.

At the conclusion of the first session, we shared information regarding what iSTEM teaching and learning should look like in an elementary classroom. The ten identifying features are actions that can be easily identified using the STEM-OP [13], a classroom observation protocol meant for use by administrators, researchers, coaches and PD providers. Each of the ten features on the STEM-OP were reviewed and discussed with participants prior to having them use the instrument while viewing classroom videos.

Day Two
During the asynchronous work time, participants familiarized themselves with the STEM-OP and created an iSTEM lesson to share.

Day Three
We discussed engineering careers and used inquiry-based activities in a 5E form. To *engage* participants, the engineering design process was introduced and discussed, and we read the book *Fly Girl, Fly!: Shaesta Waiz Soars Around the World* by Nancy Roe Pimm to model literacy integration. Participants performed a hands-on activity to *explore* and create paper airplanes. Next, they *explained* key academic terms, such as force, gravity, thrust, drag, and lift. They tested how long their planes would fly to *evaluate* their performance. We *elaborated* on the lesson by discussing mathematics integration ideas. Other pedagogical discussions arose related to what type of paper was used to construct the planes, and what impact that might have on the results. Lastly, we discussed the importance of academic vocabulary and instructional techniques to support language development. Participants shared their own iSTEM lesson plans in small groups in online breakout rooms that were purposefully arranged by grade levels. This session was extremely productive since it allowed participants to take ownership of their learning and apply it to their own instructional practice.

Conclusion
This nine-hour PD aimed to support high-quality elementary iSTEM teaching by creating a safe and interactive learning environment. We demonstrate here that online PD can be meaningful and engaging for participants. When planned carefully and drawn on educational theories and relevant research, online PD can create robust PLCs that enrich teachers' content knowledge and pedagogical skills.

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