Developing Effective STEM Professional Development Programs

To help the United States stay globally competitive in terms of innovation and invention, the teaching of science, technology, engineering, and mathematics (STEM) has become a priority in P–12 education today. As the need for students to become stronger in STEM grows, so does the need for well-qualified STEM teachers who understand what is needed to develop relevant and high-quality STEM programs. Professional development (PD) can offer opportunities for those involved in the teaching of STEM to learn how to effectively integrate various instructional approaches, including *engineering design* into their teaching and learning environments.

Engineering Design is a very popular method used by engineers to solve problems. ABET (2011) has set a variety of criteria for accrediting engineering programs and in their discussion on criteria related to developing engineering curriculum, they note that engineering programs must devote adequate attention and time to engineering design.

> Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs. (p. 4)

Engineering design is also a very important concept taught in technology and engineering education as evident by the emphasis it is given in the *Standards for Technological Literacy: Content for the Study Technology* (International Technology Education Association, 2007). For example, standards 8 through 13 in the *Standards for Technological Literacy* cover many of the concepts and principles associated with design and using the design process to solve problems. Further evidence of the importance of learning about engineering design can be seen in the draft version of the soon to be released *Next Generation Science Standards* (National Research Council, 2012) that states a commitment to

> fully integrating engineering and technology into the structure of science education by raising engineering design to the same level as scientific inquiry in classroom instruction when teaching science disciplines at all levels, and by according core ideas of engineering and technology the same status as core ideas in the other major science disciplines. (p. 1)

Teaching about engineering design to those in STEM can be accomplished through PD.

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Today in America, there is a call to increase student's interest in STEM that places an emphasis on inquiry based learning approaches and engineering design. In his 2012 State of the Union address, President Barack Obama stressed the importance of STEM education by stating, "Think about the America within our reach: A country that leads the world in educating its people. An America that attracts a new generation of high-tech manufacturing and high-paying jobs." Important in the training of the next generation of STEM education teachers is to identify ways of integrating engineering design into the science, math, and technology education areas. One method of integrating the concepts of engineering design into science, math, and technology education is through PD.

A need exists to examine factors that can contribute to successful PD in the STEM areas, especially as it concerns integrating engineering design into core academic subject areas. To help advance these efforts, a qualitative study was conducted to examine the effects of PD on infusing engineering design and problem solving into STEM curricula areas.

Professional Development in STEM Education

Professional development is important to STEM education, especially in the areas of technology and engineering. If engineering is to be recognized as an integral part of science, technology, and math education, stakeholders, organizations and/or people directly involved have to share the burden of responsibility for these ideas to become reality (Bybee & Loucks-Horsely, 2000). Many feel that this can be achieved through PD, especially PD that promotes a deep understanding of the subject matter along with the best pedagogical practices. A deep understanding of the subject matter helps teachers to facilitate student learning (Shulman, 1986).

Brophy , Klein, Portsmore, & Rogers (2007) point out that there is a need to identify methods for helping P–12 teachers develop the necessary skills and capabilities to connect students with engineering design in the classroom. Moreover, if teachers are to inspire or encourage students to pursue a career in engineering or any of the STEM fields, they need to be aware of what engineers are and what they do; this can also be achieved through PD.

In developing PD in the area of STEM, Custer, Daugherty, Zeng, Westrick & Merrill (2007) note that there are many facets related to the development and delivery of effective PD programs. These facets include: (a) research plans, (b) development of a philosophical focus, (c) identification of standards-based curriculum materials, (d) collaboration amongst STEM disciplines, (e) formulation of effective PD models, (f) research specific to pedagogical content knowledge, and (g) general justification and promotion of engineering and technology education as a recognized part of K–12 education. The focus of this study is on (e): the formulation of effective PD models

Central to this study were the STEM PD efforts conducted by the National Center for Engineering and Technology Education (NCETE). In 2005 and 2006, NCETE sponsored a series of PD activities that steered a number of research efforts at various universities including: California State University, Los Angeles (CSULA); University of Wisconsin-Stout; Brigham Young University; and the University of North Carolina A&T. The purpose of these activities were related to the identification of core engineering concepts, the production of logic models of effective PD, and the development of successive engineering design challenges (Asunda, 2007; Asunda & Hill, 2007; Custer, Daugherty, Zeng, Westrick, & Merrill (2007).; Tufenkjian & Lipton, 2007).

This study focused on the PD activities held at CSULA during the spring and summer of 2006. The purpose of the study was to investigate the overall effects that the NCETE STEM PD had on teaching practices. The results of the study were used to produce recommendations that could be used by PD developers to enhance the quality of STEM PD programs.

Background of the Study

Two years had elapsed between the 2006 NCETE-sponsored PD workshops at CSULA and the time that this study was conducted. During the interim, teachers who participated in these workshops had ample time to modify their instructional materials to include what they learned into their classroom and laboratory projects. Based on what was presented in the NCETE/CSULA PD workshops, this qualitative case study concentrated on the following research questions:

1. What effects did the PD have on teachers' classroom practices in terms of the PD content that they incorporated?
2. What types of challenges did teachers face as they implemented what they learned from the PD workshops?
3. What benefits did the PD provide in terms of teaching as well as the teachers' perceptions of benefits to student learning?

The NCETE professional workshops were broken up into two phases, consisting of a spring and a summer workshop. The spring workshop phase consisted of six Saturday meetings from 9:00 a.m. to 5:00 p.m. This schedule was intended to reduce any interference with the teachers' respective teaching schedules. The workshops focused on the following actions: (a) Setting the scene, (b) creating a cohort, (c) describing the engineering profession, (d) diagnosing abilities, (e) providing foundational instruction, and (f) introducing the engineering design method (E. Lipton, personal communication, September 15, 2008). Particularly, the spring phase was dedicated to providing each of the teachers with the necessary math and science content knowledge needed to succeed in engineering problem solving and to introduce the engineering design process. In addition, the spring phase included STEM applications and activities, presentations given by guest speakers from the CSULA engineering department (i.e., electric and civil engineering instructors), pedagogy (i.e., project-based learning involving active, collaborative learning, open-ended problem solving, critical thinking, and tangible outcomes), and outside experiences (i.e., tour of CSULA engineering facilities and a field trip to Cal Tech's seismic research facility).

The summer workshop phase consisted of five 8-hour-long sessions that were given within a one-week period. The focus of the summer workshop was to: (a) model how an engineering design challenge was performed in the class, (b) provide teachers practice with how to solve design problems, (c) teach the teachers how to infuse engineering design into high school programs, (d) study curriculum models, and (e) learn how to assess engineering design. Specifically, the summer phase concentrated on giving the participants instruction and practice in the application of an exemplar teaching model related to the design of earthquake resistant buildings.

Research Design

This qualitative case study organized three sources of data concerning NCETE PD workshops at CSULA: teacher interviews, teacher documents, and classroom observations. The data in this study were collected from four in-service high school teachers who participated in the 2006 NCETE PD workshops. The three sources of data were examined to ascertain patterns and themes. It is important to note that the teachers who participated in this study were between 2 to 3 years removed from the workshops. This gave each teacher ample time to reflect on what they learned during the workshops and to implement what they learned into their teaching practices. After receiving teacher consent, a one-hour in-person recorded interview was conducted with each teacher at their school.

The interview questions were based on the previously stated research questions, and an interview guide was used to direct the researcher during the interviews. The interview guide consisted of seven open-ended questions and a series of probing questions that were used to extract more in-depth responses. In addition to the teacher interviews, triangulation of the data was achieved through the collection of teacher documentations and classroom observations.

Teacher Documents

In this study, teachers were interviewed and teacher documents, such as course outlines, lesson plans, and design briefs, were collected and reviewed to see how teachers had revised their classroom and laboratory practices. According to Stake (1995), this method assists in the search for the convergence of information and is directly associated with data situations in the development of a case study. Examining teacher documents provided further insight into the effect that the NCETE/CSULA PD had on the infusion of STEM education into their high school curricula. Evaluation of teacher documents was facilitated through the use of a seven-step engineering design process model that contains a checklist, which included each step of the engineering design process as presented to the 2006 teacher workshops participants. The researcher evaluated the teacher documents to see how closely they aligned with each of the seven-steps.

Classroom Observations

Classroom observations were conducted during the winter of 2009 to help triangulate the findings of this study. These observations, collected as field notes, were used to corroborate statements made during each teacher interview, especially as it concerned how each teacher was using what they learned in the workshops. Overall, the classroom observations helped to provide a better understanding of student behaviors as it concerned STEM learning.

NCETE/CSULA PD Workshop Documents

An additional source of information used to inform this study was the NCETE/CSULA 2006 summer workshop documents. These documents provided guidelines for infusing engineering design into their instructional materials and were helpful in analyzing and linking teacher statements to what actually transpired during the workshop.

Data Analysis

The analysis of data was performed using a qualitative case study approach. Case studies are particularly useful in depicting a holistic portrayal of individual experiences and results regarding a program (Patton, 2002). There is no standard format that exists for analyzing and reporting case study research (Creswell, 1998). Each qualitative case study is unique; therefore, each analysis of a study is unique (Patton, 2002). The analysis of data was customized and revised to specifically address the research question (Huberman & Miles, 1994).

Data were organized in a way that illustrated how each teacher was applying what they learned in the workshops in their classrooms to develop a case study narrative. The narrative is a readable story that integrates and summarizes key information around the focus of the case study. The narrative was structured so that the results could be understood and interpreted by readers unfamiliar with the project (Creswell, 1998).

After reviewing each of the teacher's individual responses, visual images or tables of the data were created to identify themes that were common to each teacher's individual case (Spradley, 1980). This was done to package the information collected through the interviews. To do this, each teacher's case was cross-compared to isolate themes or patterns from their individual responses. From these individual responses, relevant themes emerged which were used to generate overall thematic findings. For example, individual teacher cases were compared to ascertain commonalities within each of the teachers' experiences and how each of the teachers implemented what they learned in the workshops. These commonalities highlighted the strengths and weaknesses of the

NCETE/CSULA PD workshops. Aspects of this study included: (a) demographic information about the teachers (collected prior to the interviews), (b) ways in which the teachers integrated engineering-related PD content and pedagogy into their instructional materials, (c) major differences in instructional methods noticed about the teachers after the PD workshops, (d) indicators of successes and failures, and (e) key quotes from the teachers concerning how the NCETE PD workshops affected their instructional practices.

The analysis of qualitative case study data adheres to a rather logical sequence of steps that employ an iterative model. In this study, an iterative model proposed by Huberman and Miles (1994) was used. This model conformed to a meticulous data analysis spiral and consisted of the following general procedures:

1. Data Reduction—finding a focus, managing data, reading and annotating
2. Data Display—categorizing data, linking data, connecting categories
3. Conclusion Drawing and Verification—corroborating evidence, producing an account.

Data reduction. The first step in the qualitative case study analysis process is data management (Huberman & Miles, 1994). This process helps to facilitate the organization of data into file folders, index cards, and computer files. Following the organization and conversion of audio-recordings into text, the transcripts were read thoroughly while the audio recordings were methodically reviewed several times. By doing this, an overall understanding of the material was developed (Tesch, 1990).

Data display. Each participant's interview was analyzed for a detailed understanding of the effect that NCETE-sponsored PD had on teaching methods. Subsequently, each teacher interview was scrutinized to expand the researcher's understanding of each teacher's perception. Finally, a cross-comparative analysis of all of the teachers' experiences was performed after each individual interview was scrutinized to determine what the common experiences were with regards to infusing engineering content into their classroom and laboratory instruction (Yin, 1989).

During the analysis of the data, the narratives of the teachers' statements were written as separate accounts to avoid losing the individual value of each of the teacher's statements. These individual statements were then compared with other teacher statements for connections or similarities of data which fostered the development of themes based on the effect that the NCETE-sponsored PD had on their instructional practices.

According to Lincoln and Guba (1985), interpretation involves making sense of the data or what can be called the lessons learned. These interpretations may stem from a social science construct or idea or from an amalgamation of personal insights when compared or contrasted with a social construct or idea. At this point in the analysis, the researcher had the capacity to form a more pragmatic view of what transpired in regards to the effect that the NCETE-sponsored PD had on infusing engineering design into STEM classroom and laboratory projects.

Description of PD Workshop and Teacher Backgrounds

The goal of the 2006 NCETE PD activities at CSULA was to facilitate the teaching STEM concepts and principles, especially as it concerned engineering design, to high school students. Specifically, NCETE learning outcomes that were associated with the CSULA PD goals were as follows: (a) develop teachers' instructional decision making to focus on the analytical nature of design and problem solving needed to deliver technological and engineering concepts, (b) facilitate teacher initiated change in program design, curricular choices, programmatic and student assessment, and other areas that will impact learning related to technology and engineering, (c) develop teachers' capabilities as learners so that they assume leadership for their PD activities, including recruiting and mentoring their colleagues, (d) create a pool of highly skilled cooperating teachers who would accept pre-service technology teachers into their classrooms and mentor the next generation of technology/engineering teachers to effectively teach students of diverse backgrounds, (e) develop engineering analysis and design skills in technology teachers, including strengthening their mathematics and science knowledge and skills, and (f) develop curriculum integration and collaboration skills in practicing technology teachers so that they could effectively collaborate with science and mathematics teachers (D. Maurizio, personal communication, September 16, 2008).

Population

Although there were originally seven teacher participants in the 2006 workshops, one retired (early), and another dropped out due to health reasons. So the final pool consisted of five teachers. Out of these five teachers, four teachers from the 2006 cohort agreed to participate in the study. The teachers who participated in this study included 1 female and 3 males. They will be referred to as Teachers A (female), B, C, and D.

The teachers that participated in the CSULA/NCETE PD workshops during the spring and summer of 2006 were diverse with respect to their educational backgrounds, experiential knowledge, and teaching needs. Two of these teachers (A and B) entered the workshops with no previous experience teaching STEM-related content. They both taught core academic subjects (physics and chemistry). The other two teachers (C and D) entered the workshops with previous experience teaching STEM-related content. The following paragraphs present a brief background of the teachers who participated in the study.

Teacher A. Teacher A earned a bachelor's degree in biology. Although she was credentialed to teach biology, she had been teaching physical science and chemistry classes for 6 years at the time of the study. She had experience teaching gifted and non-gifted students and also mentioned that she mentored other teachers on how to teach science. Prior to her participation in the PD workshops, Teacher A had no engineering experience and no prior involvement with STEM education.

Teacher B. Teacher B, a chemistry teacher, started his teaching career as a long-term substitute teacher who worked with troubled youth for 3 years. He spent 2 years teaching English in Costa Rica. At the time of the study, it was his third year teaching high school chemistry. Like Teacher A, he also entered the PD workshops with no engineering experience and no prior involvement with STEM education.

Teacher C. Teacher C, who had a degree in industrial education, was also credentialed in physics and math. At the time of the study, he had been teaching STEM-related courses (e.g., electronics, mechanical design) for more than 20 years. After attaining his degree in industrial education, he decided to take engineering courses to help accentuate his understanding of engineering design and problem solving. He seemed to have the most experience teaching STEM-related content.

Teacher D. Prior to his participation in the NCETE workshops, Teacher D worked as an electrical engineer who made a career change to become a high school teacher. Because he had industrial experience as an engineer, it seemed fitting that he taught Career and Technical Education (CTE) classes such as robotics, digital electronics, computer programming, and physics. Teacher D received a B.S. in electrical engineering and also had a credential in physics with an authorization in math.

Findings and Discussion

During the analysis of the data collected in this study, three major themes common to all the research questions emerged: (a) incorporation of PD content, (b) challenges with incorporating PD content, and (c) benefits of incorporating PD content. These themes were helpful in answering the aforementioned research questions and are discussed in the following sections.

Findings Related to Theme #1: Incorporation of PD Content

Research question one examined the effects that PD had on teachers' classroom practices in terms of the PD content that they incorporated into their teaching practices. Bear in mind that the NCETE PD workshops focused on STEM educational theories and issues concerning how to teach students problem-solving and analytical skills, and how to apply this knowledge within a real-world context. In this study it was found that each of the teachers mentioned that the workshops provided an educational model that demonstrated how teachers could better integrate these theories into their classroom practices through contextualized problem-solving activities and real-world applications. These findings revealed that the NCETE PD workshops appeared to have a positive effect on helping the teachers to connect STEM educational theories with teaching practices and, in turn, provide their students with more enriching learning experiences.

Findings Related to Theme #2: Challenges with Implementing PD Content

Research question two examined the types of challenges that teachers faced as they implemented what they learned from the PD workshops. In this study, it was found that challenges with implementing the NCETE PD content were as follows: (a) evaluating group projects (e.g., all teachers felt that they needed to learn how to better assess group projects), (b) standards-based pressures (e.g., Teachers A, B, and C mentioned how there was not enough time to do STEM projects for every lesson rather they needed activities or projects that could be completed in one to two class sessions), (c) availability of authentic engineering design challenges (e.g., Teachers A and B noted that very few so-called engineering design challenges required predictive analysis prior to building something), and (d) developing STEM lessons (e.g., due to the lack of STEM projects that required students to use predictive analysis, more training on how teachers could develop their own was desired, especially as it concerned Teachers A and B).

Findings Related to Theme # 3: Benefits of Incorporating PD content

Research question three examined the benefits of incorporating STEM PD content into high school curricula. This thematic finding was viewed in light of both teacher and student benefits. Based on each of the teachers' perceptions, they felt that the STEM PD benefitted their classroom practices because it: (a) facilitated teaching, (b) increased student motivation for STEM learning, (c) kept students engaged with the subject matter, (d) increased student appreciation for science and math, (e) improved student thinking and problem-solving skills, and (f) improved student learning.

The findings of this study revealed key areas/issues that are pertinent to developing effective STEM PD programs. The following paragraphs present a brief discussion of these area/issues and, in turn, were used to extract recommendations for developers of STEM PD programs.

Supportive Teacher Learning Environment

The importance of having a supportive environment cannot be emphasized enough when conducting a STEM PD program. The professionalism and support provided by the workshop staff and coordinators stood out in the minds of the teacher participants. They mentioned the importance of : 1) serving good and healthy meals, 2) providing teacher stipends, 3) having a willingness to listen to teacher ideas and recommendations for PD improvement, 4) having good PD presentational and organizational skills, 5) showing respect for what teachers do and teach, and 6) providing the necessary support for teachers to sustain what they learn through STEM PD. The above factors left a positive impression plus imparted a feeling of acceptance, worth, and appreciation for the teachers participating in PD.

STEM Teaching Model

Each of the teachers in this study noted that the engineering design challenge, which was used as a STEM teaching model, had a lasting effect on their teaching practices. This STEM teaching model helped to delineate how to teach students engineering problem-solving and analytical skills, as well as, how to apply this knowledge within a real-world context (as noted in Theme #1). For example, Teacher C stated that "the teaching method is one thing that the workshops solidified." He went on to explain,

> …what the workshops actually did for me was to give me an engineering model where you define the problem, I present the physics, and the chemistry, then the mathematical tools, then we make an actual model.

Furthermore, Teacher D explained that when he took the workshops, it was during his first year of teaching and the workshops helped him to look at his previous position as an engineer and view it within a teaching context "so it was a wonderful model to have for a reference point."

A STEM Philosophy

For each of the teachers in this study, it was important that the STEM PD workshops were based on a strong STEM educational philosophy. For Teacher D, one of the strongest impacts of the STEM PD was, in his words, "the philosophy of the workshops…the attempt to integrate [science, technology, engineering, and math] at the same time and the fact that it is possible to do it and that you will get better results." It was also noted that without a strong rationale (or justification) for doing engineering projects in the classroom, teachers and schools may be less likely to buy into STEM PD efforts.

Evaluation of Group Projects

Those who develop STEM PD should consider all aspects of developing and implementing STEM projects including student group work. Each of the teachers in this study mentioned the challenges that go along with evaluating students working in group settings. For example, Teacher A discussed how she sometimes found it difficult to discern which students were contributing and which students were not. She explained, "when you're doing group work, it's really hard to know whose really working and who is not…" Teacher D also discussed similar challenges with evaluating student projects and group work. Despite these challenges, all of the teachers noted the importance of working in a team environment. They felt that it was an important life skill that transcends the STEM disciplines.

Standards-Based Pressures

As previously noted (See Theme #2), standardized testing pressures affected the amount of time teachers could dedicate to STEM learning, especially as it involved the delivery of engineering design challenges. Although the teachers in this study expressed a desire to employ more of what they learned in the PD workshop, these standards-based pressures impeded their ability to infuse more engineering design/STEM projects into their lesson plans. For example, Teacher B stated that, "I can't have an open-ended challenge that takes two weeks…It just won't work."

To address the above concerns with standards-based pressures, the teachers in this study acknowledged that the PD workshops inspired them to develop their own standards-based STEM lessons so that they could satisfy their individual teaching needs. Teacher B stated, "I need little mini lessons…little mini challenges that the kids can do." To add, Teacher D stated, "it would actually be a distraction in the physics classroom to do a large number of projects." Overall, the teachers that taught core academic subjects, such as physics and chemistry (Teachers A, B, and D), expressed that they did not have much time to spend on one particular project. Instead, they expressed a need for smaller, less time-intensive projects that could support the educational materials needed to prepare their students for standardized testing.

Recommendations

To address the above issues and challenges, the following six recommendations are presented, as a sort of a framework, for those involved in the development and delivery of STEM PD programs:

Recommendation #1: Provide a Supportive PD Environment

It is recommended that STEM PD developers provide an environment that is: 1) organized, 2) supportive of the personal and professional needs of teachers, and 3) values the input of teachers. This way, teachers can gain a greater sense of ownership and, in turn, be more inclined to buy into and sustain STEM PD efforts.

Recommendation #2: Provide an Exemplar Engineering Design Challenge

To lay a good foundation for infusing STEM education into traditional classrooms, especially as it concerns engineering design and problem-solving, it is recommended that STEM PD developers provide an exemplar engineering design challenge (EDC) for teachers to use as a reference model. The EDC should demonstrate how to do engineering design and problem-solving within and outside of the classroom. Moreover, it should include aspects of the engineering design process, i.e., keys steps used in the problem solving processes that engineers use to solve real-world problems. The EDC should be available for teachers, if they so choose, to integrate into their instructional materials. For teachers who have never done engineering design with their students, this will help reduce uncertainties about how to effectively perform projects that involve STEM learning.

Recommendation #3: Provide Training on Managing Group Projects and Evaluating Student Contributions

It is recommended that STEM PD developers continue to provide insight and training to teachers concerning how to evaluate group projects, especially as it deals with assessing individual student participation. Group work is time consuming and may involve covering less topics but research reveals that group work helps students to develop an enhanced ability to solve problems and indicate a better grasp of the material (Cooper, 1990). Plus, it is reflective of how people work together in a real-world setting.

Recommendation #4: Developers of STEM PD Should Consider Standards-Based Pressures That Impact STEM Learning

It is recommended that designers of STEM PD continue to consider ways to help teachers remediate the standards-based pressures they face when they engage in teaching STEM-related content. The following recommendations may proffer suggestions for this overarching issue:

Recommendation #5: STEM PD Should Train Teachers How to Develop Their Own Standards-Based, Engineering Design Challenges

It is recommended that designers of STEM PD provide training to teachers on how to develop their own standards-based, STEM lessons and engineering design challenges. Furthermore, this training should provide teachers with strategies on how to develop more short term STEM and engineering design challenges. As a corollary, Wilson (2007) states that PD needs to employ teacher knowledge as an integral component of the PD design as well as bridge the gap between research and practice.

Recommendation #6: STEM PD Should Train Teachers How to Integrate STEM Concepts into Their Instructional Materials

Designers of STEM PD should include training on how teachers can integrate appropriate levels of science, technology, engineering, and math into their curriculum content. To do this, it is recommended that PD developers review appropriate STEM content standards (e.g., those that will be included in the *Next Generation Science Standards*) that provide grade appropriate learning experiences.

STEM PD should not only be viewed as a means of making learning more relevant for students but should also be considered as a means of bringing greater relevance to teaching.

Conclusion

With recent pushes in the U.S. to infuse engineering design into science, math, and technology education, the preparation of teachers with the ability to develop relevant and high quality STEM programs becomes vital to these efforts. Given that teachers have a direct influence over student learning, it is important to invest the necessary resources to help teachers provide the best quality STEM education for their students. Achievement of these goals can be realized through quality PD programs.

Because of its interdisciplinary nature, the delivery of STEM education, especially as it concerns engineering design, requires teachers to cover a wide range of academic concepts and principles while making meaningful connections between various academic subject areas. In developing STEM PD, it is important to note that teachers will be unique with respect to their educational environments, backgrounds, and experiential knowledge. This means that a one-size-fits-all model will not be conducive to preparing a diverse group of teachers with the necessary knowledge, skills, and abilities to deliver STEM education to their students. This is especially true as it concerns core academic subjects such as math and science which have added pressures due to standardized testing requirements. Moreover, teachers will be expected to provide their students with a good balance between rigor and relevance while using engineering design as an organizer for core academic subjects such as science and math.

As learned through this study, the development of effective STEM PD programs requires a synthesis of approaches that incorporate the best educational practices found in: a) general PD literature, b) science and math PD research, as well as, c) engineering and technology PD research. By doing this, as a nation, we can better provide existing and future teachers with a profound understanding of the subject matter they convey. In turn, these teachers can help cultivate the minds of the next generation of creative thinkers that will carry the world forward in terms of scientific and technological innovation.

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