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Extending Teacher Professional Development through an Online Learning Community: A Case Study

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Abstract: *The Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue University in the U.S. was established in 2006 to integrate engineering and engineering thinking into the Pre-Kindergarten-12th grade education. The institute provides elementary teachers with pioneering professional development in engineering education through a week-long face-to-face Summer Academy and an online professional development program. The purpose of this paper is to describe the process of the P-6 engineering education teacher professional development, and meanwhile, present a set of design principles to extend teacher professional development through an online learning community.*

Keywords: teacher professional development, online learning community, needs assessment, dual approach, design principles

1. Introduction

Bruner (1960) argued that children are ready to learn when teachers are ready to teach. The National Commission on Teaching and America's Future (1996) reported, "What teachers know and do is the most important influence on what students learn (p. 6)." At its root, achieving high levels of student understanding requires greatly skillful teachers and schools that are organized to support teachers' continuous learning.

The National Center for Educational Statistics (1998), the National Commission on Teaching and America's Future (NCTAF, 1996), and the Third International Mathematics and Science Study (U. S. Office of Education, 1996) stressed that students' achievement is closely related to the pedagogical knowledge, content skills, and instructional practices of teachers (Cavallo, Ferreira, & Roberts, 2005).

Engineering education in P-12 (elementary-secondary school level) became urgent in recent years. The number of engineers graduating from U.S. institutions has slipped 20 percent in recent years. The United States graduates only 75,000 engineers each year, while China graduates 350,000 and India produces 200,000 graduates. At the same time, more than half of the U.S. workforce in the sciences and engineering is approaching retirement age (Jobs for the Future, 2007). In an age whereby technology is ever evolving, the U.S. needs to keep up with competing countries and our place in the technological world.

Why is the U.S. producing so few engineers? Why are high school and university students not choosing engineering as a career? Recent data reveals that there is waning student interest in engineering, poor educational preparedness, a lack of diverse representation, and low persistence of current and future U.S. engineering students (NAE, 2008). Young scholars need to be involved in the next generation of innovative ideas that support our society's needs. Becoming increasingly clear, the answer begins in elementary school. The interest and drive to participate in engineering must be fostered at an early age (Duncan, Oware, Cox, & Diefes-Dux, 2007).

Unfortunately, engineering is not traditionally part of the P-12 curriculum in America. While engineering activities are more and more incorporated into the secondary level (grade 9-12) (see for an overview Brophy, Klein, Portsmore, & Rogers, 2008), engineering in elementary classrooms is very rare. At the same time, curricula incorporating engineering-like activities in American P-12 schools are not standardized like other curricula such as mathematics or literature (only a small amount of states such as Massachusetts have even explicit engineering standards). Similarly, pre-service teacher education does not include engineering, so teachers are not educated on how to teach or integrate engineering into the P-12 system. In addition, engineering content is not included in standardized achievement tests either. Anecdotal evidence from INSPIRE's four summer academies indicated that (a) many teachers are apprehensive about attempting to teach Engineering topics; (b) teachers are likely uncomfortable teaching engineering concepts to their students because they, themselves, hold many preconceptions about engineering; and (c) teachers are more likely to devise their own curriculum materials and their own outcome measures. Given the sporadic nature of engineering in schools, the quality of teacher preparation is critical if students' learning of engineering needs to be improved. The purpose of this paper is to describe the process of the P-6 engineering education teacher professional development as devised by INSPIRE and present a set of design principles to extend teacher professional development through an online learning community.

1.1. Online Teacher Professional Development (oTPD)

Online learning environments are rapidly emerging across various sectors of society (Dede, 2006). In education, opportunities to access a wide range of courses and professional development services are now available on the Internet. In recent years, cyber-enabled professional development has expanded rapidly throughout higher education, corporate training, and the P-12 arena. Organizations and institutions are increasingly offering cyber-enabled professional development opportunities to P-12 educators (see Dede, 2006 for many state-of-the-art examples on online teacher professional development).

Because finding time and resources for P-12 educators can be challenging, cyber-enabled instruction offers a convenient, accessible, and often inexpensive method for updating pedagogical expertise. This also provides opportunities to build a long-term plan for the development of teachers' pedagogical and content skills in an educational environment that, unlike short-term workshops, provides ongoing learning, mentoring, and networking opportunities (Barab, Kling, & Gray, 2004).

Yet, Web-based learning environments are new, and principles for the design of these environments are just emerging (Duffy & Kirkley, 2004). In particular, support practicing professionals in a "learning anytime, anywhere" mode can be quite challenging. However, the

design of these types of environments can hold unique opportunities for enabling P-12 teachers to seek convenient, yet high quality professional development opportunities to help them meet personal and professional goals.

1.2. Theoretical Perspectives Underlying Online Teacher Professional Development Community

Forming a community in online teacher professional development is essential. According to Wilson and Ryder (1996), "groups become communities when they interact with each other and stay together long enough to form a set of habits and conventions and when they come to depend upon each other for the accomplishment of certain ends" (p. 801). This description is consistent with Shaffer and Anundsen (1993), who wrote that communities can be defined as a dynamic whole that emerges when a group of people share common practices, are interdependent, make decisions jointly, identify themselves with something larger than the sum of their individual relationships, and make long-term commitments to the general group's well being (Shaffer & Anundsen, 1993).

From Vygotsky's social constructivist perspective, the sociocultural context influences the thinking and creation of meaning. Meaning making is a process of negotiation among the participants through dialogues or conversations. The opportunity to interact with other learners in sharing, constructing and negotiating meaning leads to knowledge construction. Within a constructivist model, learning is based on constructing meaning from experience, and interpreting the world largely through the social processes (Jonassen, 2000).

A constructivist framework with a focus on the situated and social nature of learning was used as theoretical framework in the majority of the research done on teacher professional development. One good example is the Learning to Teach with Technology Studio (LTTS) project. This online professional development system helps teachers learn to integrate technology into their content-focused teaching. The LTTS professional development environment was designed to aid teachers in designing teaching units or lesson plans in which knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings (Dede, 2006).

Communities of Practice are viewed as emergent, self-reproducing and evolving entities, which are distinct from, and frequently extend beyond, formal organizational structures with their own organizing structures, norms of behavior communication channels, and history (Wenger, 1998). Members often come from multiple organizations, drawn to one another for both social and professional reasons. Newcomers gain access to the community's professional knowledge tools and social norms through peripheral participation in authentic activities with other members (Schlager & Fusco, 2004).

At the third Harvard Graduate School of Education Usable Knowledge Conference (Dede, 2006), innovative online teacher professional development (oTPD) programs such as WIDE World, PBS TeacherLine, and Indiana University's Learning to Teach with Technology studio (LTTS) shared several common themes - the theoretical background of all ten presented programs were social constructivist and involved community of practice. Online professional development seems to tailor to teachers' busy schedules and the offering draws on valuable resources not only available locally but also globally. In addition, the programs provide work-embedded support. By creating additional and more

flexible delivery models and design principles, oTPD will be in a better position to support interventions that are significantly embedded in professional development.

1.3. INSPIRE

There is a need for research and discovery-based educational programs to introduce elementary educators and students to engineering. For this reason, the Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue University in the U.S. was established in 2006 to integrate engineering and engineering thinking in P-12 education. INSPIRE provides elementary teachers with professional development in engineering education through week-long face-to-face summer academies and online professional development programs. This project's concept of "teacher professional development" involves (a) knowledge and appreciation of engineering, (b) identification of different engineering disciplines, (c) association of engineering with science, math and literacy, (d) an understanding of engineering design process, (e) an awareness of resources (including digital resources) for the classroom, (f) a dedication to their own inquiry and continued professional development, (g) heightened confidence in the uses of instructional technology, and (h) a fundamental sense of wonder and passion for engineering that will inspire students.

2. A Case Study

The purpose of this paper is to describe the process of a P-6 pioneering engineering education teacher professional development, meanwhile discussing a set of design principles to extend teacher professional development through an online learning community based on an administered survey.

2.1. INSPIRE Face-to-Face (F2F) Teacher Professional Development

INSPIRE provides teacher professional development for elementary teachers to: (a) convey a broad perspective of the nature and practice of engineering; (b) articulate the differences and similarities between engineering and science thinking; (c) develop a level of comfort in discussing with P – 6th grade students what engineers do and how engineers solve problems; and (d) use problem-solving processes (i.e., science inquiry, model development, and design processes) to engage elementary students in complex open-ended problem solving. The over-arching goal is sustainable integration of engineering in elementary education with evidence of student and teacher achievement of learning goals.

The INSPIRE instructional team comprises of engineering education professors (with backgrounds in engineering), K-12 teachers, graduate students from educational psychology, engineering education, educational technology, and engineering. Our primary form of Face-to-Face TPD is the *National Summer Academy*, a one-week workshop for elementary educators interested in integrating engineering thinking into their classrooms. Since the inaugural Academies in 2006, two local and two national (representing 16 states) academies have directly impacted over 120 teachers. The Academies serve two additional purposes. First, they are a research site for piloting TPD with engineering. Second, they enable identification of research partner schools. The Academies, in their current form, will continue to be used to identify partner schools, and their curriculum will form the basis for initial TPD.

2.2. INSPIRE Online Teacher Professional Development (oTPD) Needs Assessment

We recognize that the literature on professional development for in-service teachers' points towards (a) just-in-time delivery in the setting of the teachers, (b) tailored to individual needs of teachers in regards to very specific questions in very specific contexts, and (c) community development to allow teachers point-to-point communication with other teachers and very guided online communities (Dede, 2006; Lawless & Pellegrino, 2007). Further, research in professional development of teachers shows that the highest amount of dissatisfaction stems from the teachers perception (a) that training is focused only on the lowest common denominator amongst the teachers,)"my questions are more detailed and more specific than what is addressed in the workshop"), (b) that there is a disconnect between the context of the training and the context of teaching ("my classroom environment is different than presumed in the workshop"), (c) a perceived lack of support, when ideas of the workshop are implemented ("I would need feedback and support around my classroom"), and (d) misalignment with goals and the visions of stakeholders (Lawless & Pellegrino, 2007).

To corroborate previous research and ground our TPD, the INSPIRE team conducted a needs assessment amongst participating teachers. 36 teachers participated in a survey to determine the needs for our online teacher professional development community for engineering in elementary schools (see demographics in table 1). The survey results show that there is a perceived need and willingness to participate in an online community for teachers (Figures 1&2). The respondents indicate that they would use the community for collaborative and collegial purposes (Figures 3&4). Input and participation from staff representatives from INSPIRE are also desired (Figure 5).

Table 1. Demographic Characteristics of Teacher Participants

N	Gender		Region				Years of teaching		
	Female	Male	Indiana	Texas	New Mexico	Florida	0-3 years	4-7 years	Over 7 years
36	33	3	19	6	4	7	6	8	22

Figure 1

Figure 2

I would use an online community to find others to collaborate with on INSPIRE units

Figure 3

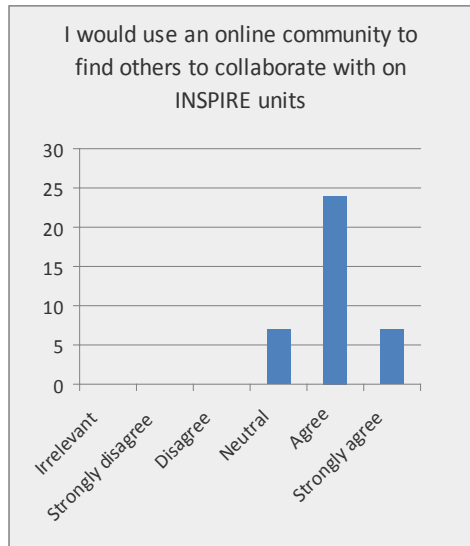I would use an online community to find colleagues with whom I could discuss issues related to engineering instruction
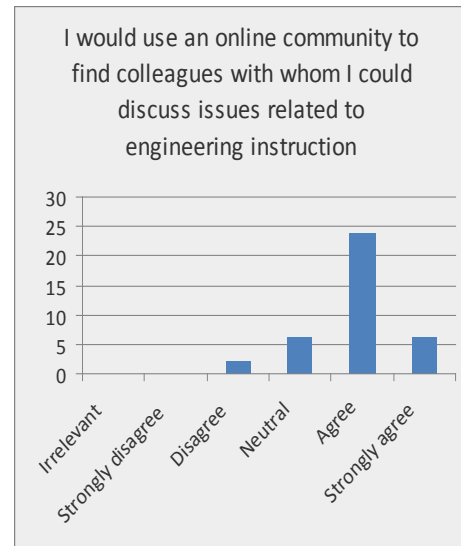
Figure 4

The teachers, which participated in the study also ranked factors that would discourage and encourage their participation in an online teacher community for INSPIRE. The participants indicated time and lack of support as primary factors that would discourage participation (Figure 6). Access to resources such as implementation guides and new activities were ranked as the primary factors that would encourage participation, followed by collaboration with other INSPIRE teachers and support from INSPIRE staff (Figure 7). In an open-ended response, one teacher desires "continual access to new information and a forum to keep the momentum going to sustain the INSPIRE effort in our school." Another teacher writes, "I would like to be able to ask someone about specific questions that I may not feel comfortable about."
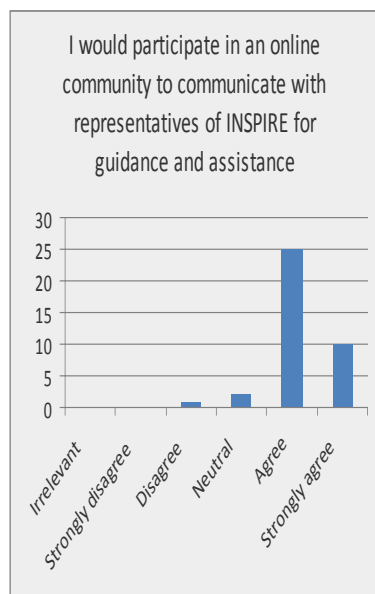

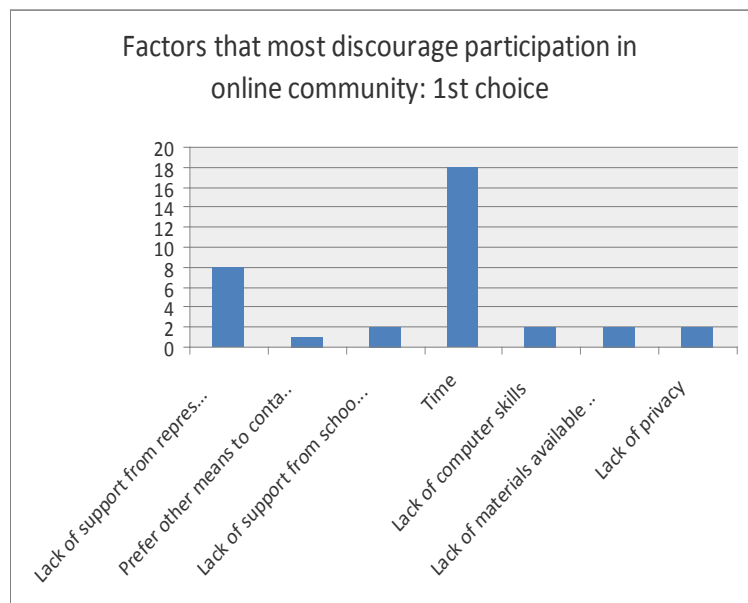I would participate in an online community to communicate with representatives of INSPIRE for guidance and assistance

Figure 5

Factors that most discourage participation in online community: 1st choice

Figure 6

Figure 7

Factors that might encourage your participation in our e-community: 1st choice

Category	Value
Access limited (for privacy concerns) to only those who have participated in the INSPIRE academies	2
Reunite with fellow academy participants, share stories and meet new participants	0
Contribute and provide feedback to INSPIRE development process	2
Access implementation guides and new activities from INSPIRE	16
Opportunity to contribute/mentor for other teachers from INSPIRE academies	2
Support from INSPIRE staff	6
Collaboration with other teachers from INSPIRE academies	10

Figure 7

Figure 8

Indicate your level of interest in each of the following things below that could be provided by an online community for INSPIRE participants

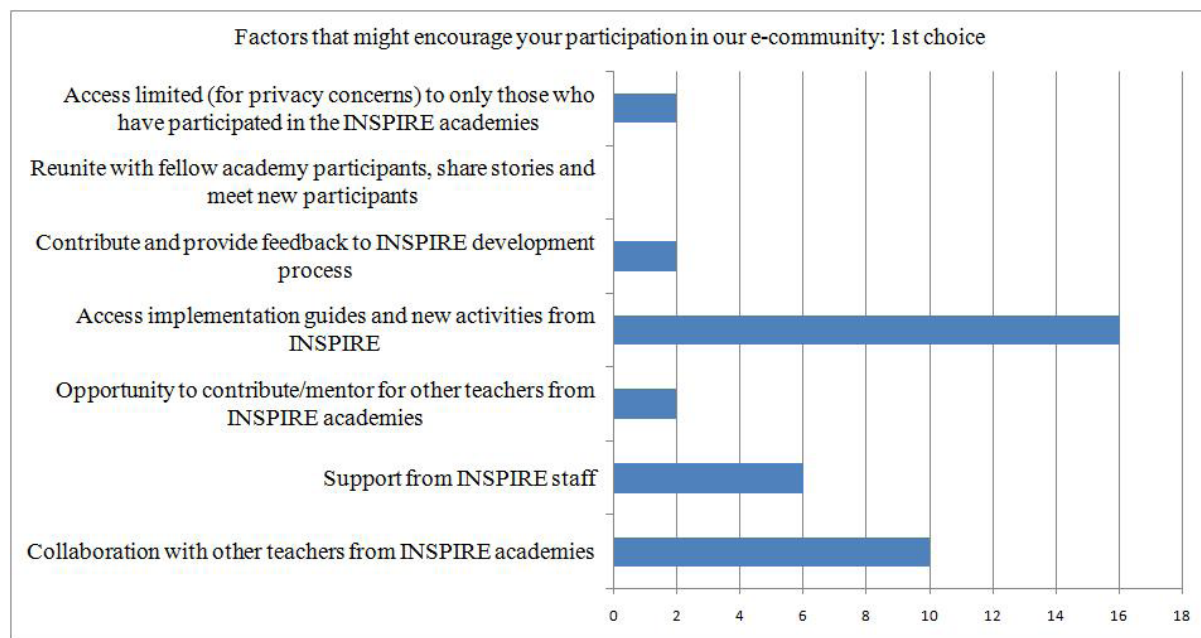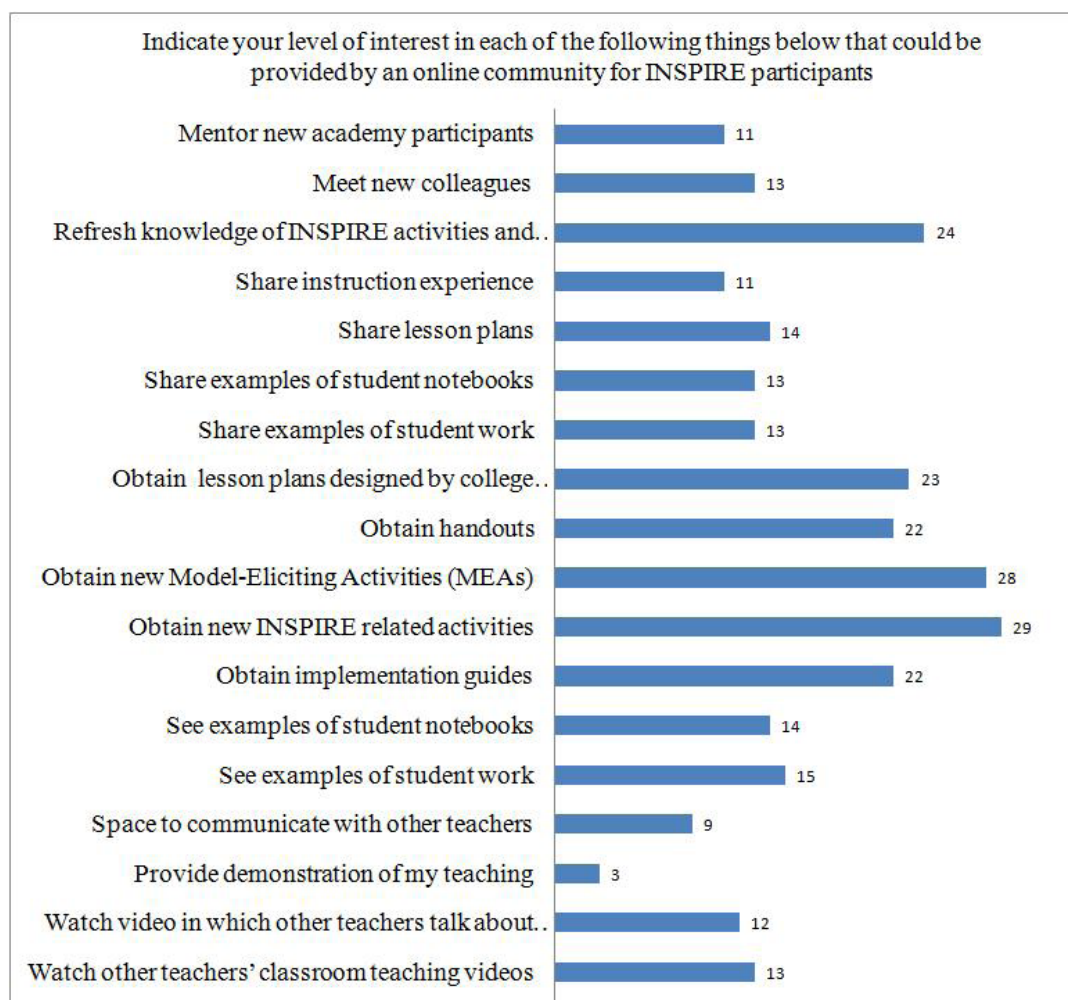| Category	Value
Mentor new academy participants	11
Meet new colleagues	13
Refresh knowledge of INSPIRE activities and..	24
Share instruction experience	11
Share lesson plans	14
Share examples of student notebooks	13
Share examples of student work	13
Obtain lesson plans designed by college..	23
Obtain handouts	22
Obtain new Model-Eliciting Activities (MEAs)	28
Obtain new INSPIRE related activities	29
Obtain implementation guides	22
See examples of student notebooks	14
See examples of student work	15
Space to communicate with other teachers	9
Provide demonstration of my teaching	3
Watch video in which other teachers talk about..	12
Watch other teachers' classroom teaching videos	13

Figure 8

Finally, the teachers were asked to identify specific features that they would be interested in by indicating their interest level in each. Obtaining new materials and knowledge refreshing were indicated to have the highest level of interest (Figure 8). One teacher writes, "I would like it to be a place where we can share ideas, experiences from teaching lessons and share lesson plans we create." Another teacher wishes to "continually increase my knowledge about engineering as well as improve and get new lessons."

3. INSPIRE Online Teacher Professional Development (oTPD)

INSPIRE provides Academy I (initial exposure to engineering education) and Academy II (reflection on year 1 and advanced engineering education) to each cohort during a two-year teacher professional development. During academic years 1 and 2, teachers will implement engineering into their classrooms and reflect on the implementation in terms of student learning achievement. Teachers will be supported by the INSPIRE staff via online learning community during the academic year both as needed and as part intentional interventions to support their reflection on current methods and opportunities for refinement.

From Table 2, our teacher professional development offers a dual approach of instruction and cyber-enabled performance support. Our model is based on (a) instruction (through summer sessions and cyber-enabled training sessions) and (b) individual performance support (at location, feedback in-time of need via online communities and video-conference-based feedback). This dual approach ensures that teachers are supported beyond an initial workshop, and will receive feedback and training in the time of need in their school and classroom context that allows for an extensive amount of contact time between INSPIRE staff and the teachers throughout the year.

Table 2. School Corporation Cohorts and Balance of F2F and oTPD

	Year 1	Year 2	Year 3	Year 4	Year 5
Sch. Corp. I, IV	Cohort 1		Cohort 4		Address
Sch. Corp. II		Cohort 2			Sustainability
Sch. Corp. III			Cohort 3		Issues
Face-to-Face TPD					
Online TPD					

Each cohort will consist of ~30 volunteer elementary (grades 2-4) teachers.
INSPIRE cohort 1 were the teachers who participated in the summer academy one year earlier than cohort 2 teachers. And cohort 2 was one year earlier than cohort 3 teachers.

Reflective video-cases are also embedded in the online community. Therefore, by videoconferencing capabilities in classrooms, INSPIRE can provide teachers with feedback after classes have been taught to support the teachers in their context with context-specific and tailored feedback. By utilizing saved videos of classroom instruction, real classroom practice becomes the anchor for professional development in the summer sessions (Academy I and II) or in sessions delivered online over an extended period of time. Last, but not least,

teachers can invite other teachers to watch their performance or collaborate on projects. Because many of our teachers are geographically separated, the video-conferencing can provide teachers with efficient and low-threshold means to communicate and collaborate with other teachers.

The cyber-enabled components of this teacher professional development enables the year-round development of an online community for participating teachers and in-time and on-site support. The academic year support ensures a sustained process to help teachers implement and integrate the curriculum they actively learned in from their summer workshops into their classes. In addition, the continuous facilitation ensures to collect feedback on the usefulness of the provided curriculum that will support further development. Finally, the year-round support infrastructure and the video collected in the teachers' classrooms allow a unique ability to assess the immediate impact of our TPD in the classroom.

Table 3. A Set of Design Principles

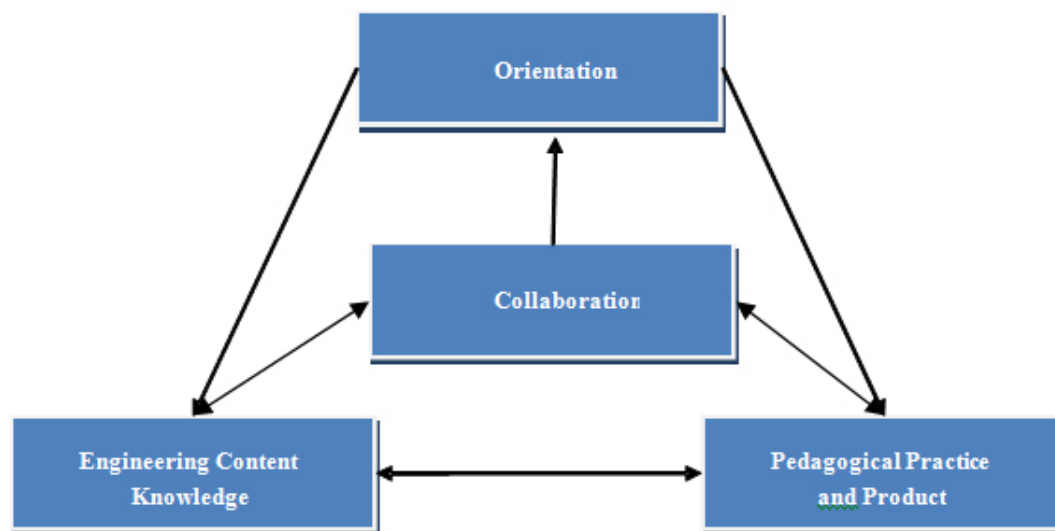| Design Principles			
Orientation	Engineering Content Knowledge	Pedagogical Practice and Product	Collaboration
Demographics Participation Trust	Learning goals Resources	Mentoring Video conferencing modeling Peer feedback	Communication Media use

Figure 9. A Set of Design Principles

3.1. Orientation

Demographics: We identify important characteristics of the participants in terms of teachers' professional goals, school districts, grade levels, class information, teaching experience, gender, and race.

Trust: Building trust starts from Summer Academy. Face-to-face opportunities for teachers to meet each other which build some level of trust in Summer Academy initiate our online community. Members of the group shape learning agenda together. We provide teachers

opportunities to collaborate on small activities in the community. Teachers were introduced to facebook, as they added each other and talked as a group. Photos taken during the academy were posted there as well. Teachers made lesson plans and shared them by using Google Docs. This medium is a free, Web-based word processor, spreadsheet, presentation, and form application offered by Google which allows users to create, edit and reposit documents online while collaborating in real-time with other users. After teaching, teachers also wrote down their reflection and shared with one other in Google Docs. Then, the researchers create a dedicated online space for teachers' interaction for content and non-content specific discussions.

Participation: Guidance is given to new community members and promotion of opportunities for established members to go outside the boundaries of the learning event or focus is made. Questions that promote learning and encourage interaction are encouraged. A signing in form for teachers to volunteer leading a weekly discussion initiates active participation in the online learning community.

3.2. Engineering Content Knowledge

Learning goals: Teachers are informed of the following learning goals when they participate in the teacher professional development.

- Teaching Engineering: Teachers are able to facilitate their students' engagement and learning of the topics described in Summer Academy.
- Encouraging creativity and critical thinking: Teachers are able to recognize the importance of allowing students to come up with creative and unique solutions, provide students with open-ended problems that allow for creative and unique solutions, and assess student

learning and solutions to open-ended problems.

- Integration: Teachers are able to recognize opportunities to integrate engineering, science, technology, and mathematics in their teaching, as well as language arts and social studies. Teachers are able to develop new learning activities to integrate subjects and also able to integrate engineering into lessons that they have used before, or integrate engineering with the standard texts and lessons used by their school/district/county.

Resources: Content related materials are available to teachers. Resources include curriculum units, implementation guides, supplementary lessons, video cases, lesson plans, worksheets, knowledge-based assessments, and teacher self-debriefing.

3.3. Pedagogical Practice and Product

Mentoring: INSPIRE mentors Cohort1.
   Cohort1 and INSPIRE mentor Cohort2.
   Cohort2 and INSPIRE mentor Cohort3.
   Cohort3 and INSPIRE mentor Cohort4.

The team developed strategies to provide learners with just-in-time guidance. At the beginning, there is more interaction of INSPIRE people to facilitate teachers' classroom instruction. As the term progresses, experienced teachers were assigned to new subgroups in the community to serve as mentors for new teachers. Therefore, INSPIRE cohort 1 were the teachers who participated in the summer academy one year earlier than cohort 2 teachers. And, cohort 2 was one year earlier than cohort 3 teachers. As a result, there is more mentoring interaction of previous cohort teachers and new teachers. By videoconferencing capabilities in classrooms, teachers received feedback after classes they taught. Individualized support of

teachers in their lesson planning via remote is a unique component to make sure the close connection between the context of the training and the context of teaching.

Video conferencing modeling: Model video case studies are provided. It is based on how useful the video is instead of who is teaching. Video includes parts of the Summer Academy workshop that documented teaching by the INSPIRE teachers. A Web-based streaming service allows automatic storage and delivery of the videos back to the teachers.

Peer feedback: Peer interaction and collaboration has been found to have a valuable impact on learning. Thus, value collaborative learning is valued. The joint application of the individual efforts of two or more teachers to a learning-related task provides teachers with the opportunity to develop critical thinking skills in Summer Academy. Also, the online learning community helps teachers develop conceptual change and new understandings through lesson design, implementation, and communication.

3.4. Collaboration

Communication: Technology is employed to allow meaningful communication through both asynchronous and synchronous computer-mediated communication, which is easy for teachers to use. These technologies are social networking through Facebook, online documents repository Google Docs, e-mail, and video conferencing.

Media use: The team promotes communication approaches that are compatible with older, less costly equipment where communities intend to be inclusive. In addition, high-end video cameras are installed to zoom into different zones of the classroom and allow the capturing of details to teach teachers how to integrate engineering into the classroom.

Directional microphones are used to allow honing into conversations at a particular zone in the classroom. And, technical support can be delivered in this way as well.

3.5. Goals

Members of the group shape learning agenda together. Throughout the project, P-6 teachers are ready to "cross the chasm" with the following criteria. Teachers could be able to (without prompt or support):

- Describe the components of the engineering design cycle
- Evaluate appropriate segments in their existing lesson plans to integrate engineering
- Apply their understanding of engineering to the development of lesson plans based on the engineering design cycle and engineering constraints
- Design lesson plans to include engineering components
- Implement engineering elements into their classrooms
- Integrate engineering thinking (including design, constrains, systematic testing, purpose, development for clients) into their existing lesson plans and with STM content
- Estimate / hypothesize difficulties of students to understand and apply engineering thinking during their lesson
- Design assessment plans for their students to measure their progression in developing engineering thinking/skills
- Assess their students' progression towards engineering knowledge (about / how-to)
- Compare/contrast the effectiveness of different strategies to teach engineering concepts and skills
- Adjust and justify changes to the lessons based on assessment results

3.6. Assessment

A post-survey was conducted to evaluate the teachers' perceptions about the effectiveness of the professional development program (Figure 10). 30 teachers out of 36 rated our program excellent.
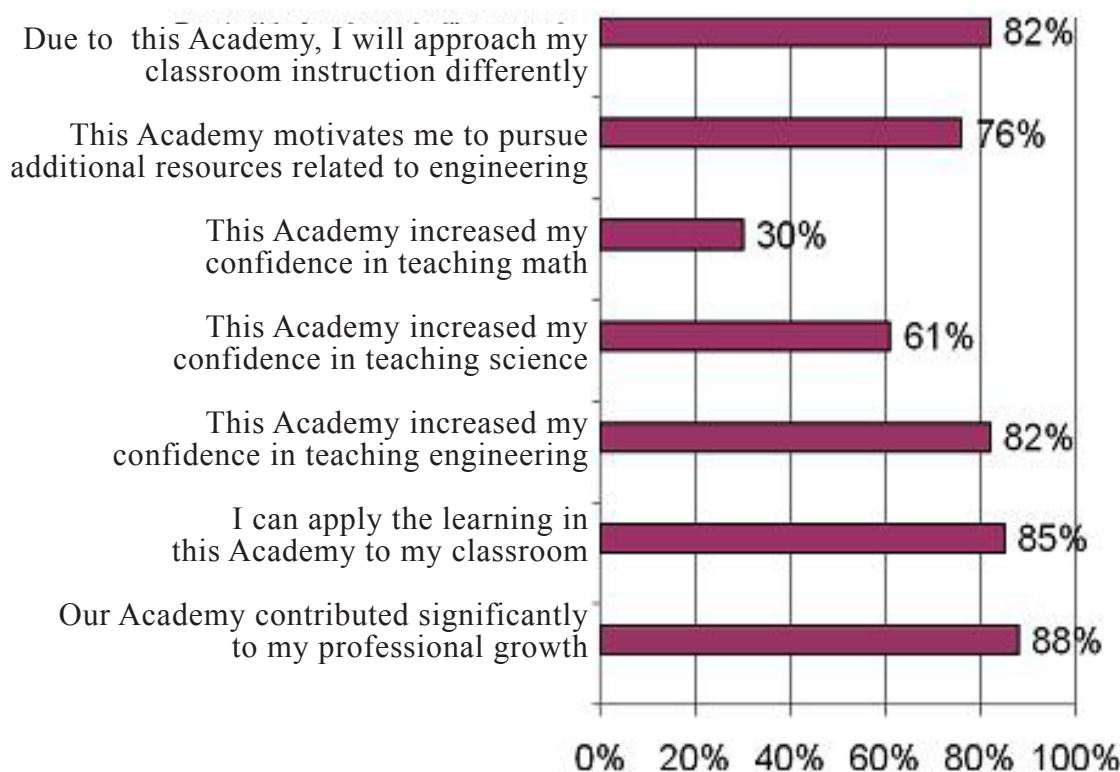

Due to this Academy, I will approach my classroom instruction differently — 82%

This Academy motivates me to pursue additional resources related to engineering — 76%

This Academy increased my confidence in teaching math — 30%

This Academy increased my confidence in teaching science — 61%

This Academy increased my confidence in teaching engineering — 82%

I can apply the learning in this Academy to my classroom — 85%

Our Academy contributed significantly to my professional growth — 88%

Figure 10. INSPIRE Program Evaluation

4. Conclusion

Extending teacher professional development through an online learning community is a promising way to deliver highly effective just-in-time and individualized support to in-service teachers in such a pioneering field. Building on the notion of situated practice, the professional development illustrated in this paper with both face-to-face and online components helps teachers develop their pedagogical knowledge, content skills, and instructional practices in engineering. Engineering-based teacher professional development could benefit more from integration of technology, the creation of community, and assessment of the impact on teachers' and students' knowledge, attitudes, and behaviors about engineering and engineering education.

More rigorous evaluation of teacher professional development, particularly with engineering, is critically needed. Documenting this case empirically is an important part in the project's agenda. The authors will continue studying how the online teacher professional development community takes shape, function, grow, nurture, support teaching to impact students' learning, and how the community can be replicated across diverse settings.

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