NCSM Journal

of Mathematics Education Leadership

WINTER/SPRING 2014 VOL. 15, NO. 1

National Council of Supervisors of Mathematics www.mathedleadership.org

Table of Contents

Professional Development Models at Science, Technology, Engineering, and Mathematics (STEM) Focused High Schools

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Over the past 30 years, many states have created opportunities to increase students' exposure to and engagement in science, technology, engineering, and mathematics (STEM) content learning. Some of the many options available to students include: dual enrollment; Advanced Placement (AP) and International Baccalaureate (IB) programs; early college entrance programs; summer programs; residential STEM schools; non brick-and-mortar type educational programs; STEM academies or schools; internships and mentorships; contests and competitions; and service learning programs. One of the advantages that STEM academies or high schools have over traditional schools is an extended time with students to go further into the stages of expertise. They design programs that move students from interest in subject area to competencies to expertise. Specialized STEM high schools come in different forms: state residential schools, schools within schools, self-contained schools, and part-time sites (Jones, 2010). Some schools are on college campuses and are organized under the state's higher education system. Others are administered under a local or regional school system. Despite the increase in the number of STEM-focused schools over the past decade, little is known regarding which of these school models is most effective (Subotnik, Kolar, Olszewski-Kubilius, & Cross, 2010).

Several networks have been formed around the development of STEM-focused schools. Some of these include: The National Consortium of Specialized Secondary Schools of Mathematics, Science, and Technology (NCSSSMST); The Ohio STEM Learning network; T-STEM academies; and the Colorado STEM network. These organizations provide a communication network for sharing ideas and obtaining professional development (PD) for specialized teaching methods and leadership. The purpose of this exploratory study was to begin gathering data from current STEM programs to inform school districts that are considering the development and implementation of a STEM program or school. Specifically, this study examined the PD opportunities offered to teachers who are designing unique academic experiences for students at STEM-focused schools. The following questions were posed:

1. What is the process for planning and implementing teacher professional development at STEM-focused schools?
2. What professional development activities are planned for faculty members in STEM-focused schools?
3. What challenges can be anticipated as we plan to scale up effective STEM teacher professional development for a national audience?

According to the National Research Council (2011), effective professional development should "focus on developing teachers' capabilities and knowledge to teach content and subject matter, address teachers' classroom work and problems they encounter in their school settings, and provide multiple and sustained opportunities for teacher learning over a substantial time interval" (p. 21). As a result, the significance of this research lies in its potential to inform the design of professional development for STEM-focused schools. For this study, STEM-focused schools were defined as schools specifically designed to offer more content, instruction, and experiences applying STEM content than what is typically offered in non-STEM schools within their school districts.

Related Literature

Given the increased attention to STEM, a body of research exists which identifies successful strategies for increasing student's success in STEM. Many of these studies have focused on teachers. Payne (2004) attributed the lack of science skills in the U.S. to poor elementary school teacher preparation. According to Payne, elementary teachers identified science as the curriculum they were least comfortable with teaching. With regard to mathematics, Lloyd (2006) suggested that many teachers have a narrow view of mathematics and its application to the real world. "Research has clearly shown that a good teacher is the single most important factor affecting student learning" (Geringer, 2003, p. 373).

To this end, teachers need training in best practices in STEM pedagogy. According to Wilkins and Brand (2004), teacher training has been successful in changing teacher's attitudes and beliefs about reformed-teaching methodologies. Lloyd (2006) recommended using K-12 standards-based curriculum to train teachers. She suggested selecting activities that are mathematically challenging, illustrate connections among concepts, and emphasize where misconceptions usually occur or real-world contexts.

Recognizing the importance of teacher training, Yoon, Duncan, Lee, Scarloss and Shapley (2007) examined more than 1,300 studies addressing the effect of teacher professional development on student achievement. The authors found that only nine studies directly assessed the effect of in-service teacher professional development on student achievement in Mathematics, Science, and Reading/English Language Arts. All nine studies focused on elementary school teachers and their students. The results of these studies indicated that the "average control group students would have increased their achievement by 21 percentile points if their teacher had received substantial professional development indicating that providing professional development to teachers had a moderate effect on student achievement across the nine studies. The effect size was fairly consistent across the three content areas reviewed" (p. 2). These results support the importance of effective professional development in STEM pedagogies.

In order for professional development to be effective, research has identified key attributes: a focus on teachers' identified needs (Hill, 2009); opportunities for teachers to be active participants in the planning and execution of the professional development (Clark & Florio-Ruane, 2001); and long-term support for implementation of reform efforts identified through the professional development (Ferguson, 2006). In addition, professional development can be most effective if it is collaborative, bringing teachers together in productive learning communities (Grossman, Wineberg & Woolworth, 2001; Lieberman, 1995; Swenson, 2003). "Professional learning communities [are] center to fostering teacher change and student learning" (Borko, 2004, p.6).

One way to avoid the oft-criticized one-size-fits-all quality of professional development is to cater it to teachers' individual needs and to offer specific feedback to teachers about their contextualized practice. Klinger (2004) wrote, "Teachers have different internal characteristics and work in diverse contexts with varying external pressures, and it is important to consider these complex factors when planning for and conducting professional development programs" (p. 252). Similarly, Hill (2009) suggested that professional development be differentiated to teachers just as teaching is differentiated to students. "Content-focused professional development based on classroom practice – including evidence around student learning, the study of curriculum materials, and so forth – is most likely to affect teacher knowledge and performance and student outcomes" (p. 474). Furthermore, professional development is "most effective when it is an ongoing process, which includes appropriate, well-thought-out training and individual follow-up" (Robinson & Carrington, 2002, p. 240). Collegial support networks help teachers implement professional development (Klinger, 2004). One additional critical element of effective professional development is a focus on a particular content area. While much of the professional development offered to teachers emphasizes pedagogical approaches, fewer examples reveal a focus on supporting growth in teachers' content knowledge. Recent research in mathematics in particular has emphasized the need for content-centered professional development. "U.S. teachers need improved mathematics knowledge for teaching" (Hill & Ball, 2004, p. 330).

Table 1: STEM School Overview

Pseudonym	Region	Grade Level	Year Est.	Locale	Charter/ Magnet	Title I	Student Enrollment	Type of school
Archimedes HS	South East	9-12	2004	Large City	N/Y	Y	689	Local/regional
Boyle HS	West	9-12	2000	Large Suburb	Y/N	Y	567	Self contained
Priestly HS	South West	9-12	2002	Large Suburb	N/Y	Y	882	Local/regional
Pythagoras HS	West	9-12	2004	Large City	Y/N	N	874	Local/regional
Einstein HS	Mid-West	9-12	2006	Large City	N/N	N	300	Part-time site
Galileo HS	North East	9-12	1997	Large City	N/N	N	1683	Self contained
Plato HS South	East	9-10	2008	Small City	Y/N	Y	367	Self contained
Marconi HS	Mid-West	9-10	2008	Large City	N/N	Y	224	Self contained
Euclid HS	North East	9-12	2008	Rural Comm.	N/N	N	1654	School within a school
Pascal HS	South East	9-12	2007	Small City	N/Y	N	1649	School within a school

Note: Data collected July 2013 from National Center for Education Statistics, 2012.

Methodology

A comparative case study method was used in this study because it provided the most comprehensive answers to questions about professional development offered at STEM-focused schools. Case studies offer a means of "investigating complex social units consisting of multiple variables" (Merriam, 1998, p. 41). The comparative case study method provided for a holistic description of each STEM-focused school including: teacher professional development opportunities, academic programs, and students served at the selected schools. According to Yin (2003), one advantage of a multiple-case study is that "the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust" (p. 46).

SELECTION OF STEM-FOCUSED SCHOOLS

A criterion-based selection was used to choose the site and participants to be studied. The initial site selection began with a national search of STEM secondary schools that were specifically intended as STEM-focused schools. According to Atkinson, Hugo, Lundgren, Shapiro and Thomas (2007), more than 100 high schools are designed with a STEM focus. The second criterion for selecting a school site was those designed specifically to enhance all students understanding of science, mathematics, engineering, and technology as opposed to programs that were primarily for advanced or gifted students. Schools designed as very selective programs or that have strict entrance requirements are often regarded as elite schools and were not included in this study. STEM schools that had statements indicating that their goal was to provide opportunities for all students, including underrepresented student populations, were selected for further study. The 10 schools that were included in this study were randomly selected from a pool of 57 STEM-focused schools.

DESCRIPTION OF STEM-FOCUSED SCHOOLS

The STEM-focused schools selected for participation in this study were located in various regions across the U.S., with five of them qualifying for Title I status. Table 1 contains a list of the participants using pseudonyms to protect their identity. Six of the schools were designed specifically for the implementation of the STEM program. These schools began with a new building, faculty, and staff members. Four schools were already in existence but were reinvented in order to change their academic emphasis to STEM content. Most of the schools had traditional school facilities while two of the new schools were located in business or commercial settings.

Student demographics. When comparing the demographics of these STEM-focused schools to all public high schools in the United States, there were noticeable differences. Results demonstrated that the STEM-focused schools in this study served a higher percentage of minority students than the national average. Student population was important to this study because it focused on STEM programs for traditionally underserved populations. Table 2 lists the percentage of students in each ethnic group that were enrolled in STEM high schools compared to those enrolled in all U.S. public high schools during the 2009-2010 academic year (School Data Direct, 2010; U.S. Census Bureau, 2011).

The percentage of black students attending these STEM-focused schools was more than three times higher than the national average of 16%. White and Hispanic students were under represented. This over representation of black students in the STEM-focused schools may be accounted for by the location as several of the STEM-focused schools were located in urban areas which have higher black populations. The average percentage of economically disadvantaged students attending STEM schools was 42%, which was the same as the national average (School Data Direct, 2008).

Student achievement. Students who attended the selected STEM-focused schools outperformed their peers on end-of-course assessments in mathematics and reading or English. Participating schools took different statewide assessments so student performance was measured by comparing the STEM-focused school average to the statewide average. When students had more than one mathematics exam (i.e., algebra and geometry), the exit level or graduation required test score was used. The data in Table 3 (see pg. 26) represents the percentage of students who passed the previous year's state standardized tests in English, Reading, and Mathematics. On average, students in STEM-focused schools had a 13% higher pass rate for English and 12.78% higher pass rate for mathematics compared to those who attended other schools. Of the nine schools that participated in state-wide testing, all performed higher than the state average in mathematics and English. Plato High school was a newly opened school and was the only school in this study that did not report end-of-course exam results.

Table 2: Ethnicity of STEM HS students vs. HS students attending U.S. public schools

	% of students enrolled in STEM HS	% of students enrolled in U.S. public high schools	Difference in population
White	32	59	-27
Black	50	16	+34
Hispanic	12	19	-7
Asian	5	4	+1
Other	1	2	-1

Note: Data collected from www.nces.ed.gov (January 2011) and U.S. Census Bureau http://www.census.gov/population/www/socdemo/school.html, (May 2011).

DATA COLLECTION AND ANALYSES

The data collected during this project included documents in print and digital format, telephone interviews, and email communication. These sources were used to provide and confirm information needed in order to answer each research question. Documents were collected from multiple sources including: school websites, State Department of Education archived test score databases, grant applications, and applications for admissions materials. In regard to the use of documentary material, Merriam (1998) identified the greatest advantages as its stability and objectivity. She wrote, "Unlike interviewing and observation the presence of the investigator does not alter what is being studied" (p. 126).

A cross-case synthesis technique was used to analyze the data in this study. Yin (2003) suggested treating each individual case as a separate study then aggregating findings across a series of individual cases. He recommended "creating a word table to display the data from the individual cases according to a uniform framework" (p. 134). Following these suggestions, the contents of the interviews and document data collected were coded and organized in a matrix. Formal analysis of the interview data began by listening to the interviews, then transcribing them, then listening and reading them at the same time. Transcript data were entered into a digital database. Variables were identified and then coded to identify emergent themes, patterns, and questions. Coding and matrices were used for comparison across interviews and interview summaries to retain the context of the data. During the analysis phase, patterns were identified, and explanations as well as rival explanations were highlighted.

Table 3: Comparisons between STEM HS End-of-Course Exams Pass Rate and the Statewide End-of-Course Exams Pass Rate

	Reading/ English	State AVG Reading/English	% Difference English/Reading	Math	State AVG Math	% Difference Math
Archimedes	72	43	+29	76	44	+32
Boyle	98	81	+17	96	81	+15
Priestly	98	92	+6	82	70	+12
Pythagoras	86	66	+20	40	30	+10
Einstein	95	85	+10	97	79	+18
Galileo	99	80	+19	98	84	+14
Plato	Data not available					
Marconi	91	83	+8	88	80	+8
Euclid	87	84	+3	83	80	+3
Pascal	91	86	+5	85	82	+3
AVG			**+13**			**+12.78**

Note: Collected from individual State Department of Education websites (January, 2011).

Results

Results from this study described a variety of ways that STEM-focused schools in the U.S. have implemented professional development for teachers designed to fulfill the goal stated in the Academic Competitiveness Council Report (U.S. Department of Education, 2007): “to prepare all students with STEM skills needed to succeed in the 21st century technological economy” (p.23). Students attending the STEM-focused schools in this study were provided rigorous courses in STEM content. The professional development activities described highlight the type of support that teachers in STEM-focused schools received.

What is the process for planning and implementing teacher professional development?

The role and number of school administrators, master teachers, and university and industry partners varied by school, but all of the schools emphasized a collaborative leadership team that guided decision-making. Master teachers in this study exhibited leadership in multiple, sometimes overlapping, ways and met the Teacher Leader Model Standards (2011). Some leadership roles were formal with designated responsibilities. Other roles were more informal and emerged as teachers interacted with their peers. The variety of roles ensured that teachers could find ways to lead that fit their talents and interests. Regardless of the roles they assumed, teacher leaders shaped the culture of their schools, improved student learning, and influenced practice among their peers. Figure 1 (pg. 27) illustrates the interactions and responsibilities of team members involved in creating professional development for teachers. School administrators, master teachers, and university and industry partners brought different expertise to the group but shared in the responsibilities of educating future scientists and mathematicians. They all had a vested interest in the success of students enrolled in the STEM program and felt a sense of responsibility for their efforts.

This collaborative professional development design model facilitated the mutual support of teachers by having professional conversations addressing the needs of the students and the community, selecting and designing curriculum, and developing an implementation plan that was conducive to all parties involved. This type of professional decision-making design encouraged and supported teacher development as they experimented with a variety of pedagogical approaches using video and hypermedia materials and real-world laboratory experiences.

What professional development activities are planned for faculty members in STEM-focused schools?

Professional development opportunities for teachers at the participating STEM-focused schools focused on developing teachers as leaders, collaborators, and creators of student learning experiences. Key features of professional development included a dedicated time set as a priority for teacher training that was done collaboratively. Teachers were leaders in selecting and leading the activities, and topics were focused on curriculum and instruction that pertained to STEM content and pedagogy. Some schools implemented cross curricular units while others focused on the needs of new faculty members. Teachers were involved in identifying the needs and assisting in the design of PD rather than having it imposed on them from an outside source. In addition, one school had a state approved teacher certification program embedded in its school.

When conducting interviews with STEM school leaders, administrators were asked to describe the professional development opportunities offered to their teaching staff. In addition, some schools provided documents with detailed descriptions of professional development activities offered in their schools. An interesting finding that emerged was the involvement of mentors to train new teachers and develop master teachers in instructional strategies focused on teaching and learning STEM content.

FIGURE 1: *STEM School Professional Development Collaborative Design Model*

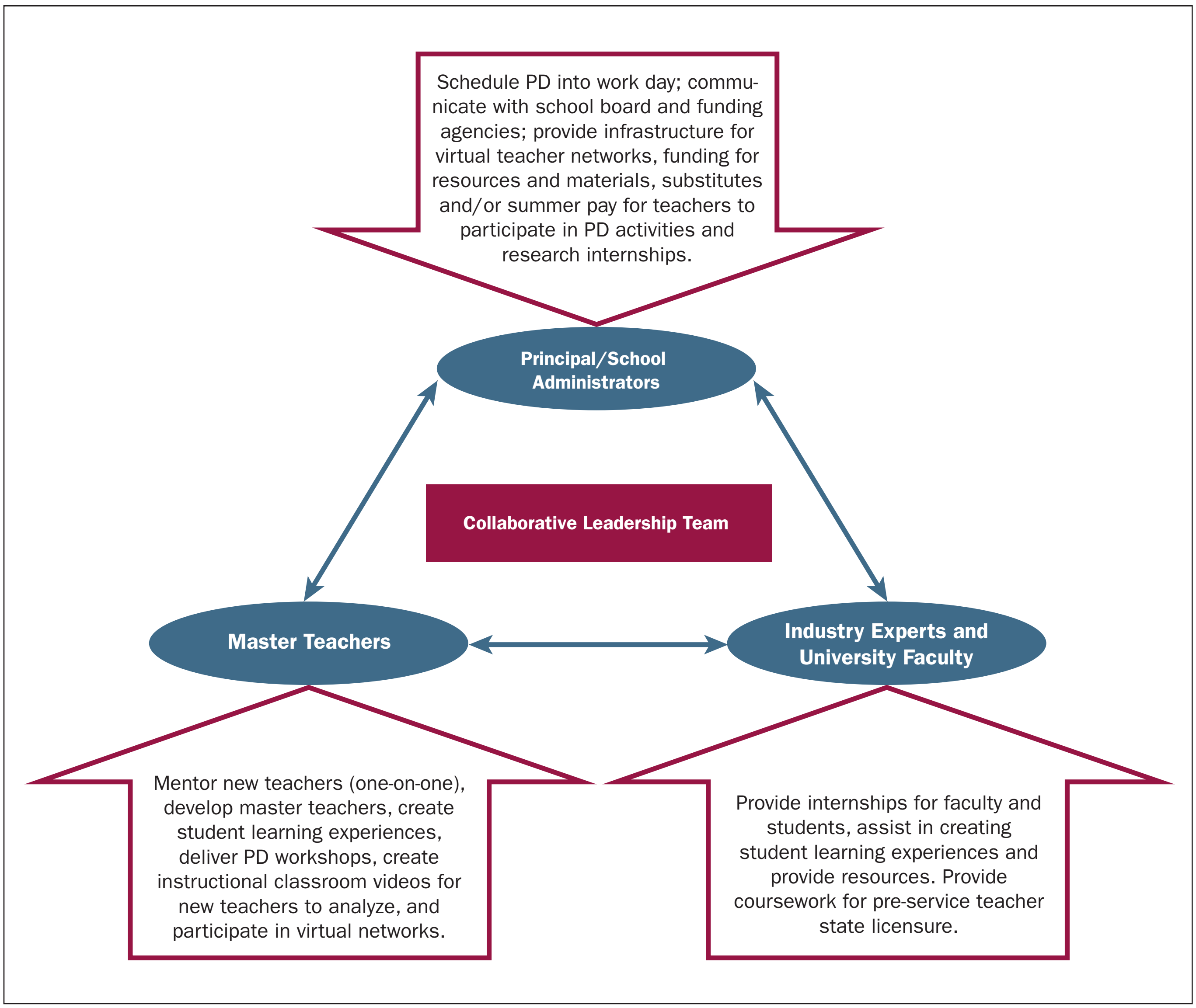

Table 4 contains a summary of some of the topics covered in the professional development activities. There are only seven schools listed in Table 4 because two of the schools were new schools that were hiring staff to teach rising 11th and 12th graders and the third school decided to change the focus of their professional development activities. A brief description for each school follows.

Archimedes High School. Teachers at Archimedes HS had regularly scheduled professional development workshops provided by instructional coaches on a variety of topics. In addition to onsite instructional coaches, educators at Archimedes were provided a virtual mentor network. This resource provided a unique, online video staff development. Teachers watched master teachers demonstrate

Table 4: Summary of Professional Development Activities

School	Topics	Leader	Format
Archimedes HS	Learning labs, Creating and executing master lesson plans, Classroom management that works, Using grading to motivate student engagement, Reading strategies, Assessment and accountability, Rigor in the classroom, Differentiating instruction, Encouraging critical thinking.	Conducted on-site by instructional coaches and online with virtual mentors	Dedicated professional development days at the beginning and throughout the school year.
Boyle HS	Guide to project-based learning, Curriculum integration, Internship program development, Teaching diverse learners, College advising, Technology implementation.	Led by experienced teachers in the school. Some teachers attended professional conferences.	Teachers met one hour before school each day. Various day long PD workshops throughout the year. Two week-long teacher preparation sessions prior to school opening.
Priestly HS	Coursework/workshops offered to fulfill initial teaching license requirements; PLCs focus on using common assessments.	Developed and delivered by the Director of curriculum and assessment	Teachers met in the summer prior to school opening and regularly scheduled weekly meetings during the year.
Einstein HS	Examining student work, Peer reviewed lessons, Developing collaborative integrated course projects.	Instructional coach met with teachers one-on-one, observed classes and designed an improvement plan for each teacher.	Teachers had a common planning period every morning and participated in professional learning communities. Substitutes were provided for teachers while working with coaches.
Marconi HS	Developing trans-disciplinary instructional units; Evaluating and integrating best practices; and Classroom research;	Teachers have participated in an internship with an industry partner. PD was led by master teachers in the school.	Teachers participated in quarterly faculty institutes and have daily common collaborative time. They participate in a 10-week instructional internship at a local business and have a week-long STEM development institute during the summer.
Galileo HS	Creativity and rigor in the classroom	Teachers observed classrooms in and out of content area;	3-day teacher orientation prior to school year and ongoing during the year.
Pascal HS	Curriculum planning; Integrating inquiry-based experiences; developing authentic real-world opportunities for students.	Teachers collaborated with university partners to develop curriculum.	Curriculum was developed during the summer and implemented throughout the school year.

techniques in real classrooms. Archimedes had developed an instructional partnership with a charter school with the purpose of building a professional learning community that observes and analyzes effective instruction.

Boyle High School. Faculty members at Boyle HS participated in ongoing professional development. This included 45 minutes per day without students for collaboration and program development. There were various daylong professional development workshops throughout the year and a two-week long teacher preparation session in August prior to the opening of the school year. The state commission on teacher credentialing had approved Boyle HS to certify teachers through its Teacher Intern Program. Boyle partnered with the state university to provide a 120-hour preservice teacher program and 600 hours of training and practice over two academic years. Interns earned full-time salaries and benefits as provisional teachers while working toward their teaching credentials. To be considered for this program, individuals first applied for a teaching position at Boyle. Once hired, they participated in the intern program. Teachers were positioned for success at Boyle HS by working in teams that dealt with the same cohort of students. They arrived at school an hour before the students each day to plan, discuss student work, and engage in professional development activities. This school offered learning opportunities for practitioners to participate in teacher residencies and institutes.

Priestly High School. Like Boyle HS, teachers could be hired at Priestly HS without a state teaching license. The school provided in-house training. The staff met two to three weeks before school started. They met with the director of curriculum and assessment who gave a very clear set of curriculum guidelines. Although teachers did not have to be certified by the state to teach at this school, Priestly HS had a prescribed training program that was very thorough. Teachers used common assessments across the departments and across the school.

Einstein High School. Einstein HS served as a laboratory for developing the best ways to teach science and mathematics. Teachers rotated in from the surrounding districts, enabling them to take what they learned back to their home classrooms. Einstein HS provided time for teachers to collaborate, support for instructional improvement, and encouragement to develop as professionals. Providing time for teachers to work together was a priority at this school: teachers had common planning time every morning. They also spent time in professional learning communities. During this time, they examined student work, peer reviewed lessons, and worked on collaborative integrated course projects. Coaching was individually tailored to meet teachers' needs. The coach met with teachers one-on-one for an hour, then observed a class, and then worked on improvements with the teacher based upon his/her improvement plan. The school provided substitutes so teachers could work with their coaches. Teachers were encouraged to develop as professionals.

Marconi High School. The professional development plan at Marconi HS included three significant characteristics: quarterly faculty institutes, daily common collaborative time, and embedded industry internship experiences. Regular professional development was focused on cross-training experiences through development of trans-disciplinary instructional units and systemic strategies for knowledge sharing amongst the STEM disciplines. A revised teacher workday allowed for quarterly one-week STEM development institutes in which STEM partners engaged in the study, evaluation, and integration of current best practices and research. Specific time was built into the workday for collaborative faculty work sessions. Marconi faculty had opportunities during the first year of operation and every four years thereafter to acquire, enhance, and refine their own STEM-related skills in four, individualized 10-week faculty internships.

Galileo High School. Galileo HS provided support to new faculty members through a three-day new teacher orientation. New teachers were paired with mentors. Teachers were encouraged to visit each other's classrooms, within their disciplines and outside disciplines. This type of collaboration allowed teachers to see how creativity and rigor worked in another content area, and to see how some of the same students, who they may find challenging, were excelling in other classes.

Pascal High School. Selected educators at Pascal HS were members of a curriculum planning committee, which collaborated with university partners. Integrated inquiry experiences were provided through collaboration between teachers and university engineers who worked with the classroom teachers. These collaborations resulted in authentic real-world opportunities for students to understand and utilize basic and advanced mathematics and science principles.

Cross-case analysis. Although all of the STEM-focused schools provided professional development for their teachers, Marconi, Einstein, and Boyle provided the most extensive training. These schools had regularly scheduled meetings during the workday throughout the school year. They also included mentor support that was instrumental in developing master teachers. Mentor teachers played a different role than master teachers. Mentor teachers were classroom teachers who played a support role for teachers new to the school building. Teachers worked in teams and were responsible for selecting curriculum, developing and delivering integrated lessons, and assessing students. Core learning goals for the state were to be accomplished first, but after that teachers have been granted permission to enhance the program as appropriate.

All schools were involved in professional development that focused on curriculum and implementation of STEM content with diverse students. Einstein High School was the only school that focused on measuring the effectiveness of the instruction by examining student work. The master teachers led professional development that focused on the development and implementation of the curriculum. Two schools included university partners or industry experts in the development of the curriculum.

What challenges can be anticipated as we plan to scale up effective STEM teacher professional development for a national audience?

Hiring and training teachers in STEM content areas was a challenge for many of the participating STEM-focused schools. The principals at Euclid, Galileo, and Pascal identified the teaching staff as key components to program success. They indicated that they tried to select the best teachers for their programs and then train them on the methods being used. To this end, six challenges were identified, each of which will be briefly described.

Teacher leadership training. Teacher leadership has traditionally been restricted to roles such as department heads, textbook adoption committee chairpersons, and teacher mentors. Involving teachers in the decision-making process and encouraging them to be facilitators of change, as typified in the participating STEM-focused schools, was a new role for which the teachers had not been trained.

Time for collaboration. One of the challenges that STEM-focused schools faced was finding time for teachers to meet on a regular basis during the school day. Many of the schools had a small number of faculty members with many tasks that needed to be completed, limiting the hours teachers were available to collaborate.

Changes in instructional methods. Another challenge was encouraging faculty to experiment with various instructional methods to meet the academic needs of the students. Some questioned the effectiveness of new teaching methods like project-based learning rather than teacher directed instruction. Others were concerned about the impact of these changes on students' end-of-course exam scores.

Retention of master teachers. The fourth challenge was finding and retaining master teachers in STEM disciplines that had the pedagogy and content knowledge to mentor his/her colleagues and deliver professional development. Administrators had limited incentives or compensation to offer master teachers for the additional hours they contributed to supporting new faculty and developing coursework.

Identifying specialty teachers. Administrators found it difficult to find teachers who were skilled at teaching specialty courses, such as Integrated Mechanics, 3-D Animation and Biohazards. As a result, some administrators relied on industry experts to teach these courses. One of the challenges to this model was the lack of pedagogical skills that the industry partners possessed. Instructors had to learn to manage 25-30 adolescents with diverse needs and to develop lessons that were developmentally appropriate for this age group. Assessing gains in students' content knowledge was a foreign concept to most of these instructors.

Real-time support for new teachers. Online professional development modules were helpful in allowing new teachers to access videotaped lessons taught by master teachers and to access lesson plans and other teaching materials. The online professional development modules were helpful to experienced teachers who wanted to learn new content or explore new teaching ideas, but they did not provide new teachers with the immediate real-time support they needed to adjust to their role in the classroom. Many novice teachers relied on the teacher next door to answer questions and to provide daily support and encouragement to complete the first year.

Conclusion

Results from this study showed that teachers at the STEM-focused schools were encouraged to improve their own instruction and to look for opportunities to support their colleagues through new and innovative strategies. They participated in regularly scheduled professional development activities that encouraged them to look for ways to improve their own practice, document their findings, and share them with their colleagues.

The principals described faculty as a key component to the success of their schools. One principal attributed his school's success to faculty who "are truly committed to developing the next generation of leaders." Additional faculty members were needed due to the fact that these schools had accelerated STEM courses and a broad range of unique electives. Some schools in this study hired business professionals to teach specialty courses while others relied on certified teachers.

STEM-focused school models in this study required a commitment from principals, industry experts, university faculty, and teachers. Teachers took a leadership role collaborating with school administrators and industry and university partners in the development of student learning experiences and teacher professional development activities. There was a deliberate plan to develop master teachers by having regularly scheduled professional development activities provided by instructional coaches and virtual mentors. The teaching staff was responsible for selecting curriculum and developing and delivering integrated lessons. Individual teachers were selected to work with university partners to develop real-world integrated inquiry experiences for students. There were various day-long workshops available during the school year and week-long intensive workshops during the summer. These schools also provided mentors or coaches that met with new faculty on a weekly basis. Some schools provided in-house training beginning 2-3 weeks prior to the start of school with continued support throughout the school year. Principals scheduled time for teachers to collaborate and participate in professional development activities. Schools in this study stressed the importance of having a dedicated time set as a priority for teachers to work together. They were led by visionary principals who were confident and committed to making a difference in the lives of students. Results from this study indicated that STEM programs are rigorous with a broad variety of STEM courses and technology enhancements requiring teachers to develop new teaching strategies and content knowledge to deliver this type of instruction.

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