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Making Connections: Evaluation of a Professional Development Program for Teachers Focused on STEM Integration

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Abstract

This article reports on a 2-year evaluation of a STEM integration professional development (PD) program for 40 math, science, and special education teachers in Grades 5–9 from a large Midwestern public school district. The National Research Council's framework for integrated STEM education (Honey, Pearson, & Schweingruber, 2014) was used to explain the goals, outcomes, nature and scope, and implementation of the program. Teachers were measured on their growth in STEM content knowledge, technology integration, teaching confidence, pedagogical beliefs, and impact of PD. Increases resulted in all these areas with statistically significant improvements in most of them, particularly in Year 2. A significant increase in math and science scores were also found in 413 students before and after participation in an integrated STEM lesson. According to teachers, the greatest strengths of the program were the STEM connections that teachers began making; the changes in teachers' instructional practices; improved attitudes, beliefs, and confidence in teaching; increased comfort with using technology; and the enthusiasm that students exhibited during a STEM lesson. Quantitative data and teacher feedback both indicate that the program was highly successful and had a positive impact on teachers and students.

Keywords: Engineering; Mathematics; Pedagogy; Professional development; Science; STEM Integration; Technology; Technology integration

Over the last 2 decades, there have been many calls for improvements in the quality of education in science, technology, engineering, and mathematics (STEM). To answer this call, advocates have proposed STEM integration as a new approach, which they argue will provide STEM instruction in a more connected manner. According to the International Technology and Engineering Educators Association (2017),

> Integrative STEM Education is operationally defined as "the application of technological/engineering design based pedagogical approaches to intentionally teach content and practices of science and mathematics education through the content and practices of technology/engineering education . . ." (Wells & Ernst, 2012/2015). (para. 3)

As early as 1996, the National Research Council (NRC) understood the need for STEM integration when they stressed in their professional development (PD) standards, the *National Science Education Standards*, that science teachers must "be able to make conceptual connections within and across science disciplines, as well as to mathematics, technology, and other school subjects" (p. 59). Sixteen years later, an NRC committee articulated a vision of STEM integration

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in *A Framework for K-12 Science Education* (2012). The framework called for deeper connections and broad learning goals within three dimensions: (1) "Scientific and Engineering Practices" (e.g., "asking questions (for science) and defining problems (for engineering)," "developing and using models," and "planning and carrying out investigations"), (2) "Crosscutting Concepts" (e.g., "patterns"; "cause and effect: Mechanism and explanation"; "scale, proportion, and quantity"; and "systems and system models"), and (3) "Disciplinary Core Ideas" (i.e., "Physical Sciences," "Life Sciences," "Earth and Space Sciences," and "Engineering, Technology, and Applications of Science"; p. 3). In support of this vision, the *Next Generation Science Standards* (NGSS) include "practices and core disciplinary ideas from engineering alongside those for science, raising the expectation that science teachers will be expected to teach science and engineering in an integrated fashion" (Honey, Pearson, & Schweingruber, 2014, p. 1). According to framework, which these standards are based on,

> Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world. Engaging in the practices of engineering likewise helps students understand the work of engineers, as well as the links between engineering and science. Participation in these practices also helps students form an understanding of the crosscutting concepts and disciplinary ideas of science and engineering; moreover, it makes students' knowledge more meaningful and embeds it more deeply into their worldview. (National Research Council [NRC], 2012, p. 42).

Likewise, the *Common Core State Standards for Mathematics* (CCSSM) call for students to use mathematics in applied contexts (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA & CCSSO], 2010). The standards also identify practices in mathematics that can link to those of science and engineering. For example, the standards explain:

> Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose. (p. 7)

Furthermore, the International Technology Education Association (ITEA; 2007) established standards for K–12 technology literacy that require students to use a variety of technologies and knowledge of design processes to solve problems and to collect and analyze data to test the solutions to those problems. In its PD standards, ITEA expects that teachers are provided with PD to achieve technology literacy, understand the basic concepts of design, and "comprehend the integrative nature that links technology with science, mathematics, engineering, and other disciplines" (ITEA, 2003, p. 43).

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Although the trend seems to be moving toward an integrated approach to STEM education, there is currently little research to help us understand how best to make cross-disciplinary connections in K–12 STEM education or research on whether more explicit connections across disciplines will significantly improve student learning (Honey, Pearson, & Schweingruber, 2014). According to the NRC, the existing research has shown to result in knowledge gains in the science, technology, engineering, and mathematics, more so for science than for mathematics, and the impact depends on the integration approach and the supportive strategies offered during instruction. The NRC also examined research from cognitive psychology, the learning sciences, and educational psychology to explain the potential and challenges of STEM integration. Based on this research, integration may be effective cognitively because connected concepts, rather than disconnected concepts, can be more effectively organized in the brain. Achieving highly sophisticated concept organization, a defining characteristic of experts, promotes concept comprehension, concept retrieval for future use, and concept transferability to novel problems. Also, being able to represent the same concept within and across disciplines in multiple ways can enhance learning. Social and cultural experiences such as teamwork, active discussion, joint decision making, and collaborative problem solving can support integrated learning and help students be successful with challenging tasks. On the other hand, integration of too many complex concepts

> (1) places excessive demands on resource-limited cognitive processes such as attention and working memory, or (2) attempts to make bridges between ideas that were not well learned, or (3) obscures important differences in STEM disciplines about how knowledge is constructed and revised. (Honey et al., 2014, p. 78)

Furthermore, the use of real-world problems can either highly engage or impede students' learning. The concrete situation can give students a more meaningful context for learning but can also prevent them from transferring their experiences to other settings. Together, the research has three key implication for STEM education: (1) connections within and across disciplines "should be made explicit" for students, (2) "students' knowledge in individual disciplines must be supported" in order to connect ideas from different disciplines effectively, and (3) "more integration is not necessarily better" (Honey et al., 2014, p. 5). The benefits and challenges of integration requires a strategic approach that considers the trade-off in cognition and learning.

Because the current literature includes a variety of integrative approaches with a range of experiences and different degrees of connections, the NRC (Honey et al., 2014) developed a descriptive framework to help them identify, describe, and investigate specific integrated STEM initiatives in the K–12 education system. This framework will be used to report on 2 years of the PD project Making Connections: Preparing Teachers to Integrate STEM, hereafter referred to as Making Connections. Teachers typically attend training in STEM subjects as separate disciplines. However, Making Connections was unique in its strong focus on STEM integration. Because integrated STEM education is a relatively recent phenomenon, little is known from research about how best to support the development of educator expertise in this domain (Honey et al., 2014). Research on programs such as Making Connections for STEM educators' can provide insight into challenges and opportunities for preparing teachers to teach integrated STEM. In this article, authors provide a description of the project and research study and discuss conclusions and implications for other researchers and individuals interested in the PD of teachers in STEM integration.

A Framework for Integrated STEM Education

The NRC framework (Honey et al., 2014) consisted of four features: (1) goals of integrated STEM education, (2) outcomes of integrated STEM education, (3) the nature and scope of integrated STEM education, and (4) implementation of integrated STEM education.

Goals of Integrated STEM Education

According to the NRC (2012), educator goals should include: (a) increased STEM content knowledge and (b) increased pedagogical content knowledge. In accord with the NRC, Making Connections goals were to provide opportunities for:

1. Teachers to review learning standards for mathematics and science and understand grade level scope, sequence, and progressions;
2. Teachers to learn and understand Thinking Mathematics principles and practices and 5E science inquiry methods;
3. Teachers to practice and become more comfortable with using technology;
4. Teachers to understand and value the concept of STEM integration and to plan and implement integrated STEM lessons; and
5. Students to be exposed to integrated STEM learning experiences.

Outcomes of Integrated STEM Education

The NRC (2012) suggested two educator outcomes of STEM integration: (a) changes in practice and (b) increased STEM content knowledge and pedagogical content. Based on these and Making Connections goals, anticipated outcomes included:

1. Teachers' increased knowledge and understanding of mathematics and science;
2. Teachers' increased attitude, beliefs, and degree of confidence in content knowledge and pedagogy;
3. Teachers' increased level of comfort with using technology during instruction;
4. Teachers' increased knowledge, understanding, and appreciation of STEM integration and ability to implement; and
5. Students' increased achievement scores in mathematics and science.

Nature and Scope of Integrated STEM Education

The NRC (2012) identified three important elements that determine the nature and scope of integration: (1) type of STEM connections, (2) disciplinary emphasis, and (3) duration, size, and complexity of initiative.

Type of STEM connections. As part of all PD in Making Connections, instructors made explicit a variety of connections among all the STEM disciplines. Two days of the program are described here to illustrate the nature of the PD and to provide examples of the kinds of connections made. In a physical science inquiry lesson on the energy of force, motion, mass and friction (science), groups of teachers collected data using a LabQuest motion sensor (technology) that measured the position and speed of a plastic car going down a ramp (science inquiry). Teachers entered the data from the trials and created position time graphs using Google Sheets (technology), allowing them to examine the slope of the line (math) from which they were able to analyze the results. Using Google Docs (technology), teachers then created lab reports to communicate their results,

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providing them time to look at the evidence, make interpretations, and develop a claim based on results (science inquiry). Time was provided for teachers to compare their results with other groups and discuss differences. In the next lesson, teachers reviewed concepts of kinetic friction including magnitude and direction (science) to examine how surface texture affects friction (science inquiry). Sliding a block of wood across surfaces with different textures, teachers used LabQuest force sensors (technology) this time to record the friction force required to slide the block across each surface before, during, and after each pull. As in the last lesson, data were entered, graphed, and analyzed (math) using a Google Sheet (technology). Google Docs (technology) was again used to communicate results.

In a subsequent lesson, online simulations (technology) were used to extend teachers' knowledge of the concepts of kinetic and potential energy (science). After teachers themselves manipulated the simulations, the instructor explained the differences between science inquiry and engineering design (practices) and introduced the Mars Rover Design activity (engineering). In this activity, teachers were asked to design a Mars exploration vehicle that could carry a 100-gram load and get the most traction over a sandy planet surface with minimum force. Teachers were provided with a small rectangular paper loaf pan, straws, round pieces of foam and lollipop sticks to design and modify their models (engineering application of motion, weight, and force of friction). Granulated sugar was provided to simulate the surface of Mars. Teachers used the LabQuest force sensor to test and evaluate their prototypes by recording the weight of the vehicle and its pulling force (weight) through the sugar when designed with the different materials for the wheels. As in previous lessons, data were recorded and graphed, and teachers discussed the weaknesses and strengths of their designs as part of the engineering design process.

Three other engineering design projects were introduced during the program: "let it fly," "keep it cool," and the roller coaster. In the second design challenge, "let it fly," the teams were asked to use the engineering design strategies to brainstorm, develop, test, and improve a rocket made of a water bottle and balloons that would travel the length of a classroom. This challenge was later improved on by finding the fastest rocket and adding a load in the form of water to the rocket. Since the project, this engineering design has been adopted into the science curriculum by several teachers and was presented at a major STEM conference, STEMCON 2017 in Cleveland. The third design challenge, "keep it cool," made use of the science content related to matter and involved the development of prototype insulation materials able to keep water cold as long as possible. Temperature readings for the cold water were recorded and analyzed (math) to evaluate different designs and proposed improvements (engineering design). Finally, the roller coaster engineering design made use of the science content related to kinetic and potential energies by designing a roller coaster using foam tubes as coaster tracks.

These kinds of experiences provided teachers with multiple types of integration. They were bringing together concepts from more than one discipline: science (force and motion, friction, materials, and kinetic and potential energy), technology use (to organize, analyze, and communicate data and to learn difficult concepts through simulations), engineering (four design challenges each requiring the teachers to brainstorm, evaluate, choose a solution, build a prototype, test the prototype, and make improvements), and mathematics (data collection, analysis, and interpretation and mathematical thinking). Teachers were also connecting a concept from one subject to a practice of another (applying force and motion to engineering design and applying mathematical practices to understand data collected from science inquiry). Finally, teachers were combining practices from two disciplines (science inquiry, engineering design, and Thinking Mathematics methods).

Disciplinary emphasis. The program was designed to give teachers equal amounts of instruction in science, math, and engineering with technology infused where needed to conduct investigations. The disciplinary emphasis in Year 1 included the following core ideas in physical sciences NGSS (NGSS Lead States, 2013): “Forces and Motion” (PS2.A), “Types of Interactions” (PS2.B), “Definitions of Energy” (PS3.A), “Conservation of Energy and Energy Transfer” (PS3.B), and “Relationship Between Energy and Forces” (PS3.C). The focus of Year 2 included the same physical sciences core ideas as in Year 1 with the addition of electromagnetism (PS4.B).

Additionally, emphasis was given to practices within all three disciplines so that teachers could increase their pedagogical skills in science practices (inquiry), mathematical practices (Thinking Mathematics), and engineering design. PD must endeavor not only to increase the content knowledge of teachers, but also, the knowledge of how students think and learn about a specific discipline and engage in the practices of that discipline. The eight practices deemed essential by the NRC (2012, p. 42) and thus the NGSS (NGSS Lead States, 2013, p. 48) for all students to learn integrate the STEM disciplines. The practices listed below, which are intended to overlap and interconnect, were interwoven in the program:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (NRC, 2012, p. 42)

The emphasis in mathematics was derived directly from the *Common Core State Standards for Mathematics* (NGA & CCSSO, 2010). The following standards, depending on grade level, were emphasized in the PD.

1. Geometry: “Graph points on the coordinate plane to solve real-world and mathematical problems” (p. 38).
2. Statistics and probability: “Develop understanding of statistical variability” (p. 45).
3. Statistics and probability: “Summarize and describe distributions” (p. 45).
4. Statistics and probability: “Investigate patterns of association in bivariate data” (p. 56).
5. Expressions and equations: “Represent and analyze quantitative relationships between dependent and independent variables” (p. 44).
6. Expressions and equations: “Solve real-life and mathematical problems using numerical and algebraic expressions and equations” (p. 49).
7. Expressions and equations: “Understand the connections between proportional relationships, lines, and linear equations” (p. 54).
8. Ratios and proportional relationships: “Analyze proportional relationships and use them to solve real-world and mathematical problems” (p. 48).

As in science and engineering, the emphasis in math was not only standards but also practices. The Thinking Mathematics principles (American Federation of Teachers, 2003) and the CCSSM’s Standards for Mathematical Practice (NGA & CCSSO, 2010) were central themes throughout

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instruction, both of which support the practices of math and engineering. The Thinking Mathematics approach to math instruction is based on scientific research about how children learn mathematics. Participants discuss research findings and their implications for classrooms and use strategies in their classrooms and reflect on the results. Participants discuss the real-time implications of practices such as using concrete models, managing classroom discussions, and maintaining students' attention and involvement. The 10 principles of Thinking Mathematics and the Standards for Mathematical Practice are linked and attention is paid to how concepts and skills develop. Practices such as reasoning, constructing viable arguments, precision, and looking for mathematical structure combine with principles of Thinking Mathematics such as helping students visualize problems, requiring them to discuss and justify their mathematical thinking, using situational problems to connect mathematics to life, and balancing conceptual and procedural knowledge to develop such understanding. The Mathematical Practices (NGA & CCSSO, 2010) include:

1. "Make sense of problems and persevere in solving them";
2. "Reason abstractly and quantitatively";
3. "Construct viable arguments and critique the reasoning of others" (p. 6);
4. "Model with mathematics";
5. "Use appropriate tools strategically";
6. "Attend to precision" (p. 7);
7. "Look for and make use of structure"; and
8. "Look for and express regularity in repeated reasoning" (p. 8).

Duration, size, and complexity of initiative. Making Connections was offered as a year-long PD program consisting of six afterschool sessions, a 10-day Summer Institute, six online monthly discussions during the academic year, and classroom visits. Faculty members from a large midwestern university provided a portion of the instruction during the program. These included a member from the Department of Math and Sciences (math), three members from the College of Education's Department of Curriculum and Instruction (educational technology, math, and special education), and two members from the College of Engineering (Departments of Engineering Technology and Mechanical Engineering). The university partnered with a local school district, and a district-level science teacher and a math teacher from that district, both already on special assignment from the classroom, provided the majority of instruction in math, science, and pedagogical practices. In Year 1, math, science, and special education teachers in Grades 5–9 were recruited.

In Year 2, four faculty members, one from educational technology, one from special education, and two from engineering worked on the project. Teams of teachers from Grades 7–8 were recruited as participants from the same school to encourage collaboration and support while planning and teaching an integrated STEM lesson. Two mentors, one science and one math teacher from the district, were also recruited to assist in the program instruction, to support teachers during instruction, and to scaffold online discussions during the academic year. Additionally, more explicit training and time was given to integrating differentiated instructional strategies in the direct instruction, inquiry-based activities, and lesson planning using the guidelines and principles of Universal Design for Learning (UDL) framework (CAST, 2011). CAST explains how the UDL framework is grounded in modern neuroscience research showing that our learning brains are comprised of three different networks: recognition, strategic, and affective. UDL guidelines align the networks with three principles: recognition to representation, strategic to action and expression, and affective to engagement. UDL draws from other research in cognitive psychology and learning sciences; therefore, it was deemed most suitable for inclusion in a program focusing on STEM integration because it could help teachers learn to strategically plan for the success of every learner in their STEM classrooms. Finally, in both years, teachers were provided with Chromebooks, notebooks with instructional materials to take back to the classroom, cables to connect Chromebooks to video projectors in the classroom, and books and other materials to use in their integrated STEM lessons.

The program was designed in large part to help teachers understand the value of STEM integration, to recognize connections across the STEM disciplines, and to provide them with time to design a STEM integrated lesson plan, which they would then teach in the formal classroom. All program instruction and participant lessons were based on current state standards and practices in each discipline. Therefore, only minor changes were needed in the classroom to implement lessons such as when teams of teachers worked together to coteach or when one of the teachers needed to change their schedule to teach a topic earlier or later in the school year.

Implementation of Integrated STEM Education

Making Connections consisted of a variety of instructional approaches. The mornings began with 15-minute icebreaker or community-building activities that at times focused on a core idea in one of the disciplines. The day typically began with direct instruction, the most common method used to deliver content knowledge, which was often accompanied by independent readings, discussions, hands-on activities, or online explorations. Direct instruction was followed in the afternoons by science inquiry experiments or engineering design problems. Teachers were given time at the end of each day to reflect on their learning and how they might incorporate their new knowledge into an integrated STEM lesson. Direct instruction of UDL Principles was presented at the beginning of the workshop and was supplemented with inquiry prompts throughout each day by faculty members, science and math personnel, and mentors about how the UDL principles may be applied within particular content areas or activities to increase student comprehension, engagement, or expression of learning. During the 10-day summer institute, teachers were provided 2 days to write design integrated STEM lessons (some combination of math, science, or engineering disciplines) and student assessments, which they were required to implement in the fall of that year. Teachers were also required to include the use of 5E inquiry and Thinking Mathematics methods, to integrate differentiated instructional strategies, and to employ technologies during in their lessons. Educator support was provided when needed by the district math and science personnel during lesson implementation, and lessons were video recorded.

In Year 1, 237 students participated in the STEM lesson taught by Making Connections teachers, and in Year 2, 190 students participated. The professional learning community that developed among teachers during the summer institute was sustained through participation in six online discussions during the school year. Discussion prompts were posted to encourage teachers to share and reflect on their pedagogical strategies, challenges, and successes during the implementation of integrated STEM lessons. Afterschool sessions were offered to either introduce new concepts, review learned concepts, or offer time for sharing and discussion on how teachers were experiencing their integrated STEM lessons. As part of participation in the program, teachers could earn district continuing education contact hours (90 hours in Year 1 and 96 hours in Year 2) and gift cards to make classroom purchases ($400 in Year 1 and $200 in Year 2).

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Method

A mixed-method explanatory research design was used to evaluate the outcomes of the Making Connections program. A large midwestern university partnered with an urban school district defined as high need, serving over 22,000 children with about 77% of them from families identified as economically disadvantaged and 59% minorities (Ohio Department of Education [ODE], 2016a). The district's 2015–2016 student proficiency data (ODE, 2016b) show a general pattern of low performance in mathematics and science with the average number of proficient students for all grade levels well below the state average, pointing towards a significant need for PD in these subject areas. This program evaluation sought to answer the following research questions.

1. Will the PD increase teachers' content knowledge in math and science?
2. Will the PD increase teachers' attitudes, beliefs, and degree of confidence in content knowledge, pedagogy, and use of technology?
3. Will the PD improve teachers' appreciation and understanding of STEM integration and ability to implement it?
4. Will the PD increase students' achievement in mathematics and science?

Participants

A convenience sample of teachers included those individuals who registered for and committed to the PD for a full year. In Year 1, 28 teachers (Grades 5–9 from 9 schools) participated in the program who served 85% of high-need students (e.g., need special services, low income, below grade level). In Year 2, 13 teachers (Grades 7–8 from 6 schools) participated in the program who served 94% high need students. None of the teachers from Year 1 participated in Year 2. Also, a convenience sample of students included those individuals assigned to each teacher at the beginning of the year and who were either in a self-contained classroom or were in a teacher's class period during the integrated STEM lesson. See Table 1 for number of teachers by discipline and grade level and number of students in each year.

See Tables 2 and 3 for participant demographics. In Year 1, there were seven males, and 21 females. Of those, there were one Hispanic, five Black, three Asian, and 19 White teachers. Eleven of those teachers were certified in high school math, two were certified in high school science, five were certified in K–12 special education (SPED), and 10 were certified in the middle grades (with math or science being an area of concentration). In Year 2, all teachers were females. Of those, there were two Black and 11 White teachers. Eleven of those teachers were certified in the middle grades (with math or science being an area of concentration), and two were certified in K–12 special education.

Table 1
Participants by Content Areas

	Year 1	Year 2	Special education[a]	Gifted & talented[a]
Math Grade 9 teachers	12		2	
Math Grades 5–8 teachers	12	7	2	1
Science Grade 9 teachers	1			
Science Grades 5–8 teachers	3	6	2	
Total teachers (n = 40)	28	13		
Total students (n = 413)	237	176	53	7

[a] Teachers or students included in total count.

Table 2
Year 1 Participant Demographics

Participant	Gender	Race/ethnicity	Grade level taught	Subject area taught	Certification
1	Female	Hispanic	9	Math	HS math
2	Female	Black	7, 8	SPED - Math	K–12 SPED
3	Male	White	9	Math	HS math
4	Female	White	9	Math	HS math
5	Female	White	9	Math	HS math
6	Female	Black	6	Math	Middle grades
7	Female	White	5, 7, 8	Math	Middle grades
8	Female	Black	5	SPED -Science	K–12 SPED
9	Female	White	5, 6	SPED - Math	K–12 SPED
10	Male	White	6, 7, 8	Math	Middle grades
11	Female	White	5	Math	Middle grades
12	Male	Black	8	Math	Middle grades
13	Female	White	6, 7, 8	Math	Middle grades
14	Female	Black	5, 6, 7, 8	Math	Middle grades
15	Female	White	9	Math	HS math
16	Female	White	6, 7, 8	SPED - Math	K–12 SPED
17	Male	White	7, 8	Science	Middle grades
18	Female	White	9	Math	HS math
19	Male	White	9	Math	HS math
20	Female	Asian	5	Math	Middle grades
21	Female	White	9	Math	HS math
22	Female	White	5, 6, 7	SPED - Math	K–12 SPED
23	Female	Asian	9	Math	HS math
24	Female	White	9	Science	HS Science
25	Female	White	6	Math	Middle grades
26	Male	White	5	Science	HS Science
27	Male	White	9	Math	HS math
28	Female	Asian	9	Math	HS math

Table 3
Year 2 Participant Demographics

Participant	Gender	Race/ethnicity	Grade level taught	Subject area taught	Certification
1	Female	Black	7–8	Science	Middle grades
2	Female	White	7–8	Math & social studies	Middle grades
3	Female	White	6–8	Science	Middle grades
4	Female	White	7–8	Science & reading	Middle grades
5	Female	White	7	Math	Middle grades
6	Female	White	6–8	Self-contained All subjects	K–12 SPED
7	Female	Black	7–8	Math	Middle grades
8	Female	White	8	Math	Middle grades
9	Female	White	6–7	Math	Middle grades
10	Female	White	7–8	Science, math intervention	K–12 SPED
11	Female	White	8	Science & social studies	Middle grades
12	Female	White	6–8	Math	Middle grades
13	Female	White	6–8	Science	Middle grades

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Instruments

Teacher content knowledge. In Years 1 and 2, teachers were given a math and science content knowledge test, designed by project personnel, at the first afterschool session and again at the end of the summer institute. The test for Year 1 was composed of 48 questions related to math, science, engineering, and pedagogical strategies with a maximum score of 48. Revisions were made on the test after Year 1 to take out questions related to Grade 5 learning standards and to include more questions specifically related to standards in Grades 6–8. In Year 2, the test contained 50 questions with a maximum score of 100.

Technology integration. The Teacher Technology Integration Survey (TTIS; Vannatta & Banister, 2009) measured teachers' attitude and level of comfort at integrating technology in the classroom using a Likert-type scale from 1 (*strongly disagree*) to 4 (*strongly agree*). This survey was given to teachers at the first afterschool session and again at the end of the year-long program. Three of the 10 TTIS subscales, which measured three constructs, were used in this study: *Risk-taking Behaviors and Comfort with Technology* (α = .8540), *Perceived Benefits in using Technology in the Classroom* (α = .8490), and *Beliefs and Behaviors about Classroom Technology Use* (α = .8790).

Teaching confidence, pedagogical beliefs, and impact of PD. The Ohio Department of Higher Education's preliminary (2016b) and follow-up (2016a) surveys were used to measure teachers' confidence levels about teaching, beliefs about effective pedagogy in teaching mathematics and science, quality of the PD, and impact of the project activities on participants' students and participants. This survey was given to teachers at the first afterschool session and again at the end of the year-long program. See Appendix for descriptions of subsections.

Student content knowledge. In Year 1, teachers created their own assessments to measure students' content knowledge before and after they taught their integrated STEM lesson. Teachers within a grade level collaborated to create the same student assessment for their specific grade level in order to offer comparisons. However, several concerns regarding Year 1 student tests motivated project personnel to change procedures in Year 2. These concerns include whether the requirement for teachers to create common tests forced some of them into teaching a particular lesson or teaching to the test and whether the test questions were entirely reliable based on content covered in the PD. Therefore, in Year 2 teachers were provided a bank of test items, created by program personnel based on content covered in the summer institute, from which they chose test items to measure student learning on their integrated STEM lessons. In both years, program personnel reviewed lesson plans and assessments to ensure they adequately measured the content knowledge that would be taught by teachers and that corresponded with the content teachers learned in the PD.

Summer institute daily evaluations. At the end of each day during the 10-day summer institute, teachers were asked in an online survey to rate the instruction provided, give suggestions for improvement, and describe what they learned or could apply in different areas such as differentiated instruction or STEM integration. Anecdotal evidence will follow from teachers' answers to the question regarding knowledge of STEM integration.

Final questionnaire. Teachers were asked to respond to seven open-ended interview questions at the conclusion of the program to provide some description of teachers' final perceptions. Some of the questions included: What has benefited you the most by participating in this project, can you describe some ways that your teaching practice has changed or improved as a result of participating in this project, what challenges have you encountered in trying to implement your lesson plans, and what are a couple of things that you thought were the major strengths of this PD or that you liked the most?

Results and Discussion

Teacher Content Knowledge

These results address Research Question 1: Will the PD increase teachers' content knowledge in math and science? A paired-samples *t*-test was calculated to compare pre- and post-test scores in math and science before and after the summer institute. In Years 1 and 2, teachers scored higher on math and science content knowledge after instruction (see Table 4). In Year 1, the difference was a statistically significant increase, $t(23) = 6.119$, $p < .0005$, $d = 1.25$. In Year 2, the difference was also a statistically significant increase, $t(12) = 3.982$, $p < .002$, $d = 1.10$ (see Table 5).

Technology Integration

These results help to answer Research Question 2: Will the PD increase teachers use of technology? Based on the TTIS, Year 1 teachers had only slightly higher scores on technology attitude after the program ($M = 3.0567$, $SD = 0.599$) than before ($M = 3.030$, $SD = 0.625$). However, Year 2 teachers showed statistically significantly higher scores after the program ($M = 3.692$, $SD = 0.210$) than before ($M = 3.196$, $SD = 0.390$), $t(11) = 6.153$, $p < .0005$, $d = .168$. However, the TTIS more closely measures teachers' comfort level in taking risks when using technology (e.g., troubleshooting and learning new technologies) and perceiving the benefits of using technology (e.g., technology is a priority for me and modeling effective use for students), all of which require greater levels of comfort and continued practice that go beyond the initial use of

Table 4
Paired Samples Statistics for Teachers' Content Knowledge in Years 1 and 2

	N	*M*	*SD*
Year 1			
Pre	24	15.458	6.199
Post	24	24.666	8.442
Year 2			
Pre	13	65.538	15.387
Post	13	78.307	13.437

Note. Scores were only reported for teachers who completed both the pretests and posttests. Teachers who did not complete the posttests either dropped the program or were not present on the day of testing.

Table 5
Paired Samples Test for Teachers' Content Knowledge in Years 1 and 2

	Paired differences							
				95% CI for mean difference				
	M	*SD*	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
Year 1: Pre–Post	9.208	7.3719	1.504	12.321	6.095	6.119	23	.000
Year 2: Pre–Post	12.769	11.562	3.206	19.756	5.782	3.982	12	.002

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technology. In Year 2, more focused instruction was provided on using Google Classroom and other classroom technologies through online tutorials, which may have resulted in higher scores for these teachers.

Teaching Confidence, Pedagogical Beliefs, and Impact of PD

The results presented in this section (including Sections 1–6) answer Research Question 2: Will the PD increase teachers' attitudes, beliefs, and degree of confidence in content knowledge, pedagogy, and use of technology? The following data describes the outcomes of the Ohio Department of Higher Education's preliminary (2016b) and follow-up (2016a) surveys.

Section 1: Teaching confidence. Year 1 teachers had slightly higher scores on confidence about their teaching after the program (M = 1.773, SD = 0.706) than before (M = 2.000, SD = 0.724). In Year 2, teachers had statistically significantly higher scores after the program (M = 1.369, SD = 0.350) than before (M = 1.991, SD = 0.215), $t(11) = 6.153$, $p < .0005$, $d = .269$).

Section 2: Teaching approach. With a continuum of 1 (*strongly agree*) to 5 (*strongly disagree*), higher scores indicated that teachers use more student-centered or constructivist approaches. Table 6 reports mean scores by teacher, and Table 7 reports mean scores by teaching approach.

Overall, teachers tended to use a mix of traditional and constructivist teaching approaches (middle score = 3) with equal numbers of teachers leaning slightly more toward one of the approaches. Year 1 teachers became only slightly more constructivist in their teaching approaches after the program (M = 3.086, SD = .320) than before (M = 2.920, SD = .616). In Year 2, teachers were also only slightly more constructivist after the program (M = 3.170, SD = .247) than before (M = 3.053, SD = .356), but the increase was not statistically significant.

Table 6
Mean Scores on Teaching Approaches by Teacher

	Year 1		Year 2	
Teacher	Pre (n = 15)	Post (n = 15)	Pre (n = 13)	Post (n = 13)
1	3.13	3.00	3.00	3.63
2	3.25	3.75	3.50	3.38
3	2.75	3.25	3.00	3.50
4	2.75	3.00	2.50	2.75
5	2.88	3.13	3.75	3.13
6	3.13	3.13	2.75	3.13
7	3.25	3.00	3.38	3.25
8	2.88	3.00	2.75	3.13
9	3.13	3.00	2.75	3.13
10	2.88	2.50	3.13	3.13
11	2.88	3.38	3.13	3.00
12	2.38	2.88	3.00	2.88
13	2.63	3.63		
14	3.00	2.88		
15	2.88	2.75		
Grand mean	2.92	3.09	3.05	3.17

Table 7
Mean Scores by Teaching Approach

	Year 1		Year 2	
Teaching approach (traditional vs. constructivist)	Pre (n = 15)	Post (n = 15)	Pre (n = 13)	Post (n = 13)
Teacher-led lecture vs. dialogue	3.73	4.00	3.75	3.58
Cooperative group learning vs. independent work	2.53	2.47	2.17	2.17
Central ideas vs. broad coverage of topics	2.27	1.93	2.33	1.92
Students' role is to receive facts vs. apply inquiry	3.47	3.80	3.75	4.33
Hands on approaches vs. reading and lectures	2.40	3.73	3.75	4.00
Encouraging vs. difficulty in encouraging	2.07	1.53	2.25	2.00
Conventional assessments vs. alternative methods	3.20	3.27	2.92	3.50
Use same instructional techniques vs. differentiation	3.67	3.93	3.50	3.83

In Year 1, teachers tended to move toward student-centered, constructivist teaching approaches by using more dialog and interaction, inquiry, hands-on learning, and differentiation. In Year 2, teachers moved towards using more inquiry, alternative assessments, and differentiation.

Section 3: Impact of PD on teachers' content knowledge. Based on mean scores, teachers strongly agreed that the PD impacted their content knowledge with a majority of scores falling between 1 and 2. Technology, inquiry and hands-on learning, and improvement of teaching were three areas most impacted, closely followed by enthusiasm for teaching, math or science concepts and standards, and instructional approaches. Student assessment and questioning techniques were the least impacted but still received high scores of 1.93 and 2.01 respectively. See Table 8 for means scores by teacher and Table 9 for mean scores by content area.

Section 4: Quality of PD. Table 10 depicts teachers' mean scores on the quality of PD. All scores were between 1 and 2, indicating teachers' agreement that the PD was of very high quality.

Table 8
Mean Scores on Impact of PD on Content Knowledge by Teacher

Teacher	Year 1	Year 2
1	1.90	1.25
2	1.40	1.75
3	1.40	1.38
4	2.00	2.13
5	2.00	1.00
6	2.50	1.75
7	1.60	2.13
8	1.00	1.63
9	1.90	1.00
10	1.00	2.75
11	1.30	1.75
12	2.00	1.13
13	1.00	
14	1.00	
15	1.30	
Grand mean	1.55	1.64

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Table 9
Mean Scores on Impact of PD by Content Area

Content Area	Year 1	Year 2	Grand mean
Math/science concepts	1.47	1.67	1.57
Math/science standards	1.47	1.67	1.57
Ways to assess students	1.93	1.92	1.93
Questioning techniques	1.93	2.08	2.01
Technology	1.40	1.17	1.29
Differentiation	1.87	1.92	1.90
Instructional approaches	1.40	1.75	1.58
Inquiry, hands-on activities	1.27	1.33	1.30
Improvement of teaching	1.33	1.42	1.38
Increased enthusiasm for teaching	1.47	1.50	1.49

Table 10
Mean Scores on Quality of PD

	Year 1	Year 2	Grand mean
Ample time	1.73	1.75	1.74
Adequate follow-up	1.80	1.58	1.69
Useful resources	1.67	1.33	1.50
High quality, sustained and intensive	1.67	1.50	1.59
Linked to state and national standards	1.47	1.33	1.40

Highest agreement was that the PD was linked to state and national standards, that it provided useful resources, and that it was sustained and intensive. Lower scores might indicate that teachers desired ample time and adequate follow-up as part of the PD, even though these areas were still relatively high with scores of 1.74 and 1.69, respectively.

Section 5: Impact of PD on students. Table 11 depicts teachers' mean scores on the impact of PD on their students. With scores between 2 and 3, teachers agreed that students were impacted positively by the PD, reporting increased attention, enthusiasm, and involvement in classroom activities as well as improved quality in their school work.

Section 6: Impact of PD on teachers. Table 12 shows mean scores on the impact of PD on teachers. Scores ranged between 1 and 2, indicating that the PD had a very positive impact on teachers. All teachers would recommend this program to other teachers, established a professional network among participants, maintained contact with other participants, and shared what they learned with others.

Student Content Knowledge

These results will answer Research Question 4: Will the PD increase students' achievement in mathematics and science? Based on student assessments that were given before and after instruction of an integrated STEM lesson, both Years 1 and 2 resulted in statistically significantly higher scores after instruction than before, showing that student content knowledge greatly increased as a result of the STEM lesson. It also indicates that the instruction of teachers while integrating STEM produced positive results in students (see Table 13).

Table 11
Mean Scores on the Impact of PD on Students

	Year 1	Year 2	Grand mean
My students are more attentive, enthusiastic and involved in classroom activities	2.13	2.17	2.15
The quality of student work is noticeably improved	2.20	2.42	2.31
My students are participating in science and/or math activities outside of the classroom to a greater degree	2.53	2.83	2.68

Table 12
Mean Scores on the Impact of PD on Teachers

	Year 1	Year 2	Grand mean
Maintained contact with other participants	1.13	1.00	1.07
Maintained contact with college faculty	1.47	1.42	1.45
Established a professional network among participants	1.20	1.25	1.23
Attended a professional association conference	1.93	1.33	1.63
Have or would recommend this program to other teachers	1.00	1.00	1.00
Shared what I learned with colleagues through informal interactions	1.07	1.00	1.04
Have shared what I learned with colleagues through formal interactions	1.53	1.75	1.64

In Year 1, the difference was a statistically significant increase, $t(236) = 23.856$, $p < .0005$, $d = 1.59$. In Year 2, the difference also was a statistically significant increase, $t(170) = 15.756$, $p < .0005$, $d = 1.20$ (see Table 14).

Summer Institute Daily Evaluations

These results will partially address Research Question 3: Will the PD improve teachers' appreciation and understanding of STEM integration? On the survey given at the end of each day of the summer institute, teachers were asked, "What new knowledge did I learn today about integrating math and science/engineering content, technology use, or teaching methods?" The quotes that follow provide some anecdotal evidence.

- "Data collection in science offers many opportunities to use math with the data."
- "I could work with the science teacher to use the numerical results from the electric circuit experiment and have my students find which central means of tendency best represents the data."
- "Physics, Engineering and Math use a multitude of cross-curricular concepts. Graphing and analyzing data is one way; following formulas is another; converting units is a third."
- "The creation of table and graphs from the data collected during the electricity lab could be integrated into a STEM math lesson."
- "Engineer a solution to an insulation/heat transfer problem, using science background to inform the engineering process. Then use technology to collect and graph data, and graph and interpret the data collected using math knowledge."
- "The science is directly related and an amazing connection to math that we cover in the 7th grade."

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Table 13
Paired Samples Statistics for Students' Content Knowledge in Years 1 and 2

	N	*M*	*SD*
Year 1			
Pre	237	27.722	20.583
Post	237	69.532	22.945
Year 2			
Pre	171	41.374	17.389
Post	171	68.830	21.656

Table 14
Paired Samples Test for Students' Content Knowledge in Years 1 and 2

	Paired differences							
				95% CI for mean difference				
	M	*SD*	Std. error mean	Lower	Upper	*t*	*df*	Sig. (2-tailed)
Year 1: Pre–Post	41.81	26.981	1.753	45.263	38.357	23.856	236	.000
Year 2: Pre–Post	27.456	22.788	1.742	30.896	24.016	15.756	170	.000

- "I could have students make rockets and use their distances as data to use to find the central means of tendency."
- "I use hot wheels cars for my force and motion activity, I would like to use the engineering piece where they design and test their own car. I would give them ownership of the activity."
- "Having the Mathematics embedded with the Science and engineering shows me how I can adjust parts of my lesson plan to incorporate data and make the connections to math and the real world connection to engineering."
- "STEM is heavy in problem solving, kids needs to get better at this and making mistakes and being okay with that."
- "The lessons will be more meaningful to the students. Collecting real data to graph is so much more personal and interesting than data someone else gathered."
- "These concepts are so interconnected and by integrating students will see the connection and might gravitate towards careers in one of the areas."
- "Students will benefit in the long run, understanding that learning, math, science, problem solving, designing goes on outside of the four walls of a classroom."

Final Questionnaire

These results will also answer Research Question 3: Will the PD improve teachers' appreciation and understanding of STEM integration and ability to implement? Evidence of the ability to implement STEM integration can best be found in the lesson plans and video recordings of actual lessons as they were implemented. Lesson plans were completed at the end of the summer institute and were examined for accuracy and fidelity to the concepts learned in summer. However, the videos are in the process of being analyzed and will be reported in a future article examining teachers' ability to implement STEM integration. For now, comments on the final questionnaire will give some evidence that teachers made concerted efforts to teach their integration STEM lesson and discovered positive results for themselves and their students.

On one question, teachers were asked how they benefited most from this program. For many teachers, the math and science instructional strategies were deemed most valuable. Thinking about how to integrate mathematics and science was a new concept for some of the teachers, but they shared how this project helped them to better understand how science and mathematics are related and the how the two subjects can be integrated easily in a lesson. Most teachers mentioned a better understanding of learning standards in their content area. They found the various resources, particularly those available in the schools, to be helpful in supporting STEM integration. One participant commented,

> I have benefited the most from being forced to plan that math/science lesson. I had to see how I could incorporate the math into the science and vice versa. I had to also utilize technology. Now I think about these things and look for ways to incorporate as much as I can into my lessons.

They felt the need to spend more time on a topic and add more exploration so that students could further deepen their understanding. Another participant wrote,

> Participating in this project has allowed me to open my eyes about combining classes that don't typically learn together. For example, I have combined my MD [moderately disabled] class with a regular education class for labs at various times during the year so far.

Teachers also found the collaboration with colleagues in workshops and in online discussions valuable because it gave them time to share ideas and get feedback and to explore instructional strategies for teaching math and science. Several teachers commented on how much the technology training impacted their teaching. One teacher shared,

> Access, time, and instruction on how to use technology in my classroom. This has changed my life and teaching. I feel more connected than ever to my students and the way they think. I am easy for them to access and my class is almost 1/2 online now. I love keeping connected with my students who have attendance issues as well.

Receiving a Chromebook as part of the project helped teachers to have immediate access to apps and software as well as finding relevant resources for integrating mathematics and science. The teachers also discussed how apps and software could promote student comprehension and student expression of that learning, thereby, supporting UDL principles. Teachers mentioned having greater comfort with using technology in the classroom and a newfound interest in looking for other ways to use technology with their students.

Teachers were also asked how their teaching practices had changed or improved as a result of the project. One teacher commented,

> I am emphasizing more of the math that is present in science and see the connection much more clearly. My students are making that connection as well and have started talking to me about what they are learning in math class. I have always been an "out-of-the-box" thinker, but having all of this knowledge has given me more tools to explore that thinking.

Other teachers shared that they were incorporating more hands-on experiences and labs that include engineering and found that students responded really well to those activities. Another teacher said,

> I have my students do activities using Chromebooks much more frequently now. I used to only use them for testing. Now we enter data and make graphs, create slide show presentations, go on math websites like prodigy to play games, etc.

Other teachers commented that they were including more UDL strategies to promote student access

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to learning. Workshop faculty members observed such strategies being included, for example, using graphic organizers to promote comprehension (UDL Principle 1), gradually releasing scaffolds to increase independence (UDL Principle 2), and providing contextually relevant problems (UDL Principle 3). Other teachers noted that they were incorporating more intentional connections between math, science, and technology.

When asked about challenges, teachers mentioned the lack of resources to do engineering design projects, available technology, and time needed to implement more student-centered, hands-on approaches because these require more time "to prepare, set up, and put away equipment." Standardized testing was another issue that took away time from classroom instruction. When asked what the major strengths of the project were, teachers responded: learning about technology, connections of mathematics and science, Thinking Mathematics methods, LabQuest activities, strengthened knowledge of standards, making the instruction and materials useful for the classroom, and hands-on lessons. The following quotes offer a clearer view of teacher perceptions of strengths.

- "Actual lessons I can take back to my classroom."
- "Google Chromebooks!!!!! Hands-on Labs Time to work!"
- "Getting time over the summer to actually create a unit plan. In the PDs, having access to information presented so we can easily implement it in our classrooms."
- "I liked the hands-on labs and engineering design challenges. I think I am much more likely to do them in my classroom after doing them myself."
- "I liked the incorporation of the Vernier technology into the labs. I thought the after-school sessions were beneficial because they helped remind me throughout the year of what we worked on over the summer."
- "I really enjoyed the presentation of information and activities related to the STEM instruction. I had no idea there were so many free resources online and ready to use. The summer session was the most beneficial for me. I appreciated that we focused on different topics each day and were shown firsthand how to integrate math, science, and engineering."

Teachers were asked what improvements were needed in the program. Some teachers felt that the physics instruction or engineering challenges were too advanced or did not relate well to their math content, even though the content was chosen according to the grade group. Teachers would have liked more resources to take back to the classroom to do hands-on labs and more training in using the Chromebook. Finally, more time was needed to "practice some of the stuff."

Summary and Conclusions

Improvements were implemented after Year 1 to make the program more successful in Year 2. These included narrowing the ranges of grade levels served, adding mentors to assist with instruction and scaffolding with online discussions, and focusing more intentionally on modeling STEM integration during workshops. However, more improvements still need to be considered. For example, although teachers who opt for Middle Childhood Licensure may have a stronger background in mathematics and science as chosen subjects for specialization, it is likely that some of them still did not have as much content knowledge or a deep understanding of these subjects. Future programs might consider the range of content experience of participants either in the proposal or planning stages, particularly when offering higher level content such as physics. On the other hand, the authors believe that teachers should be prepared at a significantly deeper level of understanding of the material covered in class to gain confidence and be able to convey and explain the concepts correctly and to better understand misconceptions that their students may develop when transferring their experiences to other settings. Program personnel might also want to focus on fewer concepts during the PD and provide more depth of these topics with time to explore. The program might also consider how to provide more resources for teachers to implement hands-on activities in the classroom.

The greatest strengths of the program were the STEM connections that teachers learned about and the changes in instructional practices that resulted. Nonetheless, future efforts might find it rewarding to incorporate more follow-up or sustained efforts with teachers who have participated in the program from year to year as a way to continue the momentum begun in STEM integration. The introduction of various technologies and ways to use them was another strength of the program. Learning to make STEM connections, having dedicated time to design integrated STEM lessons, and providing technology were factors that most likely enabled teachers to be successful in their STEM lessons. Teachers' comments illustrated how the program experiences encouraged them to begin thinking more about and incorporating other STEM connections in their classroom instruction, which in turn enabled students to increase their understanding and engagement in STEM.

This program evaluation clearly shows that all the program goals were met and that anticipated outcomes were achieved. Teachers significantly increased their knowledge of math and science and relevant state learning standards; improved in attitudes, beliefs, and degree of confidence in teaching; developed more comfort with using technology; and learned to appreciate and understand the practice of STEM integration. Student scores in STEM also increased after participating in an integrated STEM lesson. However, this finding is tentative because it is difficult to ascertain whether the students gained more than they would have in any other classroom situations. Teachers did note students' enthusiasm during these lessons, how they were learning to make their own connections between subjects, and how responsive they were to hands-on and engineering activities. Quantitative data and teacher feedback both indicate that the program was highly successful and had a positive impact on teachers and students.

Although the program design might be replicated, one of the limitations of this research study is that it examined a program that served particular grade levels. Programs may need to be designed differently for lower elementary or even high school levels above ninth grade. Additionally, participating schools only included teachers and students from an urban school district, so any results should not be generalized to other populations.

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Appendix

Subsections of Teaching Confidence, Pedagogical Beliefs, and Impact of PD Instrument

Section 1: Teaching Confidence (Pre- and Post-Test)

Some of the questions in this section included: I have a good understanding of fundamental core content in my discipline, I have a good understanding of Ohio's New Learning Standards in Mathematics and/or in Science, I have a good understanding of how to differentiate instruction in the classroom, I have a good understanding of the methods necessary to teach math and/or science concepts effectively, and I believe I am an effective teacher. A Likert-type scale from 1 (*strongly agree*) and 5 (*strongly disagree*) was used on all sections except Section 2.

Section 2: Teaching Approach (Pre- and Post-Test)

Teachers described along a continuum (1 = *traditional*, 5 = *student-centered or constructivist*) their teaching approach on the following eight items: teacher-led lecture versus dialogue among teacher and students, cooperative group learning versus independent work, focused on central ideas versus broad coverage of topics, students' role is to receive facts vs apply inquiry, hands on approaches versus reading and lectures, encouraging vs difficulty in encouraging, conventional assessments vs alternative methods, and use same instructional techniques vs differentiation.

Section 3: Impact of PD on Teachers' Content Knowledge (Posttest Only)

Teachers rated 10 items such as: I learned new content in Math and/or Science (concepts, facts and definitions); I learned about learning standards in Mathematics and/or in Science; I learned inquiry-based, hands-on activities; and I learned methods to differentiate instruction in my classroom.

Section 4: Quality of PD (Posttest Only)

Teachers rated the following five items regarding the quality of the PD: It provided ample time to achieve the stated objectives, provided useful resources and/or materials to assist with my instruction in the classroom, was high quality, was sustained and intensive, and was linked to state and national standards.

Section 5: Impact of PD on Students (Posttest Only)

Teachers rated the impact of the PD on their students on the following three items: My students are more attentive, enthusiastic and involved in classroom activities; the quality of student work is noticeably improved; and my students are participating in science and/or math activities outside of the classroom to a greater degree.

Section 6: Impact of PD on Teachers (Posttest Only)

Teachers rated the impact of the PD on themselves on the following seven items: I have maintained contact (or plan to maintain contact) with other participants, I have maintained contact (or plan to maintain contact) with college/university faculty who provided the professional development, The program led to the establishment of a professional network among participants, I attended a professional association conference, I have or would recommend this program to other teachers, I have shared what I learned with colleagues through informal interactions, and I have shared what I learned with colleagues through formal interactions.