Exemplary STEM Programs: Designs for Success

Edited by Robert E. Yager and Herbert Brunkhorst

Hawker Brownlow
EDUCATION

Contents

STEM Starters

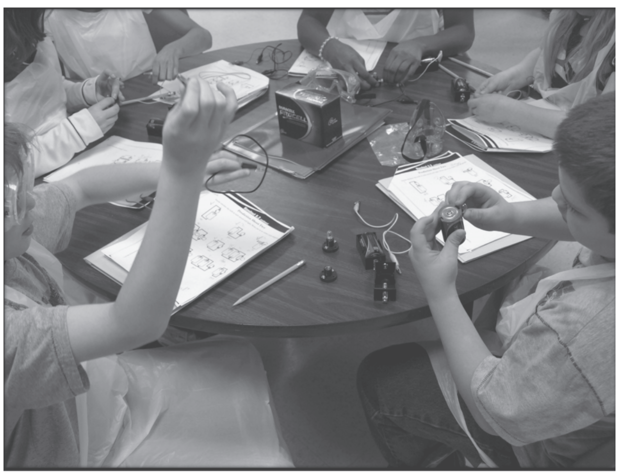
An Effective Model for Elementary Teachers and Students

Ann Robinson, Debbie Dailey, Gail Hughes, and Tony Hall
University of Arkansas at Little Rock
Little Rock, AR

Alicia Cotabish
University of Central Arkansas
Conway, AR

Setting

In a midsize rural school district near the capitol city of Arkansas, a fourth-grade classroom is full of students eagerly engaged in building electrical circuits to power a fictitious city. With brightly colored neon goggles and lab aprons, groups of students tackle the city's electrical design. One group is constructing a baseball park, and another is diligently wiring a replica of a fast food eatery. Other groups are building model storefronts and businesses, which all require electrical circuitry. The classroom teacher and a peer coach, an expert in science, circulate the room, monitoring student progress. The classroom teacher pauses at one group and asks, "Why do you suppose the park will not light up?" One boy jumps in, "Because there is a broken connection." The teacher promptly asks the group to review their circuitry diagram in front of them before proceeding. Next, the peer coach chimes in to elaborate, "If any part of the circuit is opened, or broken, the current will not flow." She then asks the students, "What happens when the current will not flow?" Students respond that the device will not receive power and the lights will not work. The peer coach asks for the students' attention as she reviews the basic rules of electrical


STEM Starters students explore circuitry.

circuits on the interactive whiteboard. The class discussion continues as the peer coach provides further explanation of the behavior of electricity and then tag-teams with the classroom teacher to deliver this well-orchestrated science lesson.

Combined with problem-based science curriculum, expert peer coaching, and intensive teacher professional development focused on science, this classroom is one of 60 from two rural communities in central Arkansas that participated in STEM Starters. A team of researchers collaborated with classroom teachers, gifted and talented facilitators, and building principals to create a culture of inquiry, and to engage in lively instruction that "hooks" children early through the excitement of science and innovation.

Grounded in scientifically based research studies, STEM Starters project components, goals, objectives, and activities focus on increased science learning for all students in grades 2–5, and increased content knowledge and process skills in the STEM disciplines for their elementary teachers. The model was developed with funding from the U.S. Department of Education and validated through randomized field studies of teacher and student outcomes.

Overview of STEM Starters

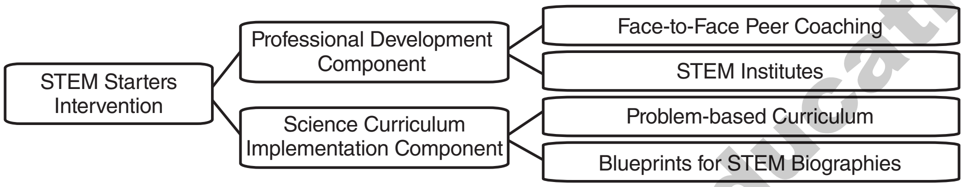
To advance the national STEM agenda, the National Science Board (NSB 2010) recommended students be provided early opportunities to engage in inquiry-based learning with real-world problem solving and that their teachers be supported with research-based STEM preparation and professional development programs. The NSB emphasized early exposure to STEM opportunities to develop and nurture science interest in young innovators. In *A Framework for K–12 Science Education*, the National Research Council (NRC 2012) cautioned that omitting science at *any* grade level, including the early grades, potentially impacts students' conceptual learning and places additional demands on teachers in higher grades.

STEM Starters was guided by the principle that sustained and embedded teacher professional development, coupled with the implementation of an inquiry-based science curriculum, can positively influence student achievement. Brandwein (1995) and more recently, Worth (2010) stressed the importance of both the teacher and the curriculum in developing the science talent in young students. Brandwein emphasized that the greatest barriers to developing science talent included inadequately prepared teachers and an outdated curriculum that neglects the needs and interests of the child. Bitan-Friedlander, Drefus, and Milgrom (2004) suggested that the lack of follow-up support received by teachers constituted a major barrier in implementing a new innovation. Bitan-Friedlander and colleagues recommended that professional development be lengthy enough to internalize the innovation and extend into the *real-world* of the classroom. Finally, Johnson, Kahle, and Fargo (2007) reported increases in science achievement among students when their teachers participated in a sustained and embedded professional development program focused on standards-based practices, including inquiry-based instruction. With this theoretical framework guiding the intervention, STEM Starters focused on two major components: (a) teacher professional development and (b) the implementation of standards-based science curriculum in classrooms.

Major Features

The major features of STEM Starters included a two-year job-embedded professional development component and support and resources for implementing a standards-based science curriculum. The STEM Starters intervention is presented in Figure 1.1.

Figure 1.1. STEM Starters Intervention Model



Professional Development Component

To provide teachers with sufficient professional development to change practice, STEM Starters combined summer institutes and peer coaching sustained over a minimum of two years. Multiple research studies support the efficacy of increased professional development contact time on teacher instructional practices (Gerard, Varma, Corliss, and Linn 2011; Lumpe, Czerniak, Haney, and Beltyukova 2012; Sandholtz and Ringstaff 2011) and ultimately on student achievement (Desimone 2009; Guskey 1986; Johnson, Kahle, and Fargo 2007; Shymansky et al. 2010). Specifically, researchers recommended teachers receive 80+ hours of professional development to implement an inquiry-based curriculum effectively (Cotabish, Dailey, Hughes, and Robinson 2011; Corcoran, McVay, and Riordan 2003; Roehrig et al. 2011; Supovitz and Turner 2000).

STEM Institutes

STEM Starters teachers participated in weeklong summer institutes across two summers. The institutes focused on science content and pedagogy, specific curriculum units aligned with science standards, technological applications, and differentiation of instruction. As recommended by Duschl, Schweingruber, and Shouse (2007), Haney and Lumpe (1995), and Penuel, Gallagher, and Moorthy, (2011), the summer institutes provided explicit instructions necessary for the implementation of a new program. For example, teachers actively took the role of students during the curriculum units. They participated in multiple activities such as using the Taba Model for Concept Development to brainstorm, categorize, and make generalizations about the overarching concepts of the specific units. They also participated in laboratory investigations such as determining the effect of temperature on the evaporation rate of water. In addition, they were engaged with real-world problems and scenarios and were guided to generate evidence in support of a conclusion. Through the implementation of the curriculum units, an expert science instructor modeled effective science pedagogy and checked for teachers' understanding of science content. The science instructor emphasized overarching concepts, higher-order thinking skills, inquiry-based instruction, experimental design, and the use of technology as recommended by the National Research Council (2012) and now embedded in the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013).

During the STEM Starters summer institutes, an emphasis was placed on the use of technology in the classroom to enhance the learning processes. Teachers were exposed to multiple web-based resources that aligned with their specific units. These resources provided content information for the student and for the teacher as well as offering multiple activities and games to motivate student learning. During the second year of summer institutes, STEM Starters offered iPad training to teachers. Teachers were provided with information on iPad applications to enhance their teaching experience and their students' learning.

Peer Coaching

A unique feature of STEM Starters is the use of one-to-one peer coaching to deliver embedded professional development in science. The configuration of pairing a generalist teacher and a science expert is uncommon in most elementary schools; however, results indicate that the STEM Starters approach to increasing teacher science content knowledge and student achievement in science works. With the need for increased hands-on STEM education in the elementary grades (NSB 2010), and the lack of science expertise among elementary educators (Fulp 2002), the marriage between peer coaching and STEM makes sense.

In a peer coaching intervention, the relationship forged between the teacher and the peer coach is crucial; it must be one of mutual trust and shared purpose (Caccia 1996). The National Foundation for the Improvement of Education (NFIE 1999) provided a list of qualities necessary for an effective peer coach including: demonstrating commitment to lifelong learning, being flexible and open-minded, being viewed as an expert in pedagogy and content area, exhibiting confidence in teaching, collaborating well with others, providing positive and productive critiques, maintaining confidentiality, and being approachable and patient.

Tschannen-Moran and Tschannen-Moran (2011) further elaborated on the characteristics of an effective coach. They suggested coaches focus on five concerns to mentor teachers effectively, including concerns for consciousness, connection, competence, contribution, and creativity. Tschannen-Moran and Tschannen-Moran described a *concern for consciousness* as a nonjudgmental awareness of what is going on in the teacher's classroom. Specifically, when making suggestions for improvement, an effective coach will focus on the positives that happen in the classroom. By emphasizing what a teacher does well and how it connects to student progress, the teacher is more likely to increase the frequency of the positive aspects of his/her teaching. Tschannen-Moran and Tschannen-Moran maintained "By discovering and developing their strengths, teachers can transform their weaknesses without having to tackle them head on" (p. 16).

In addition, Tschannen-Moran and Tschannen-Moran (2011) stated a *concern for connection* allows the coach to build a trusting relationship with the teacher; thereby, opening necessary channels of communication. In this instance, a teacher is more likely to share his/her fears and frustrations with the coach, then the pair of professionals can work together to make improvements. The authors suggested a coach demonstrate a *concern for competence* by appreciating teachers' current level of expertise, thus, allowing them to focus and build on their strengths. Tschannen-Moran and Tschannen-Moran stated a *concern for contribution* involves teachers having opportunities to voice concerns in a nonjudgmental format that confirms professional equality between the coach and the teacher. Finally, Tschannen-Moran and Tschannen-Moran said "For true learning to take place, coaching must also unleash creativity" (p. 15). The authors described the *concern for creativity* as a desire to instill in teachers a motivation and ethic for continuous improvement. Through a desire for improvement, teachers will search continuously for creative and new avenues to increase their effectiveness.

Peer coaching in the STEM Starters model is used to extend professional development beyond the summer institute to the classroom, enabling teachers to practice their newly learned skills in familiar surroundings with support from their peer coach. The positive effects of peer coaching in multiple domains have been reported. For example, Slater and Simmons (2001) found teachers increased knowledge, skills, and confidence due to participation in a peer coaching program and Showers (1984) reported increased achievement scores among students whose teachers had participated in peer coaching.

In addition to the general literature on peer coaching, there is an emerging literature on coaching in the STEM disciplines. In a peer coaching study with middle school science teachers, Appleton (2008) found teachers reported benefits from the support provided by the peer coach. In the intervention reported by Appleton, the peer coach provided teacher support through modeling instruction, facilitating classroom discussion, reflecting on the previous lesson, and collaboratively planning the upcoming science lesson. The teachers indicated their science instructional practices had improved due to the support provided by the peer coach. In addition, the teachers felt the presence of the peer coach increased their confidence in leading students in exploratory and self-discovery activities. The STEM Starters studies reported in a later section of this chapter add to the science-specific literature on coaching.

STEM Starters' Peer Coaching Intervention

STEM Starters provided peer coaching on a weekly basis to the participating teachers. During the developmental stages of the model and in the studies published on the model, the peer coach was a former secondary chemistry and physics teacher as well as a gifted and talented facilitator. During the school year, the peer coach was in each classroom two to three times per month, providing approximately 60 hours of professional development over two years. Initially, the peer coach acted as an instructional leader and modeled effective science teaching for the teachers and the students. Eventually, the role of the peer coach transitioned to an instructional facilitator, where she assisted the teacher with instruction and monitored and encouraged student involvement. The peer coach also acted as a materials facilitator by ensuring all necessary science materials were available in the schools and ready for use in the individual classrooms. The peer coach maintained continuous contact with the teachers through e-mail and personal visits, ensuring that their needs were being met.

The primary objective of the STEM Starters peer coach was not to evaluate the teachers but rather to encourage and support them in implementing a new science program. In the early months of the intervention, teachers were hesitant about the program. They were nervous about the role of the peer coach, the extra time needed for implementation, and about their own lack of science content knowledge. Once they realized the peer coach was not in the school to pass judgment but to help them, they welcomed her into their classrooms. In addition, the reaction of the students to the program was very positive, which in turn encouraged the teachers. The professional development intervention is summarized in Table 1.1.

Table 1.1. STEM Starters Teacher Professional Development Across Two Years

	Summer Institute	Peer Coaching
Year 1	• 30 hours (out-of-school) • curriculum units • inquiry-based strategies • differentiation for high-ability learners • *talent-spotting* of students from underrepresented groups	• 30 hours (in-school) • implementation of curriculum units • model teaching • instructional facilitator • materials facilitator • science content expert
Year 2	• 30 hours (out-of-school) • science content development • inquiry-based strategies • classroom management	• 30 hours (in-school) • instructional facilitator • materials facilitator • science content expert

Science Curriculum Implementation Component

Given the commitment to inquiry-based pedagogy, particularly with a problem-based learning approach, STEM Starters researchers reviewed and selected rigorous curriculum that had been validated with low-income students. Due to the low average-income demographic of the districts in the initial field trials, both quality and cost of the materials were considerations. In addition, the units selected are of sufficient length that they provide an in-depth inquiry experience. They are self-contained and therefore can be *post-holed* into the elementary curriculum schedule that generally focuses heavily on literacy and numeracy rather than on science and engineering.

William and Mary Science Curriculum Units

The William and Mary science curriculum units implemented through STEM Starters situated science learning in the context of a real-world problem. Each unit introduced students to advanced content, engaged students in problem solving and critical thinking, and was focused on specific overarching concepts that were integrated throughout the unit, including change (Grades 2 and 3) and systems (Grades 4 and 5). To increase student understanding, students were asked to brainstorm examples and non-examples, categorize, and make generalizations about each overarching concept.

The Grade 2 and 3 units were inquiry-based learning units focused on exposing young students to science concepts and scientific processes. These units engaged students in creative and critical-thinking opportunities through investigations and problem solving (Bracken et al. 2008). Each unit provided real-world scenarios where students were to use their newly acquired knowledge and skills to solve a meaningful problem. For example, in *What's the Matter?* students were challenged to solve the mystery of the missing water. The unit was introduced through the following scenario: "The principal of the school approached the class and asked for help. She had recently brought to her office a bowl of ocean water. After a couple of days, her water disappeared." Through the re-creation of the scene and using a need-to-know-board, the students