CORRELATED SCIENCE AND MATHEMATICS: 
A NEW MODEL OF PROFESSIONAL DEVELOPMENT FOR TEACHERS
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Abstract
This article describes a new professional development (PD) model of linking science and mathematics instruction called Correlated Science and Mathematics (CSM), which enables teachers to integrate science and mathematics curriculum. Integration usually implies that science teachers use mathematics as a tool or mathematics teachers use a science as an application of a mathematics concept. Although both the science and mathematics standards recommend integration, unless there are effective PD models that will facilitate it, broad-scale integration is not likely to occur. The CSM model of PD links science and mathematics more thoroughly and uniquely than the traditional integration model. Each discipline is taught with seven fundamental goals: (a) teaching for conceptual understanding, (b) using each discipline’s proper language, (c) using standards-based learning objectives, (d) identifying the natural links between the disciplines, (e) identifying language that is confusing to students, (f) identifying the parallel ideas between the disciplines when possible, and (g) using a 5E (Biological Science Curriculum Study [BSCS], 1989) inquiry format for science and mathematics when appropriate. Use of the CSM PD model resulted in grades 5-8 science and mathematics teachers planning and teaching integrated lessons and using the proper language of each discipline.

Introduction
Research has successfully demonstrated that teachers make a significant difference in how well students learn (Hiebert & Grouws, 2007; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Continued professional development (PD) provides teachers with an avenue to better understand the content of their discipline, as well as improve their pedagogical strategies that will enhance the students’ conceptual understanding of the content. The literature on the importance of PD in improving the quality of teaching is substantial (Darling-Hammond, 1998; Office of Educational Research and Improvement, 1998; Porter, Grant, Desimone, Yoon, & Birman, 2000; Wenglinsky, 2000). Reform-based PD providing opportunities for active learning, attending as a group, study groups, mentoring relationships, and teacher networks have a positive impact on teaching practice (Cohen & Hill, 1998; Desimone, Porter, Garet, Suk Yoon, & Birman, 2002; Sowder, 2007).

Connecting Science and Mathematics
Both the National Council of Teachers of Mathematics (NCTM) and the National Academy of Sciences (NAS) advocate linking the disciplines of science and mathematics. NCTM (2000) states, “The process and content of science can inspire an approach to solving problems that applies to the study of mathematics” (p. 66). Likewise, NAS (1996) acknowledges the indispensable role that mathematics plays in scientific inquiry when they state that “mathematics is essential to asking and answering questions about the natural world” in scientific inquiry (p. 148). The integration of science and mathematics is one way to improve teacher achievement in
each discipline. Basista, Tomlin, Pennington, and Pugh (2001) report significant gains in the participating teachers’ understanding of content and confidence to implement integrated science and mathematics. Similarly, Basista and Matthews (2002) report increased understanding of content and confidence. Additionally, they reported increased pedagogical knowledge of teachers, increased administrator awareness of the science and mathematics standards, and increased administrative support for teachers.

The Correlated Science and Mathematics Model
Integrating science and mathematics traditionally means linking the two disciplines in some manner (Davidson, Miller & Metheny, 1995). Science integrates mathematics by using mathematics either as a tool to work science problems (e.g., solving genetics or rate problems) or to actually teach a science concept (e.g., using ratios in the equation to teach photosynthesis). Similarly, mathematics integrates science by using science applications to explain or practice mathematics concepts or to employ the science to reinforce students’ interest in mathematics or to enable the students to recognize the broad utility of mathematics. The need to infuse mathematics and science more completely was recognized by West and Tooke (2001) and termed Correlated Science and Mathematics (CSM). The CSM PD model was developed in 2006 and has been continually revised and refined. The CSM model is unique in that it integrates science and mathematics in a more comprehensive manner than other integration models. Each discipline is taught with seven fundamental goals: (a) teaching for conceptual understanding, (b) using each discipline’s proper language, (c) using standards-based learning objectives, (d) identifying the natural links between the disciplines, (e) identifying language that is confusing to students, (f) identifying the parallel ideas between the disciplines when possible, and (g) using 5E inquiry format in science and mathematics when appropriate (see Figure). The CSM approach to PD is “centered in the critical activities of the profession—that is, in and about the practices of teaching and learning” (Ball & Cohen, 1999, p. 13).

A new continuum is proposed that spans from pure mathematics to pure science with the midpoint now representing a correlated lesson including each of the seven goals of CSM.

Figure. CSM Continuum of mathematics and science correlation.

Components of the CSM PD Model
The seven components of the CSM PD model are described as follows. (a) Conceptual understanding: Developing a deep understanding of a one’s discipline is a critical attribute for teaching for conceptual understanding (Darling-Hammond, 1998; Devlin, 2007; National Research Council, 2001). Conceptual understanding is defined as the ability to apply concepts to new contexts or connect new concepts to existing information or to use general principles to
explain and justify (Malloy, Steinthorsdottir, & Ellis, 2004; Wiske, 1997); (b) Proper language: Each discipline has its own language or vocabulary (Jacobs, 1989). Content expertise, as well as content pedagogy expertise, is required of the instructional team to achieve the CSM goal of proper use of each discipline's language; (c) Standards: National and state standards are purposefully considered as the CSM lessons are planned and the science and mathematics learning objectives are identified. Also, many of the national PD standards are met with the CSM model. As stated by the National Staff Development Council (NSDC), "It is essential that staff development leaders and providers select learning strategies based on the intended outcomes and their diagnosis of participants' prior knowledge and experience" (n. p.); (d) Linkages between disciplines: Science uses some mathematical concepts and skills as tools, and mathematics uses science to explain mathematics concepts; (e) Confusing language: In the CSM model, language that may be confusing to students is identified and clarified. An example of confusing language is the difference between the meaning of distance in mathematics and science. In mathematics, distance is the linear length from one point to another, whereas in science the same concept is called displacement; (f) Parallel skills, ideas, processes or concepts: Concepts, etc. that are similar because they behave similarly in both science and mathematics or share many characteristics; (g) 5E: The CSM science lessons developed generally follow the 5E model for inquiry. The CSM instruction is team-taught by a science expert and a mathematics expert, both of whom are well versed in both content and content pedagogy. The instructors design lessons purposefully to meet the defined goals for the PD participant. CSM is implemented with middle school science and mathematics teacher teams and their principals. Each project consists of 70-hour summer institutes and 30 hours of academic year (AY) trainings for the teachers. The principals received 12 hours of summer training and an optional 30 hours of AY training. According to the NSDC (2001), “An extended summer institute with follow-up sessions throughout the school year will deepen teachers' content knowledge and is likely to have the desired effect” (n. p.). To follow the CSM model, the first five goals must be addressed whether the lesson or project is primarily focused on science or primarily focused on mathematics. The last two goals of identifying parallel ideas and using inquiry are met when appropriate since not every lesson contains parallel ideas between science and mathematics or is suitable for inquiry. For example, a skill in science, such as using a piece of equipment, is more effectively taught using a direct instruction model rather than inquiry and does not share parallel ideas with mathematics.

Research Questions and Methods
Several research questions concerning the CSM projects arose as the CSM projects were developed and revised over time. This paper contains data from the 2009-2010 project. Data concerning improved student achievement is under analysis but not available at this point in time. However data concerning improved teacher content knowledge and integration of lessons is available and will be addressed in this paper. Research questions: (1) would CSM training increase teachers’ content knowledge in physics and mathematical reasoning, (2) would CSM training enable science and mathematics teachers to plan integrated science and mathematics lessons, (3) would CSM training enable science and mathematics teachers to implement integrated science and mathematics lessons?

Teachers' content knowledge was accessed with pre and post-tests in physics and mathematical reasoning at the beginning and end of the two-week summer institute. Teachers’ increase use of integrated lessons in their classrooms was assessed using level four of Gusky’s (2002) critical
levels of professional development evaluation. Three data sources concerned with Guskey’s level four, a change in professional practices, were utilized: (1) AY classroom observations in conjunction with teacher and principal interviews, (2) observations of sample integrated lessons taught by the participants during the AY Saturday sessions, and (3) examples of integrated lessons reported by teachers during interviews and during AY sessions. Twenty teachers (ten mathematics, ten science) participated in this study. The teachers worked in teams to create lessons that included science and mathematics concepts. A minimum of two classroom observations of each participant were conducted during the fall and spring of the AY following the summer institute. Interviews of both the teacher and their principal were conducted after each set of classroom observations. During each AY session, teachers taught lessons to their fellow participants and used planning time to create lessons.

Data Analysis
Teacher Pre and Post-tests: Participant teachers were administered pre and post-tests in physics and mathematical reasoning at the beginning and end of the two-week summer institute. A related-samples t-test was conducted for each content test to determine whether teacher content knowledge of physics and mathematics significantly improved as a result of the summer institute. Results indicate that participant teachers did significantly improve their knowledge of both physics and mathematical reasoning. The mean score on the physics post-test ($M = 62.29, SD = 12.970$) was significantly higher than the mean score on the physics pre-test ($M = 45.76, SD = 11.377, t(16) = 4.992, p = .000$). The effect size was large ($d = 1.211$), and 61% of the variance was accounted for by the treatment ($r^2 = 0.609$). The 95% confidence interval for the mean difference between pre and post-test physics scores was 9.51 to 23.55. The mean score on the mathematical reasoning post-test ($M = 82.00, SD = 12.817$) was also significantly higher than the mean score on the mathematical reasoning pre-test ($M = 73.50, SD = 13.135, t(15) = 2.984, p = .005$). The effect size was medium ($d = 0.746$), and 37% of the variance was accounted for by the treatment ($r^2 = 0.372$). The 95% confidence interval for the mean difference between pre and post-test mathematical reasoning scores was 2.43 to 14.57.

Through observations and interviews, three major findings were revealed. Classroom observations disclosed an increased ability to create and teach integrated science and mathematics lessons and to use the proper language of each discipline. Teachers reported that prior to the training they never even thought about teaching integrated lessons, whereas after training they were teaching from one to eight integrated lessons per month. Teachers reported that the integrated lessons went well and they were planning to use the lesson again the next year. During each afternoon of AY training the teams were given time to design an integrated science lesson and an integrated mathematics lesson. During the planning, each teacher taught their partner the content and proper language of the lesson. At the end of the day, the teams shared their written plans with the entire group. Providing joint planning time is an integral part of CSM PD. As stated by NSDC, “teachers are likely to adapt their instruction to new standards-based curriculum frameworks through the joint planning of lessons”.

Principals reported seeing science and mathematics teachers collaborating more and creating integrated lessons. Also, the principals stated that prior to training they looked for general instructional strategies, not science or mathematics specific ones. They reported that they now see the connections between mathematics and science so that when observing a science or mathematics lesson they ask themselves whether the lesson could be integrated. Moreover, they
are asking themselves if some manipulatives or science equipment could be used in hands-on strategies during the lesson.

**Contribution to Teaching and Learning of Science**

The integration of science and mathematics has long been advocated by both disciplines and their national standards, *National Science Education Standards* and the NCTM Principals and Standards for School Mathematics. Although the discussion for developing an integrated science and mathematics curriculum has been ongoing, teachers have not been trained to develop an integrated curriculum. Moreover, no PD model was structured and described well enough to support trainers in facilitating teachers to integrate science and mathematics. Research indicates that teachers are better able to help their students learn mathematics when they have opportunities to work together to improve their practice, time for personal reflection, and strong support from colleagues and other qualified professionals (Brown & Smith, 1997; Putnam & Borko, 2000). The critical attributes of CSM can enable teacher teams to effectively teach integrated science and mathematics. The CSM model of PD seems to support teachers in the integration of mathematics and science. As stated by a recent CSM participant,

> Through intense hands-on instruction, numerous investigations, use of manipulatives, and the instructors’ questioning strategies and modeling of collaboration, I was able to work side-by-side with a fellow teacher to develop wonderful integrated lessons for our students. This team-teaching approach to lesson planning and construction will help to keep my students’ interest in math and science alive. (CSM participant, 2008)

**References**


