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Considerations for Teaching Integrated STEM Education

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Abstract

Quality Science, Technology, Engineering, and Mathematics (STEM) education is vital for the future success of students. Integrated STEM education is one way to make learning more connected and relevant for students. There is a need for further research and discussion on the knowledge, experiences, and background that teachers need to effectively teach integrated STEM education. A support, teaching, efficacy, and materials (s.t.e.m.) model of considerations for teaching integrated STEM education was developed through a year-long partnership with a middle school. The middle school was implementing Project Lead the Way's *Gateway to Technology* curriculum. The s.t.e.m. model is a good starting point for teachers as they implement and improve integrated STEM education.

Keywords: integrated STEM education, engineering, Project Lead the Way, teaching

Introduction

There is a limited amount of research that examines the prerequisite skills, beliefs, knowledge bases, and experiences necessary for teachers to implement integrated instruction (Fykholm & Glasson, 2005). For integrated Science, Technology, Engineering, and Mathematics (STEM) education, since it is relatively new, this statement rings even more true. The importance of focusing on what teachers need to effectively teach STEM education was noted by the National Science Board (NSB) in the document *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System.* The NSB in this document state that well-qualified and highly effective teachers should teach STEM classes. They call for more national attention on attracting, preparing, and retaining qualified and committed teaching candidates (NSB, 2007). The best way in which to attract, prepare, and retain qualified teachers remains to be answered.

This paper will describe support for a middle school's implementation of the integrated curriculum Project Lead The Way (PLTW). According to PLTW, they are the largest non-profit provider of middle school and high school STEM education programs (Lock, 2010). Recommendations for how teachers can be effective at teaching integrated STEM education will be discussed. The recommendations are based on a support, teaching, efficacy, and materials (s.t.e.m.) model that was developed by the authors from the literature and work with the middle school in implementing the PLTW curriculum.

Research Questions

The purpose of this paper is to describe factors that must be considered for teachers to effectively implement integrated STEM education. The information in this study provides recommendations for both PLTW teachers and in general for integrated STEM education teachers. The research questions that guided this study are as follows:

(1) What are the main considerations for teaching integrated STEM education?
(2) For the middle school in this study what were the main factors that affected the teachers' implementation of the PLTW curriculum?

Theoretical Framework

There are many benefits that have been connected with the use of integrated education, "Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners" (Furner & Kumar, 2007; p.186). Other benefits that have been found are that it is student centered, improves higher level thinking skills and problem solving, and improves retention (Fllis & Fouts, 2001; King & Wiseman, 2001; Smith & Karr-Kidwell, 2000).

Similar benefits have been found with a more specific focus on integrated STEM education. Several benefits of STEM education include making students better problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate (Morrison, 2006). Studies have shown that integrating math and science has a positive impact on student attitudes and interest in school (Bragow, Gragow & Smith, 1995), their motivation to learn (Gutherie, Wigfield & VonSecker, 2000), and achievement (Hurley, 2001). The National Academy of Engineering and the National Research Council (Katehi, Pearson & Feder, 2009) list five benefits of incorporating engineering in K-12 schools: improved achievement in mathematics and science, increased awareness of engineering, understanding and being able to do engineering design, and increased technological literacy.

With all of the possible benefits of integrated STEM education, it is important to ascertain how teachers can effectively teach integrated STEM education. Issues related to supporting teachers, teaching practices, teacher efficacy, and materials needed to implement integrated STEM education are vital to consider.

Supporting Teachers in STEM Integration

There is a growing number of institutions that are partnering with schools to support STEM education. Tufts University has been working for over 15 years to integrate engineering into K-12 classrooms. They believe that engineering motivates students learning of the mathematics and science concepts that make technology possible. Professors, staff members, and students go into classrooms every week to assist teachers; they have monthly teacher support meetings, and training for teachers on technology resources (Rogers & Portsmore, 2004). In a study, researchers from the University of Nevada, Reno paired with middle school science teachers to help the teachers implement engineering. The researchers found that students not usually engaged in science were actively engaged in the design process (Cantrell et al., 2006). In another study, faculty from the University of Nebraska developed a two-week summer professional development program to help middle and high school science and mathematics teachers implement engineering lessons. In studying the impact of the lessons they found student interest in mathematics, science, and engineering was encouraged (Nugent et al., 2010). Other support for teachers has come through federally funded mathematics and science teacher professional development trainings to help teachers implement STEM integration (Harris & Felix, 2010).

More integration of content is taking place in teacher education programs in mathematics and science methods courses (Berlin & Lee, 2005). Several studies have looked at the difficulties and benefits of using integrated content courses or methods courses with preservice teachers (Beeth & Mc Neal, 1999; Elliott et al., 2001; Frykholm & Glasson, 2005; Furner & Kumar, 2007; Lewis et al., 2002). Most of the studies found benefits to an integrated course, but do mention the extra time needed to plan and effectively teach the courses.

Teaching Practices around STEM Integration

The research on teaching integrated mathematics and science provides a good basis for teaching integrated STEM education. Successful integration of science and mathematics depends largely on teachers' understanding of the subject matter (Pang & Good, 2000). Many teachers have holes in their own subject content knowledge (Stinson et al., 2009) and asking math and science teachers to teach another subject may create new knowledge gaps and challenges (Stinson et al., 2009).

What is known from research on effective practices in science and mathematics education provides insight into effective practices in STEM integration. Zemelman, Daniels & Hyde (2005) list ten best practices for teaching math and science:

(1) use manipulatives and hands-on learning;
(2) cooperative learning;
(3) discussion and inquiry;
(4) questioning and conjectures;
(5) use justification of thinking;
(6) writing for reflection and problem solving;
(7) use a problem solving approach;
(8) integrate technology;
(9) teacher as a facilitator;
(10) use assessment as a part of instruction.

A focus on connections, representations, and misconceptions can also aid teachers' pedagogy (Walker, 2007). The benefits of using an integrated STEM approach is that many of these practices lend themselves naturally to integrated STEM activities.

Integrated STEM activities also allow teachers to focus on big ideas that are connected or interrelated between subjects. Berlin & White (1995) provide recommendations on how teachers should approach student knowledge:

(1) build on students' prior knowledge;
(2) organize knowledge around big ideas, concepts, or themes;
(3) develop student knowledge to involve interrelationships of concepts and processes;
(4) understand that knowledge is situation or context specific;
(5) enable knowledge to be advanced through social discourse;
(6) understand that knowledge is socially constructed over time.

Recommendations five and six tie in nicely with many of the best practices of math and science given by Zemelman et al. (2005).

Teacher Efficacy within STEM Integration

Teacher efficacy is extremely important for successful teaching. Teachers' self-efficacy can be viewed as teachers' beliefs about their capabilities to produce a desired effect on student learning. Content knowledge and quality pedagogy play a large part in feelings of efficacy. Caprara et al. (2006) note that a number of studies have pointed to the influence of teachers' self-efficacy beliefs on student achievement and success at school. In addition, teachers' feelings of self-efficacy have been found to be associated with enhanced student motivation, self-esteem, more positive attitudes in classes, and students' own feelings of self-efficacy. They also state that teachers' sense of efficacy is related to their satisfaction with their choice of profession.

Materials Needed to Implement STEM Integration

Integrated STEM education often requires numerous materials and resources for students to investigate solutions to real world problems through designing, expressing, testing, and revising their ideas. Materials can include construction tools such as saws, measuring devices, and hammers; electronic materials such as computers, design programs, robotics kits, and calculators; and other materials used in design, which could include wood, styrofoam, glue, cardboard, or construction paper. Through the use of these materials in design activities students can better understand technology. A broad definition of technology is anything that is human made that makes life easier. An engineers' job is to design technologies that can solve problems. For authentic learning to take place, students need to be given opportunities to design processes or products.

Integrated STEM education is an effort to combine science, technology, engineering, and mathematics into one class that is based on connections between the subjects and real world problems. However, in general, integrated STEM education can involve multiple classes and teachers and does not have to always involve all four disciplines of STEM. Engineering is becoming more prevalent in K-12 schools and can provide great problem solving opportunities for students to learn about mathematics, science, and technology while working through the engineering design process.

Method

Setting

The middle school in this paper was a large suburban 6^{th} to 8^{th} grade school in a Midwestern state. There were four PLTW teachers at the middle school with different subject backgrounds. Two teachers had mathematics backgrounds, one a science background, and one a technology education background. The teacher with a science background taught science classes for half of her teaching load. The teacher with the technology education background was the district coordinator for the PLTW program for the district's four middle schools. All students at the school were enrolled in PLTW classes.

The middle school was implementing an integrated STEM curriculum, *Gateway to Technology*, from PLTW. PLTW is a non-profit organization that seeks to develop effective interdisciplinary STEM education for middle and high schools and whose stated goal is to prepare "students to be the most innovative and productive leaders in Science, Technology, Engineering, and Mathematics (STEM)" (Lock, 2010). In order to accomplish this "PLTW courses are designed to provide students with opportunities to understand the scientific process, engineering problem-solving, and the application of technology; understand how technological systems work with other systems; use mathematics knowledge and skills in solving problems; communicate effectively through reading, writing, listening and speaking; and work effectively with others" (Brophy et al., 2008, p. 378). PLTW provides a document that aligns their curriculum to national standards to support their claims to be an integrated STEM curriculum. However, a research study that mapped the *Gateway to Technology* curriculum to the Minnesota state mathematics and science standards found the specific mathematics and science content in the curriculum to be limited (Stohlmann et al., 2011).

During the 2009–2010 school year two graduate student fellows collaborated with and helped the PLTW teachers at the middle school one day a week. This was made possible by funding from the 3M corporate foundation. The 3M STEM Education Fellowship Program funds graduate students to work with schools to help bring known best practices around STEM integration in K-12 classrooms through (1) professional development and (2) curriculum development, implementation, and assessment. The fellows were former teachers and one was a doctoral student in science education and the other in mathematics education. During the school year the fellows mapped the curriculum to the state standards, provided ideas for curriculum implementation, assisted in the classrooms, developed supplemental curriculum materials, helped teachers with organization, were a resource for any problems or questions, and conveyed the importance of STEM education.

Other support programs were in place that helped the planning, organization, and content knowledge of the teachers. PLTW had a required two-week training session during the summer, PLTW trainers could be contacted with questions throughout the school year, and teachers attended a year-long STEM integration teacher academy that the middle school had signed up for that included five days of training and 16 hours of Professional Learning Communities (PLCs). The PLTW teachers that taught the same class also talked often to share ideas and keep similar class pacing.

Data Collection and Analysis

The collection of data in this study involved weekly researcher field notes, three formal classroom observations of each teacher using a structured observation protocol, and weekly informal conversational interviews. The classroom observations were done at the beginning, the middle, and towards the end of the school year. The graduate fellows kept field notes from the weekly informal conversational interviews and from their work with students in the classrooms.

Data was analyzed by using the constant comparative method (Corbin & Strauss, 2008). Each data source was coded first using open-coding and then axial-coding to develop themes. Then the data sources were compared against each other for themes that were supported across all three data sources.

Results

Teaching

The PLTW teachers tried to rely on quality pedagogy to help them be more comfortable with the curriculum. In eleven of the twelve classroom observations, the teachers employed a student-centered approach to teaching including student presentations, designing a Rube Goldberg machine, building dragsters, designing dragsters with 3-D modeling software, small group discussions of readings, and measurement activities. The teachers were not focused on lecturing, but on having students work together and develop their own ideas.

However, at times not knowing what direction students would go in the lessons made teachers less comfortable and confident in their knowledge. Teachers had difficulties knowing how long lessons would last and knowing how to best guide students in their work. Three of the four teachers mentioned this several times throughout the year. In one activity, students dissemble a device and look for the six simple machines in the device. Then students are asked to create a new mechanical device that represents a simple machine from the dissembled pieces. Since students brought in their own devices, it made it difficult for the teachers to be familiar with what each device consisted of in order to help students struggling to find simple machines as they took apart their device.

Teachers' Comfort Level

While teachers worked hard throughout the year, there were signs that at times teachers were not confident in their implementation of the curriculum. In the informal interviews with the PLTW teachers throughout the year, this appeared to be an important topic that affected what was accomplished in the classes. For example, one teacher felt that she had always done a great job teaching in her over ten years of teaching experience, but really struggled with feeling that she was helping students learn important content this year and enjoy the class.

The teachers' comfort level was also affected by whether or not teachers felt a passion to continue to develop a career as a PLTW teacher and by their uncertainty about the future of PLTW classes. Since the teachers had been trained to teach subjects other than PLTW classes, all of them appeared to have been unsure if they wanted to keep teaching PLTW long term. One teacher made several comments throughout the year that she just wanted to teach a mathematics class because she did not go to school to teach STEM. All of the teachers at several times noted being uncomfortable teaching the curriculum. If the PLTW teaching job is just a short-term job until a math or science teaching job becomes available, then it may affect the amount of investment and work that teachers are going to put into developing the PLTW classes. STEM specific classes are still relatively new and with any new curricular implementation, there can be uncertainty regarding its longevity. This can affect both the amount of time teachers are willing to invest and retention of PLTW teachers.

Another aspect that affected the teachers' implementation is that the PLTW teachers had different teaching backgrounds. It is important that teachers share their knowledge, because if content knowledge is lacking in areas, it can lead to less effective pedagogy: "Limited subject matter knowledge restricts a teacher's capacity to promote conceptual learning among students" (Ma, 1999; p.36). The PLTW teachers had different subject backgrounds (mathematics, science, technology) and felt more comfortable with certain parts of the PLTW curriculum. However, this is a possible strength, because teachers with different backgrounds can be a resource for teachers with questions and possibly can find connections beyond the curriculum as written.

The PLTW teachers talked during the week to share ideas about how to teach the classes. Also, twice during the year the PLTW teachers from four middle schools in the district meet to discuss what was working and to share teaching ideas. This was beneficial and helped the teachers feel more comfortable.

Materials

PLTW sells materials kits that the middle school purchased for the activities in the curriculum. The materials kits have to be purchased each year as students use the materials in projects such as designing a dragster out of wood and building a Rube Goldberg machine. Through the use of various materials, students can see that technology is not just electronics but can involve many different things. Since the different projects require materials used over several class periods, room space can be a concern. Teachers will need storage or a large classroom for keeping student projects and materials organized. Teachers need to make sure that their school will support their program fully to provide students the necessary materials.

Electronic technology materials are also necessary for teachers to be the most effective. Internet websites, applets, design programs, dynamic software, robotics software, and calculators can all be integrated into lessons. Three of the four PLTW teachers taught in rooms that had an high number of computers for class use. Access to the Internet is useful for students to do background research on the problems that they are trying to solve.

Discussion

There are several implications from this article for administrators, teachers, and schools that are considering implementing a PLTW program or STEM integration program in their school or continuing to improve a current program. Implementing effective STEM education requires dedicated, organized, and knowledgeable individuals. It is important to have teachers that are committed to being long-term PLTW teachers and not just waiting for a math, science, or other job to become available. Teacher turnover can have negative effects for schools in terms of school cohesion, teaching effectiveness, and students' achievement (Cochran-Smith, 2004). While teachers are developing their content knowledge of integrated STEM education, they can focus on quality strategies for teaching. A growing number of institutions are offering integrated programs that lead to licensure in both math and science, particularly at the middle school level that might serve to lessen the effect of this issue (Frykholm & Glasson, 2005).

Since teachers may have different licensures and backgrounds, it is important for schools to provide support and time for collaboration. The middle school in this article used a variety of approaches to support teachers. Partnering with a local university or a nearby school, attending professional development, taking advantage of training offered by curriculum companies, having common teacher planning time, and encouraging open communication can help teachers to feel that they have the support they need to be successful. Mathematics, science, and PLTW teachers should try to collaborate to make sure that they are maximizing student learning. Similar concepts and information can be reinforced in classes or skipped if students have mastered the content. Simple machines were covered so well in the PLTW classes during the year that the science teachers skipped that topic in their curriculum.

The s.t.e.m. model of considerations for teaching integrated STEM education classes provides useful information for teachers to be successful (see Figure 1). The teaching category is the largest since content knowledge is the most important for teachers new to integrated STEM education. Teachers can build on the recommendations for effective teaching of integrated science and mathematics. While this study did not investigate self-efficacy, it is an important area for further study. Research has shown that teachers' content knowledge, experience, and pedagogical content knowledge have a large impact on self-efficacy. Over time, employing a student-centered approach to teaching with well-structured activities will allow for teachers to become more comfortable with the curriculum and for students to be successful. Supporting teachers in various ways and providing teachers with the necessary materials to do their job well may enable integrated STEM education teachers to be successful.

Conclusion

Much of the newest and most valuable knowledge involves more than one subject. Integrated STEM education can motivate students to careers in STEM fields and may improve their interest and performance in mathematics and science. Effective STEM education is vital for the future success of students. The preparation and support of teachers of integrated STEM education is essential for achieving these goals. Future research can focus on the development of curricula materials and instructional models for STEM integration, connections between teacher education programs for integration and teachers' subsequent classroom teaching practices, and also ways in which teachers view STEM integration. The s.t.e.m. model discussed here can serve as a starting point for teachers to be successful in facilitating student learning in STEM integration classes.

<table>
<tr><th colspan="2">Support</th></tr>
<tr><td colspan="2">• Partner with a university or nearby school
• Attend professional development
• Teacher collaboration time
• Curriculum company training and contacts</td></tr>
<tr><th colspan="2">Teaching</th></tr>
<tr><td>Lesson Planning</td><td>Classroom Practices</td></tr>
<tr><td>• Focus on connections
• Translations of representations
• Understand student misconceptions
• Understand student capabilities
• Problem solving based
• Student centered
• Build on previous knowledge
• Focus on big ideas, concepts, or themes
• Integrate technology
• Real world and cultural relevancy</td><td>• Question posing and making conjectures
• Justifying thinking
• Writing for reflection
• Focus on pattern understanding
• Use assessment as part of instruction
• Cooperative learning
• Effective use of manipulatives
• Inquiry</td></tr>
<tr><th colspan="2">Efficacy</th></tr>
<tr><td colspan="2">• Content knowledge and pedagogical knowledge contribute to positive self-efficacy
• Commitment to STEM education is vital
• Planning and organization are critical</td></tr>
<tr><th colspan="2">Materials</th></tr>
<tr><td colspan="2">• Technology resources
• Broad view of technology
• Materials kits for activities
• Room space and storage for materials
• Tables for group work</td></tr>
</table>

Figure 1. The s.t.e.m. model of considerations for teaching integrated STEM education.

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References

Beeth, M., & Mcneal, B. (1999). Co-teaching science and mathematics methods courses. Retreived from ERIC database. (ED443666).

Berlin, D., & Lee, H. (2005). Integrating science and mathematics education: Historical analysis. *School Science and Mathematics*, *105*(1), 15–24.

Berlin, D., & White, A. (1995). Connecting school science and mathematics in House, P. & Coxford, A. (Eds.), *Connecting Mathematics across the Curriculum: 1995 Yearbook*. Reston, VA: NCTM.

Bragow, D., Gragow, K.A., & Smith, E. (1995). Back to the future: Toward curriculum integration. *Middle School Journal*, *27*, 39–46.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in p-12 classrooms. *Journal of Engineering Education*, *97*(3), 369–387.

Cantrell, P., Pekcan, G., Itani, A., & Velasquez-Bryant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education*, *95*(4), 301–309.

Caprara, G., Barbaranelli, C., Steca, P., & Malone, P. (2006). Teachers' self-efficacy beliefs as determinants of job satisfaction and students' academic achievement: A study at the school level. *Journal of School Psychology*, *44*, 473–490, doi: 10.1016/j.jsp.2006.09.001.

Cochran-Smith, M. (2004). Stayers, leavers, lovers, and dreamers: insights about teacher retention. *Journal of Teacher Education*, *55*(5), 387–392, doi: 10.1177/0022487104270188.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research* (3rd edn) Thousand Oaks, CA: Sage.

Elliott, B., Oty, K., Mcarthur, J., & Clark, B. (2001). The effect of an interdisciplinary algebra/science course on students' problem solving skills, critical thinking skills and attitudes towards mathematics. *International Journal of Mathematics Education in Science and Technology*, *32*(6), 811–816, doi: 10.1080/00207390110053784.

Fllis, A., & Fouts, J. (2001). Interdisciplinary curriculum: The research base: The decision to approach music curriculum from an interdisciplinary perspective should include a consideration of all the possible benefits and drawbacks. *Music Educators Journal, 87*(22), 22–26, 68.

Frykholm, J., & Glasson G. (2005). Connecting science and mathematics instruction: pedagogical context knowledge for teachers. *School Science and Mathematics 105*(3), 127–141, doi: 10.1111/j.1949-8594.2005.tb18047.x.

Furner, J., & Kumar, D. (2007). The mathematics and science integration argument: a stand for teacher education. *Eurasia Journal of Mathematics, Science & Technology*, *3*(3), 185–189.

Gutherie, J. T., Wigfield, A., & VonSecker, C. (2000). Effects of integrated instruction on motivation and strategy use in reading. *Journal of Educational Psychology*, *92*, 331–341, doi: 10.1037/0022-0663.92.2.331.

Harris, J., & Felix, A. (2010). A project-based, STEM-integrated team challenge for elementary and middle school teachers in alternative energy. Retrieved from saintfrancisuniversity.edu, October 9th, 2010.

Hurley, M. (2001). Reviewing integrated science and mathematics: The search for evidence and definitions from new perspectives. *School*

Science and Mathematics, *101*, 259–268, doi: 10.1111/j.1949-8594.2001.tb18028.x.

Isaacs, A., Wagreich, P., & Gartzman, M. (1997). The quest for integration: school mathematics and science. *American Journal of Education*, *106*(1), 179–206, doi: 10.1086/444180

Katehi, L., Pearson, G., & Feder, M. (Eds). (2009). National Academy of Engineering and National Research Council *Engineering in K-12 education*. Washington, DC: National Academies Press.

King, K., & Wiseman, D. (2001). Comparing science efficacy beliefs of elementary education majors in integrated and non-integrated teacher education coursework. *Journal of Science Teacher Education*, *12*(2), 143–153, doi: 10.1023/A:1016681823643.

Lewis, S., Alacaci, C., O'Brien, G., & Jiang, Z. (2002). Preservice elementary teachers' use of mathematics in a project-based science approach. *School Science and Mathematics*, *102*(4), 172–180, doi: 10.1111/j.1949-8594.2002.tb18199.x.

Lock, J. (2010). *About us*. Available at: http://www.pltw.org/about-us/who-we-are.

Ma, L. (1999). *Knowing and teaching elementary mathematics*. Mahwah, NJ: Lawrence Erlbaum Associates.

Morrison, J. (2006). *TIES STEM education monograph series, Attributes of STEM education*. Baltimore, MD: TIES.

National Science Board. (2007). *A national action plan for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system*. Available at: http://www.nsf.gov/nsb/documents/2007/stem_action.pdf

Nugent, G., Kunz, G., Rilett, L., & Jones, E. (2010). Extending engineering education to K-12. *The Technology Teacher*, *69*(7), 14–19.

Pang, J., & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School Science and Mathematics*, *100*(2), 73–82, doi: 10.1111/j.1949-8594.2000.tb17239.x.

Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education*, *5*(3), 17–28.

Smith, J., & Karr-Kidwell, P. (2000). The interdisciplinary curriculum: a literary review and a manual for administrators and teachers. Retrieved from ERIC database. (ED443172).

Stinson, K., Harkness, S., Meyer, H., & Stallworth, J. (2009). Mathematics and science integration: models and characterizations. *School Science and Mathematics*, *109*(3), 153–161, doi: 10.1111/j.1949-8594.2009.tb17951.x.

Stohlmann, M. Moore, T, Roehrig, G& McClelland, J. (2011). Year-long impressions of a middle school STEM integration program. *Middle School Journal*, *43*(1), 32–40.

Walker, E. (2007). Rethinking professional development for elementary mathematics teachers. *Teacher Education Quarterly*, 113–134.

Zemelman, S., Daniels, H., & Hyde, A. (2005). *Best practice: New standards for teaching and learning in America's school* (3rd Edition). Portsmouth, NH: Heinemann.