Virginia Mathematics and Science Coalition
Science Specialist Task Force Report

February 2007

In October 2006, the Virginia Mathematics and Science Coalition (VMSC) directed a task force to write a report to present to the LEAs, DOE, BOE, and policy makers on how a science teacher specialist will improve student learning in science. Based on input from the Virginia Science Education Leadership Association (VSELA) in November 2006, it was determined that consideration should be given to science specialists at the elementary, middle, and high school levels. This report includes, but is not limited to, the job description, competencies, licensure, and preparation for science specialists.

Science Specialist Task Force Members

Donna R. Sterling, Chair
Professor of Science Education
George Mason University

Patrick Dexter
Headquarters Community Relations Advisor
Exxon Mobil Public Affairs

Delores Dalton Dunn
Education Consultant
Virginia Association of Science Teachers

Wendy Frazier
Assistant Professor of Science Education
George Mason University

Jodi Hepner
Elementary Science Specialist, K-3
Fairfax County Public Schools

Paula Klonowski
Science Coordinator
Virginia Department of Education

Juanita Jo Matkins
Assistant Professor, Science Education
College of William and Mary

Enza McCauley
Assistant Professor of Science Education
Longwood University

Jacqueline T. McDonnough
Assistant Professor, Science Education
Virginia Commonwealth University

Laura J. Nelson
President of VSELA
Director Science Education
Portsmouth Public Schools

Eric M. Rhoades
Supervisor of Mathematics and Science
Stafford County Public Schools

Yvonne Smith-Jones
Director of Mathematics, Science, and Technology
Hopewell City Schools

Science Specialist Writing Committee

Mollianne G. Logerwell
High School Science Teacher
Fairfax County Public Schools

Erin E. Peters
Albert Einstein Distinguished
Educator Fellow, NASA
Middle School Science Teacher
Arlington Public Schools

Amos O. Simms-Smith
Middle School Science Teacher
Fairfax County Public Schools

Dawn Renee Wilcox
Elementary Science Coordinator
Spotsylvania County Public Schools

Science Specialist Task Force Report

Introduction

Virginia has a long history of educational progress in science. In 1995, well ahead of most other states and the federal government, Virginia created new Standards of Learning for Virginia Public Schools to describe the expectations for student learning and achievement in grades K-12 for the four core academic areas: mathematics, science, English, and history and social science (Virginia Department of Education, 1995). Recently, Gross (2005) reviewed each state's science standards and rated them according to their (1) expectations, purpose, and audience, (2) organization, (3) science content and approach, (4) quality, and (5) seriousness. Also included were scores on inquiry and evolution. Virginia was one of only seven states to receive an "A" and ranked as second overall in the nation. Even with this excellent track record, however, there are still significant issues that need to be addressed in Virginia's schools regarding science education. For example, even though science scores on the Standards of Learning tests improved between 1998 and 2002, there were significant gaps for disabled, limited English proficient, African-American, and Hispanic students (see Table 1).

Table 1: Selected Science 2002 Virginia Standards of Learning Tests Pass Rates
(VDOE, 2002)

Science Test	Overall State Pass Rate Change 1998-2002	Difference Between Disabled and Non-Disabled (2002)	Difference Between LEP and non-LEP (2002)	Difference Between African-American and State Average (2002)	Difference Between Hispanic and State Average (2002)
Grade 3	+15	-21	-18	-18	-13
Grade 5	+17	-23	-25	-22	-13
Grade 8	+14	-30	-18	-15	-9
Earth Science	+12	-28	-37	-21	-14
Biology	+11	-30	-28	-15	-14
Chemistry	+24	-28	-16	-19	-14

One reason for these achievement gaps could be differences in access to effective teachers. Tuerk (2005) found in his study of 1450 schools across Virginia that students who go to schools in higher poverty areas are more likely to have underqualified teachers and lower standardized test scores. The importance of quality teaching to student achievement has been substantiated over the past 20 years by several notable research studies that have shown a positive connection between teachers' subject matter preparations and higher student achievement (Darling-Hammond, 2000; Ferguson & Womack, 1993; Goldhaber & Brewer, 2000; Guyton & Farokhi, 1987; Hawk, Coble, & Swanson, 1985; Monk, 1994; Rowan, Chiang, & Miller, 1997). The effects of teacher expertise are so powerful on student achievement that a comprehensive study showed that the achievement gap between white and black students was almost entirely attributable to teacher qualification (WestEd, 2000). Additionally, quality teaching has been shown to be of greater impact on student performance than socio-economic variables (Wenglinsky, 2002).

In spite of this clear link between teacher preparation and student achievement, research has shown that teachers at all grade levels lack expertise related to science instruction. Duschl (1983) found that elementary teachers are often reluctant to teach science because they feel unprepared. More recently, Weiss, Banilower, McMahon, and Smith (2001) found that only 25% of elementary teachers feel that they are very well qualified to teach science and 67% are not familiar with national science standards. Further, few elementary teachers attempt to improve their content knowledge after they graduate. Less than 20% of elementary teachers have taken additional coursework since they entered the classroom, and 75% of middle school science teachers reported that they felt they needed more professional development (Horizon, 2000). Gain in content knowledge, however, is only an initial step in teacher preparedness. Teachers must also be given the time to organize their content knowledge into connected, accessible information. Studies reveal that even science majors, those most likely to teach at the high school level, reconfigure their knowledge of content into a more meaningful framework after their first year of teaching (Gess-Newsome & Lederman, 1993).

Need for Targeted Professional Development

The lack of teachers' science content and science pedagogy knowledge can be difficult to address once teachers are in the classroom. Because they have many responsibilities throughout the day, reading current research or enrolling in further coursework tends to be a low priority. Additionally, even though inquiry-based science teaching is advocated by national curriculum documents (AAAS, 1993; NRC, 1998) and has been linked to advanced student learning (Marx, Blumenfeld, Krajcik, & Soloway, 1996) and higher standardized test scores (Geier, Blumenfeld, Marx, Krajcik, Fishman, & Soloway, 2004), teachers need sustained professional development over several years to master it (Fishman, Marx, Best, & Tal, 2003; Marx, et. al., 1996; Marx, Freeman, Krajcik, & Blumenfeld, 1998). In-depth, long range professional development is also necessary to successfully integrate literacy and science instruction in elementary and middle schools (Hapgood, Magnusson, & Palincsar, 2004; Moje, Peek-Brown, Sutherland, Marx, Blumenfeld, & Krajcik, 2004).

The current model for professional development is not sufficient to meet these needs. Teachers' voices are seldom given prominence in the planning and implementation of professional development (National Education Association, 2006; Zemke & Zemke, 1988; Showers, Joyce, & Bennett, 1987; Tallerico, 2005). In contrast to what is known to be effective, local expertise, organizational routines, and resources dictate the content and context of professional development that teachers receive (Loucks-Horsley, Love, Stiles, Mundry, &

Hewson, 2003; Association for Supervision and Curriculum Development, 2006). In a review of research on professional development for science teachers, Loucks-Horsley and Matsumoto (1999) found that in order to be effective and improve student achievement, professional development must (1) integrate subject matter and teaching methods, (2) give teachers guidance in and time for reflection about what they are learning and how to apply it, (3) provide time for collaboration, and (4) be aligned with school and district initiatives. Further, knowledge in the areas of learning, teaching, the nature of science, professional development, and how change occurs provide a valuable framework for shaping decisions about the design and implementation of professional development (Loucks-Horsley, et. al., 2003). Professional development will substantially improve teaching (1) when it happens through the specific contexts in which teaching occurs, (2) when there are substantial opportunities to study and obtain feedback in collaboration with peers, and (3) when teachers have control over the process of professional development (King & Newman, 2000; Loucks-Horsley, et. al., 2003).

In a review of the research, Rice (2003) found that teacher coursework in both the subject area taught and pedagogy positively contribute to education outcomes and that pedagogical knowledge coupled with content knowledge contributes to teacher effectiveness at all grade levels. Further, research suggests that a balance between the two is necessary. Monk (1994), for example, found that above a threshold level, teachers' content knowledge is negatively related to student achievement. However, the balance between subject matter and pedagogical knowledge may differ between elementary, middle, and high school levels, necessitating differentiated professional development.

Elementary teachers face the difficulty of having to be an expert in each subject area and require assistance in learning more content and teaching using inquiry methods (Kielborn &

Gilmer, 1999). Their lack of experience with science often prevents elementary teachers from teaching challenging science content to their students (Atwater, Gardener, & Kight, 1991; Schoeneberger & Russell, 1986). The need at the elementary level is to develop science content and pedagogical content knowledge in order to address this deficiency.

Middle school teachers face different challenges based on their backgrounds. Since there are few teacher training programs that focus on the middle level, middle school teachers tend to be high school teachers that move down or elementary teachers that move up. At the middle school level, the need is addressing concerns of the elementary trained teacher, which could include content knowledge, as well as the concerns of the high school trained teacher, which could include more pedagogical content knowledge.

High school teacher training programs focus on one discipline of science and have the ability to prepare teachers to be deeply knowledgeable in their particular discipline (biology, earth science, chemistry, or physics). Professional development for high school teachers would look different than professional development efforts for elementary teachers. High school teachers have had training in their preparation programs in two separate realms, content and pedagogy. Ideally, teachers should combine their knowledge of content and pedagogy to determine the best instructional practices. However, teacher training programs tend to teach content and pedagogy separately from each other, and teachers rarely have the chance to explore the overlap between the two. At the high school level, the need is to develop pedagogical content knowledge to help teachers who are highly knowledgeable in their content but need assistance in using this knowledge in effective instructional practices.

Teachers need accessible support in both content and pedagogy. At the same time, it must be developed and presented in a format and setting that meets their individual needs. The

National Education Standards note that “[w]henever possible, the professional development of teachers should occur in the contexts where the teachers’ understandings and abilities will be used. Although learning science might take place in a science laboratory, learning to teach science needs to take place through interactions with practitioners in places where students are learning science, such as classrooms and schools” (NRC, 1998, p58). Teachers need time to reflect on their current teaching and ways to increase student achievement. Teachers are often not in the position to find the resources needed to address these issues. It is also difficult and often unreasonable to expect building level administrators to have the time or possess the expertise needed to lead the changes necessary to improve instruction in science education.

The Task Force believes that the addition of school-based certified science specialists would be an effective way to address these issues. Science specialists are defined as teachers whose interest and distinctive preparation in content and pedagogy are coordinated with particular teacher leadership assignments to support teaching and learning in the context of science instruction (Reys & Fennell, 2003). The need for school-based specialists is demonstrated by research findings that teachers are better able to cultivate strong expertise in the teaching and the learning of science when drawing on support from a building level content specialist (Elmore, 2002) and that the use of school-based leaders who have knowledge and expertise in science, teaching, learning, and leadership is critical to affecting long-term change (Spillane, Diamond, Walker, Halverson, & Jita, 2001).

Need for School Based Science Specialists

School-based science specialists would have the time and expertise to meet the needs of science teachers. In terms of content and pedagogy, research has shown that while most elementary teachers’ science lessons were teacher-centered, textbook-driven, and geared toward lower level knowledge, science specialists engage students in extended inquiry-based activities that are aimed at helping students to construct meaning, apply their science content knowledge to novel everyday situations, develop intellectual and manipulative inquiry skills, and achieve higher order objectives (Schwartz, Abd-El-Khalick, & Lederman, 2000). Further, these practices employed by science specialists have been directly linked to higher levels of student achievement (Wenglinksy, 2002). In regards to professional development, the more professional development teachers receive in hands-on learning and teaching specific groups of students, the more likely they are to change their instruction and impact student learning (Wenglinsky, 2002). This is even more likely, if the science specialist can provide embedded support while the teacher learns new content and tries new strategies. Due to their proximity, science specialists also will be immediately available to address teachers' concerns and would have knowledge of local resources and constraints. The science specialist can model lessons, co-teach lessons, and assist teachers in getting appropriate resources. They can be a facilitator for a professional learning community to further school improvement goals. Further, they will have the time to remain current on educational research and translate this research to the teachers, thus overcoming the documented gap between research findings and practice (WestEd, 2000). The science specialists are the support mechanism for the teachers to make them more effective.

Examples of Science Specialists in Virginia

With the establishment of No Child Left Behind and the increasing emphasis on high stakes testing and accountability, many school leaders are seeking more effective organizational behavior by taking advantage of the leadership potential of all stakeholders, including teachers. Schools making this change are creating and expanding teachers' roles as leaders (Gabriel, 2005). Across the commonwealth, several school divisions have already taken the initiative and are working to strengthen science education by utilizing teacher leaders. Below are examples of the efforts a few divisions are taking.

Arlington County Schools: Arlington has a division Science Supervisor and Science Specialist, both K-12. Three elementary schools have Science Specialists who are devoted to science education at those K-5 schools.

Hampton City Schools: Hampton City has one division wide Science Curriculum Leader and two teacher specialists. One is primarily responsible for providing technical support for eleven not-Title 1 elementary schools, six middle schools and four high schools. The other provides technical support for the fourteen Title 1 elementary schools. They provide workshops, visit the schools, observe teachers, occasionally model instruction and prepare tests, quizzes and invent activities that correspond to the Science Standards of Learning Tests. Each school has a “science instructional leader.” The instructional leaders’ role is to assure that teachers have needed supplies and support to teach science with direction from the Science Curriculum Leader and teacher specialists.

Prince William County Schools: Old Bridge Elementary School has a state-of-the art science lab and maintains a part-time science specialist to assist teachers in teaching scientific processes. The math and science programs at Signal Hill, Victory, Cedar Point, Bennet, and Rosa Parks Elementary Schools are each supported by a Math/Science specialist.

Spotsylvania County Schools: Spotsylvania County Schools has one division wide Science Supervisor and one Science Coordinator. Each of the elementary and middle schools has a specific “SOL Resource Teacher” for each content area. The role of the science resource teacher is to serve as a content leader for the school. They work collaboratively with building administrators and the division Science Supervisor and Coordinator to provide instructional leadership and support to teachers.

The above examples reveal that consensus continues to grow throughout Virginia that science teacher specialists are key in facilitating teacher learning and lead to improvement in student learning. However, in view of the fact that there is no state sanctioned definition of "science specialist," each division, or in some cases each school, has defined the role of that "specialist" category position differently. School divisions have also chosen to utilize different titles for the position.

In Virginia there is no consistent, uniform, and coherent approach to training and employing the services of teachers who become specialists in science. The lack of state licensure creates another problematic issue in terms of job preparation. Confirmation of who is highly qualified to fill the role is not currently attainable. Further, school divisions are at different places in their science education efforts, and some have limited time and resources available to develop specialist programs on their own. Based on our research and from information gathered through dialogue with Virginia school leaders, the Task Force advocates that a statewide licensure program for school based science specialists be implemented in order to address these issues.

Recommended Responsibilities for School Based Science Specialists

Specifically, the licensure programs for science specialists should include coursework and other preparation that will enable science specialists to:

- Serve as a liaison to translate science standards and current research into classroom practice to facilitate implementation of the Virginia Standards of Learning.

- Lead, organize, and facilitate professional development sessions to focus on the needs of staff members in the implementation of a high quality and challenging science program for all students.
- Work collaboratively and supportively with central office and building administrators and staff to plan, implement, support, and evaluate effective science programs that provide for the improvement of teaching and learning.
- Work collaboratively with teachers to implement a variety of instructional and assessment strategies that meet the needs of the school's student population.
- Support teachers in identifying, implementing, and refining the use of current instructional resources and strategies through observation, coaching, co-teaching, and modeling lessons.
- Work collaboratively with central office and school administrators and teachers to analyze student work, identify students' level of understanding and/or proficiency, interpret assessment information to inform the instructional program, and assist teachers in differentiating instruction.
- Serve as a mentor to provide ongoing assistance to new or struggling teachers, including first year teachers and "career switchers" in science content and science pedagogy.
- Seek partnerships with scientists and engineers in order to increase interactions among the scientific and business community, teachers, and students.
- Facilitate workshops in order to support parents in helping their children learn science.

Preparation for Science Teacher Specialists

A program leading to an endorsement as a science specialist must provide an environment where content, pedagogy, and leadership are equally represented. This must be an environment where candidates work collaboratively to ensure quality science teaching for all students, learn from their mistakes, and use their experiences to create a deeper understanding of science in the field and in the classroom. In higher education and teacher development programs, the tendency is for science courses to focus on content and education courses to focus on pedagogy. There are limited offerings that integrate content and pedagogy, and even fewer that include leadership. A science specialist endorsement program must develop and maintain collaborative relationships with school districts and research institutions and incorporate the expertise of faculty across both the education and sciences departments.

Recommended Competencies for Science Specialists

A science specialist needs to possess a variety of skills that utilize (1) science subject content knowledge, (2) pedagogical content knowledge, and (3) educational leadership proficiency. Science specialists should have a strong vision of integrating these three competency areas to enhance science curriculum, teaching, and learning using research and experience. The following describe the competencies for this position.

- Committed to all children learning science.
- Possess a deep understanding of the science disciplines and science education standard strands, including: science as inquiry, biology, chemistry, physics, Earth and space science, science and technology, science in personal and social perspectives, and history and nature of science.
- Focus on the thorough development of basic science ideas and skills, including understanding the sequential/scaffolding nature of scientific principles embedded within the content strands.

- Possess a strong understanding of connections among science concepts and applications of these concepts to solve problems.
- Possess a strong understanding a current research in science content, science pedagogy, and education leadership.
- Possess an understanding of and the ability to effectively use cognitive processes in both academic and nonacademic settings, including: scientific reasoning, scientific communication, connecting scientific knowledge, and using scientific representations.
- Possess the ability to create quality, developmentally appropriate assessments that monitor student skills and understanding of science in order to guide instructional practice.
- Have an understanding of appropriate educational technologies and support their integration into science teaching and learning.
- Continue to enhance knowledge and skills in science content, pedagogy, leadership, and technology in order to translate these innovations into classroom practice.
- Possess a deep understanding of safety rules and regulations as well as how to design and maintain a safe classroom environment.
- Demonstrate the ability to collaborate with and support teachers through co-teaching, mentoring, modeling, and coaching.
- Demonstrate the ability to work collaboratively with teachers and maintain open communication with central office and school administrators, counselors, and educators outside of the classroom.
- Demonstrate the ability to assess and identify teacher professional development needs and develop appropriate measures to address those needs.

- Demonstrate the necessary leadership skills to administer staff development in science content, science pedagogy, and monitoring/assessment of student learning.

Recommended Licensure for Science Specialist

The Task Force reviewed the possible role and responsibilities that a specialist in Virginia's school might take on and the competencies necessary to carry out these responsibilities. Based on the review of research at the national level as well as information gathered from school divisions in Virginia, we recommend science specialist licenses for preK-6 and 6-12. We recommend that a candidate seeking an endorsement as a science specialist have:

- Completed at least three years of successful classroom teaching experience in which the teaching of science was an important responsibility,
- Graduated from an approved science specialists preparation program (master's level) or completed a master's level program in science, science education, or related education field with at least 30 semester hours of graduate course work in the competencies described above, and
- Strong science content background during their bachelor's or master's degrees that includes for preK-6 at least 21 semester hours of coursework in undergraduate or graduate-level science and for 6-12 at least 42 semester hours of coursework in undergraduate or graduate-level science.

Recommended Professional Coursework for Science Specialist

Teachers who want to become a science specialist select a preK-6 and/or 6-12 endorsement. Although coursework will vary among the grade levels, the programs will lead to a master's degree. To become a preK-6 elementary specialist, candidates will complete 15 graduate semester hours of science content, 9 graduate semester hours of science teaching and leadership, and 3 graduate semester hours of professional experience. To become a 6-12 secondary specialist, candidates will complete 12 graduate semester hours of science content, 12 graduate semester hours of science teaching and leadership, and 3 graduate semester hours of professional experience in addition to having a bachelor's degree, or the equivalent, in a science content area.

Science Content

All teachers preparing to be science specialists must develop a deep understanding of science content. Safety, the nature of science, use of technology, data collection/analysis, and experimental design must be embedded in each course. Coursework must be both relevant to the work of science specialists and reflect current research. The courses will reflect the grade level endorsement (preK-6 or 6-12) the candidate is working towards. Candidates preparing to become preK-6 elementary specialists will take 15 graduate semester hours of coursework that covers, at a minimum, the content contained in the K-12 science standards of learning for Virginia. Candidates preparing to become 6-12 secondary specialists will take 12 graduate semester hours of coursework in the subject areas (i.e., earth science, biology, chemistry, and physics) in which they do not have a science teaching license or a bachelor's or master's degree major.

Science Teaching and Leadership

Teachers preparing to be science specialists must be able to translate their understanding of science content into effective instruction. To do this, coursework offered will reflect three aspects of science education, including (1) curriculum and pedagogy, (2) research and assessment, and (3) leadership and policy. These courses will reflect the grade level endorsement (preK-6 or 6-12) the candidate is working towards. Candidates will develop a clear understanding of how students learn science and the pedagogical knowledge essential to science teaching and learning. They will learn to develop curriculum based on state and national standards to meet the needs of a diverse group of learners. To enhance leadership skills, courses will provide those seeking a science specialist endorsement the experiences, methods, and strategies to become a positive motivating force in implementing state and national guidelines and policies. Candidates will develop an understanding of past and current trends in education policy and use this knowledge to effectively guide their schools' science education efforts. Coursework will also enable candidates to develop skills in collecting, analyzing, and interpreting individual and collective data. They will learn how to use data from educational research to guide instructional decisions, strategies, and program development. In addition, candidates will learn to provide professional development to teachers in order to integrate the implications of research into instruction. Candidates seeking a preK-6 elementary science specialist endorsement will complete 9 semester hours in these areas, while candidates seeking a 6-12 secondary science specialist endorsement will complete 12 semester hours in these areas.

Professional Experience

In addition to traditional coursework, candidates for science specialist endorsement will complete a three-part internship addressing (1) science research, (2) curriculum/pedagogy, and (3) leadership/policy. Each portion of the internship will be divided equally, for a total of 100 hours (3 graduate semester hours). The science research component must be done within a laboratory or field setting with a practicing research scientist. Interns must complete the curriculum/pedagogy component within a school setting, to be determined by the grade level endorsement the candidate seeks, where they are able to assist classroom teachers with science curriculum and instruction. The leadership/policy component of their internship must be completed at the school division level or higher (e.g., state, regional, national) and involve direct experiences in science education leadership and/or policy. This program requirement is the same for both preK-6 elementary and 6-12 secondary science specialist candidates.

Conclusion

By establishing a science specialist endorsement Virginia will continue in its tradition of excellence in science education. The need for sustained, relevant professional development in science education at the elementary and secondary level has been extensively documented in research and practice. All learners will benefit from having access to a trained science specialist who can develop effective instruction, provide professional development, partner with the science and education communities, and translate research into practice. Endorsed science specialists will have a deep understanding of science content, pedagogical content knowledge and education leadership. They will use their knowledge and skills to improve instruction in their communities, demonstrating Virginia's commitment for all students to learn science.

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy: Project 2061*. Washington, DC: Author.

American Association for the Advancement of Science. (1990). *Science for All Americans: Project 2061*. Washington, DC: Author.

Association for Supervision and Curriculum Development. (2006). *Research brief: Translating research into action.* Retrieved October 24, 2006, from http://www.ascd.org/cms/objectlib/ascdframeset/index.cfm?publication=http://www.ascd.org/publications/researchbrief/volume1/v1n15.html

Atwater, M. M., Gardener, C., & Kight, C. R. (1991). Beliefs and attitudes of urban primary teachers toward physical science and teaching physical science. *Journal of Elementary*

Science Teaching, 3, 3-11.

Darling-Hammond, L. (2000), Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives, 8*. Retrieved January 7, 2007 from http://epaa.asu.edu/epaa/v8n1/2000.

Duschl, R. A. (1983). The elementary level science methods course: Breeding ground of an apprehension toward science? A case study. *Journal of Research in Science Teaching, 20*, 745-754.

Elmore, R. F. (2002). *Bridging the gap between standards and achievement: The imperative for professional development education*. Albert Shanker Institute.

Ferguson, P. & Womack, S. T. (1993). The impact of subject matter and education coursework on teaching performance. *Journal of Teacher Education, 44*, 55-63.

Fishman, B., Marx, R. W., Best, S., & Tal, R. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*, 643-658.

Gabriel, J. G. (2005). *How to thrive as a teacher leader*. Alexandria, VA: ASCD.

Geier, R., Blumenfeld, P., Marx, R., Krajcik, J., Fishman, B., & Soloway, E. (2004). Standardized test outcomes of urban students participating in standards- and project-based science curricula. In Y. Kafai, W. Sandoval, N. Enyedy, A. Nixon, & F. Herrera (Eds.), *Proceedings of the sixth international conference of the learning sciences* (pp. 310-317). Mahwah, NJ: Erlbaum.

Gess-Newsome, J. & Lederman, N. G. (1993). Preservice biology teachers' knowledge structures as a function of professional teacher education: A year-long assessment. *Science Education, 77*, 25-45.

Goldhaber, D. D. & Brewer, D. J. (2000). Does teacher certification matter? High school teacher certification statistics and student achievement. *Educational Evaluation and Policy Analysis*, *22*, 129-145.

Gross, P. R. (2005). *The state of state science standards*. Washington, DC: Thomas B. Fordham Institute. Available at http://www.fordhaminstitute.org/institute/publication/publication.cfm?id=352

Guyton, E. & Farokhi, E. (1987). Relationships among academic performance, basic skills, subject matter knowledge, and teaching skills of teacher education graduates. *Journal of Teacher Education*, *38*, 37-42.

Hapgood, S., Magnusson, J. J., & Palincsar, A. S. (2004). Teacher, text, and experience: A case of young children's scientific inquiry. *Journal of Learning Sciences*, *13*, 455-505.

Hawk, P. P., Coble, C. R., & Swanson, M. (1985). Certification: It does matter. *Journal of Teacher Education*, *36*(3), 13-15.

Horizon Research Inc. (2000). *2000 National survey of science and mathematics education*. Retrieved January 7, 2007 from http://2000survey.horizon-research.com

Kielborn, T. L., & Gilmer, P. G. (Eds.) (1999). *Meaningful science: Teachers doing inquiry + teaching science*. Tallahassee, FL: SERVE.

King, B. & Newmann, F. (2000). Will teacher learning advance school goals? *Phi Delta Kappan*, *81*, 576–580

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S., & Hewson, P. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.). Thousand Oaks, CA: Corwin Press.

Loucks-Horsley, S. & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. *School Science and Mathematics, 99*, 258-271.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1996). Enacting project-based science: Challenges for practice and policy. *Elementary School Journal*, *97*, 341-358.

Marx, R. W., Freeman, J. G., Krajcik, J. S., & Blumenfeld, P. C. (1998). The professional development of science teachers. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 667-680). Dordrecht, The Netherlands: Kluwer.

Moje, E. B., Peek-Brown, D., Sutherland, L. M., Marx, R. W., Blumenfeld, P., & Krajcik, J. S. (2004). Explaining explanations: Developing scientific literacy in middle school project-based science reforms. In D. S. Strickland & D. E. Alvermann (Eds.), *Bridging the literacy achievement gap* (pp. 227-251). New York: Teachers College Press.

Monk, D. H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review, 13*, 125-145.

National Education Association. (2006). *Listening to teachers: Classroom realities and 'No Child Left Behind'.* Retrieved October 23, 2006, from http://www.nea.org/esea/teachervoiceexecsum.html

National Research Council. (1998). *National science education standards.* Washington, DC: National Academy Press.

Reys, B. J. & Fennell, S. (2003) Who should lead mathematics instruction at the elementary school level? A case for mathematics specialist. *Teaching Children Mathematics, 8*, 277-282.

Rice, J. K. (2003). *Teacher quality: Understanding the effectiveness of teacher attributes*. Washington, DC: Economic Policy Institute.

Rowan, B., Chaing, F. S., & Miller, R. J. (1997). Using research on employees' performance to study the effects of teachers on students' achievement. *Sociologyof Education*, *70*, 256-284.

Schwartz, R. S., Abd-El-Khalick, F., & Lederman, N. G. (2000). Achieving the reforms vision: The effectiveness of a specialists-led elementary science program. *School Science and Mathematics,100*, 181-193.

Schoeneberger, M. & Russell, T. (1986). Elementary science as a little added frill: A report of two case studies. *Science Education, 70*, 519-538.

Showers, B., Joyce, B., & Bennett, B. (1987). Synthesis of research on staff development: A framework for future study and a state-of-the-art analysis. *Educational Leadership, 45*(3), 77-87.

Spillane, J. P., Diamond, J. B., Walker, L. J., Halverson, R., & Jita, L. (2001). Urban school leadership for elementary science instruction: Identifying and activating resources in an undervalued school subject. *Journal of Research in Science Teaching, 38*, 918-940.

Tallerico, M. (2005). *Supporting and sustaining* teachers*'* professional development*: A principal's guide.* Thousand Oaks, CA: Corwin Press.

Tuerk, P. W. (2005). Research in the high-stakes era: Achievement, resources, and No Child Left Behind. *Psychological Science, 16*, 419-425.

Virginia Department of Education (2002). *Standards of learning tests pass rates*. Available from http://www.pen.k12.va.us/VDOE/Assessment/2002SOLpassrates.html

Virginia Department of Education (1995). *Standards of learning for Virginia public schools*. Retrieved on January 27, 2007 from http://www.pen.k12.va.us/VDOE/Superintendent/Sols/home.shtml

Weiss, I. R., Banilower, E. R., McMahon, K. C., & Smith, P. S. (2001). *Report of the 2000 National Survey of Science and Mathematics Education*. Chapel Hill, NC: Horizon Research, Inc.

Wenglinsky, H. (2002). How schools matter: The link between teacher classroom practice and student academic performance. *Education Policy Analysis Archives, 10*(12). Retrieved January 4, 2007 from http://epaa.asu.edu/epaa/v10n12/

WestEd Policy Brief (2000). *Ensuring teacher quality: A continuum of teacher preparation and development*. Retrieved January 7, 2007 from http://web.WestEd.org/online_pubs/po-00-05.pdf.

Zemke, R., & Zemke, S. (1988). 30 things we know for sure about adult learning. *Training, 25*(7), 57-61.