Professional Development of Chemistry Teachers

by Mickey Sarquis and Lynn Hogue

Mickey Sarquis*, professor of chemistry and biochemistry and director of the Center for Chemistry Education at Miami University, is an internationally recognized leader in chemistry and science education because of her pioneering chemistry-based teacher enhancement and curriculum development. She has received numerous teaching and service awards, including the Chemical Manufacturers Association National Catalyst Award for Excellence in Chemistry Teaching, and has published more than 60 books, monographs, chapters, and articles. Contact e-mail: sarquiam@muohio.edu*

Lynn Hogue*, associate director of Miami University's Center for Chemistry Education, has served as teacher programs director and lead instructor for more than 50 funded National Science Foundation and Ohio Board of Regents programs. A science educator for 30 years, she is a coauthor of teacher resource books, including* Investigating Solids, Liquids, and Gases with TOYS *and* Science Projects for Holidays Throughout the Year. *She has assisted school districts throughout the country with updating their science curriculum and presenting teacher inservices. Contact e-mail: hoguelm@muohio.edu*

Introduction

This chapter is written for the professional development provider and offers practical guidance, as well as supporting theory, to inform and improve professional development of chemistry teachers. Inservice teachers will benefit from reading this chapter and learning what best practices and aspects to look for when selecting a professional development opportunity. Throughout the chapter, "Less emphasis on …" and "More emphasis on …" examples highlight the nature of professional development envisioned in the *National Science Education Standards* (NRC, 1996).

The National Research Council (1996) and others (U.S. Department of Education, 2000; American Chemical Society, 2004; Loucks-Horsley et al., 1996) call for a professional development continuum that provides coherent and integrated opportunities for teachers to build and extend their content knowledge, pedagogical skills, and pedagogical content knowledge, while promoting professionalism and "understanding and ability for lifelong learning." (NRC, 1996) Many currently available professional development opportunities for chemistry teachers do not provide the broad spectrum of activities that are necessary for growth and called for in the *National Science Education Standards*. Additionally, many opportunities focus exclusively on content or pedagogy or attempt to teach content and pedagogy as two separate entities, rather than the richly intertwined elements that they are. Most professional development completely ignores the element of pedagogical content knowledge.

ACS Education Division

It is important to clarify that content knowledge means more than the acquisition of facts, vocabulary, laboratory skills, or mathematical algorithms. Content knowledge encompasses building mastery of the conceptual underpinnings of the subject matter that extend throughout the discipline. It means being able to identify the "big ideas" that drive science (see chapter 3) and to use these ideas to assist students in discovering the links between topics as we seek to provide opportunities for them to forge their own conceptual understanding. Finally, we should not forget that content knowledge also includes the dynamic of the nature of science as a process; educators must understand and be able to facilitate science processes such as questioning, observation, prediction, and argumentation in their classrooms (see chapter 4 on inquiry).

The building of pedagogical skills is equally important to the construction of content knowledge, particularly as a means of providing student-centered learning experiences, including inquiry, questioning to advance understanding, and science argumentation. Teachers need to have a thorough understanding of the process of scientific inquiry and develop ways to guide their students in this process. Dyasi and Dyasi (2004) state that "just as with student learning, continuing science education for teachers must center on firsthand experience with the ordinary physical world." The effective science teacher actively guides students to help them understand what they are doing and why they are doing it and to help them develop conceptual understanding.

Pedagogical content knowledge goes beyond content knowledge and pedagogical skills—it involves integrating knowledge of science, learning, pedagogy, and students and applying that knowledge to science teaching. Pedagogical content knowledge also includes finding ways to make the subject matter comprehensible to others, understanding what makes learning topics easy or difficult, and understanding what conceptions and preconceptions students may have and knowing strategies that will help them reorganize their understandings (Shulman, 1986).

For reform to take place, "professional development must include experiences that engage prospective and practicing teachers in active learning that builds their knowledge, understanding, and ability" (NRC, 1996). This chapter explores this challenge and the issues associated with the preparation and continuing education of chemistry teachers and provides examples of best practices.

Preservice Teachers

Less emphasis on: Separation of science and teaching knowledge
More emphasis on: Integration of science and teaching knowledge

The job of educators is not simply to impart what we know to our students, but rather to engage students in constructing their own understanding and fitting this understanding into their existing framework of knowledge (NRC, 1996). The means to achieve this goal include student-centered practices such as authentic experiential learning—opportunities for students to be involved in the real work of science, thereby developing critical thinking and problem-solving skills.

A disconnect exists in preservice teacher education that weakens the efforts to effectively prepare teachers (Ball, 2000) to lead student-centered classrooms. Preservice science teachers take courses in their disciplines, liberal arts, and education. Unfortunately, a lack of integration among these experiences dilutes the impact of this education. Although education courses challenge prospective teachers to learn the theory and practice of education, the time devoted

to practice and integration of the pedagogy into disciplinary content is typically not enough to allow mastery. This problem is exacerbated by the fact that the research scientists who teach many undergraduate science content courses generally focus on traditional methods of teaching, such as lectures and verification laboratory experiences, rather than modeling the research-based pedagogical approaches that preservice teachers are learning about.

Such a disconnect between theory and practice makes it difficult for prospective teachers to acquire the important ability to blend content and pedagogy. If preservice teachers learn science as a collection of facts in which large chunks of information must be digested, then it would seem more likely that they, in turn, would teach this way. Ball (2000) states that the fragmentation of subject matter and pedagogy "leaves teachers on their own with the challenge of integrating subject matter knowledge and pedagogy in the contexts of their work." Furthermore, if these preservice teachers do not master reasoning and understanding in their content area, they may subsequently pass this "disability" on to their students (Arons, 1984). It is crucial that preservice teachers are taught science in ways that model research-based pedagogical approaches and that they have repeated opportunities to practice these approaches.

Preservice teachers must go beyond simply garnering factual knowledge and memorization—they must gain an understanding of how and why things happen, why science is important, how it relates to other ideas, and above all, see the big ideas of science (Shulman, 1986). Even if effective pedagogical methods are implemented, in the absence of adequate teacher content knowledge, student learning and achievement will be compromised, and in some cases, may result in reinforcement of student misconceptions (Kruegar, 2001).

While sound conceptual understanding of science is imperative, Duggan-Haas (2004) notes that "…content understanding without pedagogical skill is fruitless." Preservice teachers are faced with the often overwhelming challenge of learning pedagogy when they have no basis for understanding it until they have tried to implement it. Shulman (1986) poses a question that is central to the challenge of educating science teachers: "How does the successful college student transform his or her expertise in the subject matter into a form that high school students can comprehend?" The answer to this question lies in mentoring of preservice/novice teachers and practical experience in the classroom.

In-the-field experiences become increasingly important in the later stages of preservice teachers' development through clinical work, student teaching, and research. In a review of research, Luft (2003) found that beginning teachers experience a disparity between their teacher training programs and the actual classroom. Proposed solutions include increased independent instruction during student teaching or longer, more significant experiences in the field. A study by Adams and Krockover (1997) found that new science teachers' perceptions of their preservice program included a belief that field experiences should be increased.

Best Practice: Preservice Teachers

An example of exemplary teacher training, The Shady Hill Teacher Training Course is conducted at Shady Hill School in Cambridge, MA. The school's first director, Katharine Taylor, said in a 1937 speech, "The more you think of teaching, the more you realize that it can never be classified as a science. It is nearer to being an art." The program focuses on learning through experience and intense supervision in the following experiences:

Participants begin by observing the classroom and eventually "solo" under the supervision of the directing teacher.

The directing teacher provides guidance on how to introduce a lesson, the pacing of instruction, the importance of repetition, how to break down concepts into digestible pieces, and how to prepare new units of instruction.

Participants attend seminars on issues such as multiculturalism, child development, student assessment, and equity.

The program not only gives participants a deeply significant experience in the field, but it also allows the directing inservice teachers to grow, learn, and reflect on the effectiveness of their own teaching (Archer, 2002).

While this program is similar in some ways to the student teaching that most preservice teachers experience, the Shady Hill course is different in that the rest of the coursework and activities are intimately connected to this teaching experience.

Inservice Teachers

Less emphasis on: Transmission of teaching knowledge and skills by lectures
More emphasis on: Inquiry into teaching and learning

Best Practice: Inservice Teachers

A year-long professional development program conducted with Indiana high school science teachers (and described and researched by Lotter et al. (2006)) highlights some of the essential qualities for a program to help teachers reform their teaching using inquiry. The program offers a rich spectrum of professional development experiences, including summer workshop and research experiences, three one-day academic-year follow-up workshops, and a program Web site. The summer research experience immersed teachers in a research lab environment (placement based on previously indicated interests), in which they joined ongoing investigations as active participants. The workshop components emphasized a plan to help teachers address students' learning difficulties, including the following:

- Identify a student-learning bottleneck and develop a lesson that would address the bottleneck;
- Develop ways to model the problem-solving process for students;
- Develop motivational techniques for students;
- Create practice opportunities for students where the learning activities utilize thought processes to successfully overcome the learning bottleneck;
- Assess student learning through written assignments, drawings, evaluations, etc.; and
- Share learning experiences with other teachers and develop a model of the professional development process that could be shared with colleagues.

Participants reported an increased understanding of inquiry teaching, as well as renewed confidence in using inquiry methods in the classroom. Teacher ideas of inquiry broadened to encompass ideas that had been emphasized in the program, while they reported discovering a renewed empathy for students who continually face unfamiliar situations or content.

A main challenge of educating preservice teachers involves their lack of experience in the classroom on which to base their understandings of complicated pedagogical content knowledge (NRC, 1996). However, the challenge with inservice teacher professional development can be quite the opposite—inservice teachers have a wealth of experience to draw upon; however, this experience may serve as a barrier to change.

In pursuing professional development, inservice teachers draw upon the resources of higher education, science-rich centers, and the scientific community (NRC, 1996). Also, by conducting action research, being involved in the mentoring process, and participating in research at the scientific level, inservice teachers can enhance their growth and learning. It is crucial to the future of science education in our nation that practicing science teachers be able to identify and participate in quality professional development. As pointed out in the Standards for Professional Development chapter of the *National Science Education Standards* (NRC, 1996), we must provide opportunities that are *less* about individual learning, fragmented, one-shot sessions, staff developers as educators, and *more* about collegial and collaborative learning, long-term coherent plans, and staff developers as facilitators, consultants, and planners.

Loucks-Horsley et al. (2003) have suggested a set of elements that professional development programs should feature, given the needs of adult learners. These features are based on the constructivist learning theory, as well as transformative learning, i.e., learning that produces "changes in deeply held beliefs, knowledge, and habits of practice" (Loucks-Horsley et al., 2003, citing Thompson and Zeuli, 1999). The features include

- opportunities for teachers to make connections between their existing ideas and new ideas;
- opportunities for active engagement, discussion, and reflection to challenge existing ideas and construct new ones;
- activities that challenge teachers' thinking by producing and then resolving dissonance between old and new ideas;
- learning in contexts which teachers find familiar; and
- help for teachers to develop a range of strategies that address student learning across all levels.

These features resonate with the constructivist view of learning, as does the NRC (1996) with their position that "*learning is something students do, not something that is done to them*." Learners must use their existing repertoire of experiences and ideas as building blocks or bridges to new learning. As a result, Spigner-Littles and Anderson (1999) point out that instructors of professional development for teachers should assume the role of a facilitator or moderator to keep the teachers focused on sharing their previous experiences, views, and perspectives.

Effecting Change

Less emphasis on: Teacher as target of change
More emphasis on: Teacher as source and facilitator of change

The goal of any professional development program for teachers is to effect change (NRC, 1996). Change may occur in teachers' beliefs, attitudes, content knowledge, or other facets, but the end result must be change in classroom practice. Many programs fail to effect change because they do not address the special needs of teachers who are contemplating change.

The Concerns-Based Adoption Model (Hall and Hord, 1987) describes the stages of concerns for teacher-learners who are experiencing change. At each stage of concern, the teacher-learner asks questions. In the early stages, questions are more self-oriented in nature; for example, "what is it?" and "how will it affect me?" After these questions are resolved, questions become more task-oriented, such as "how do I do it?" In the latter stages, individuals focus on the impact of the changes at hand. For example, teachers begin to question whether the new process is working for their students or whether the process can be modified to work better (Loucks-Horsley, 1996). Professional developers can capitalize upon this model by addressing their presentation to each stage of questioning. For example, a teacher may need to learn how a process will affect them (e.g., "how much class time will this actually take?") before they can learn how it will help their students. Depending on what type of change is being effected, different stages of concern will take varying degrees of time. The need for sustained support and follow-up is inherent in this model. The strength of this model is in the idea that individuals and their various needs for information, assistance, and moral support are considered while developing professional development activities (Loucks-Horsley, 1996).

As older learners become attached to their practices, beliefs, knowledge, values, and views, they are likely to reject or explain away new ideas (Spigner-Littles and Anderson, 1999). As a result, professional developers must tackle this issue head on by empowering teachers to buy into the change and support them over time with well-constructed follow-up activities. Sarquis (2001) offers recommendations for continued follow-up and sustained impact in professional development activities that will provide continued motivation and support while sustaining the creative momentum initiated during workshops. Some of these recommendations include hosting return visits for the teachers, supporting teachers' participation in professional meetings, and helping teachers to increase their leadership roles and responsibilities within their districts.

One professional development tool that encourages and supports change in teaching practice is action research. Action research allows teachers to reflect on their teaching practices by analyzing their teaching and their students' learning. Loucks-Horsley et. al. (2003) suggest that that the strength of action

Best Practice: Leadership

Professional development programs do not often include development of teacher leadership skills and teacher leaders. One of the exceptional aspects of North Carolina's FIRST (Fund for the Improvement and Reform of Schools and Teaching) programs, as described by Wallace et al. (2001), was the inclusion of strategies to develop teacher leaders and support them in their new roles to bring about reform of their entire schools and not just individual classrooms. In order to ensure that these professional development programs were effective, a series of four critical elements and accompanying strategies were put into place (Wallace et al., 2001):

- Designing and implementing long-term professional development by
  - building a multiphased 18-month program that included preassessment sessions, summer institute, academic year follow-up sessions, and a final workshop the following summer and
  - creating time for reflection.
- Building teachers' capacity for shared decision making by
  - administering a needs assessment to help identify strengths and weaknesses,
  - designing a school improvement plan (SIP) with objectives and strategies for addressing their needs,
  - allowing for review of professional development activities that modeled the shared decision-making process and ensured that the activities would assist the teacher leaders in their SIPs, and
  - processing leadership content and practicing leadership skills.
- Creating a supportive environment for the teacher leaders by
  - providing principal support, including resources, release time, space, encouragement, and praise,
  - allowing time for two-teacher team collaboration, which provided the teachers with support from each other during the school year,
  - including time for teams of teacher leaders to problem solve with other teams, and
  - including project staff support during implementation phase, including school site visits, telephone calls, workshop presentations at the school, and one-on-one discussions.
- Incorporating assessments by conducting
  - formative assessment and
  - summative evaluation.

research as a form of professional development is that the teachers themselves are developing the research questions or are contributing to the questions in a meaningful way. This gives them ownership and control over their learning; thus, they are committed to promoting changes in their teaching practices as revealed through their research results.

Professional development that effects change in teacher practice often leads to the professional growth of teachers as they assume increased leadership and responsibility within their school districts (Sarquis, 2001). Teachers who move up the ranks of the leadership development path develop stronger content and pedagogical knowledge, work toward development and implementation of materials and curriculum in the classroom, and also work toward outreach to other teachers and the community, thereby synergizing the change they have undergone to impact their colleagues.

Professional development can also empower teachers to become leaders in their schools, districts, and professional organizations. Such leadership enables teachers to become powerful agents of change in their own school reform. A study by St. John and Pratt (1997) (as cited in Pratt, 2001) pointed to leadership as an essential factor for reform. The study suggests that the best cases of school reform occurred where there was long-term, committed leadership. Leaders who were connected to many sources of support and focused primarily on educational substance were critical to change, as were leaders who use the standards and policy as vision to guide their reform.

Best Practice: Retention

The Valle Imperial Project in Science (VIPS) is a professional development plan for teacher retention and renewal in California (Klentschy et al., 2003). Teacher retention and renewal, as well as development of a broad countywide base of sustained teacher leadership, are the goals of this project. Briefly summarized, the 10 elements of this action plan are

- developing a link between preservice and actual classroom practices through specific science methods courses that are linked to teacher practices,
- local and national institutes and opportunities to attend a local master's degree program to deepen teacher content understanding,
- opportunities for teachers to strengthen their pedagogical skills,
- in-classroom support from science resource teachers, including weekly visits to novice teachers,
- leadership development of teachers, where lead teachers act as leaders in professional development activities and work to bring about systemic change,
- materials support, where teachers receive VIPS materials on a quarterly basis,
- time for collaboration and networking within and between schools,
- applications of technology, including workshops on technology applications for teachers as well as online professional development activities where teachers can communicate with each other,
- workshops focusing on student work as the centerpiece of standards-based performance assessment, and
- opportunities to refine instructional delivery through reflection and lesson study groups, where there is a cyclic process of lessons being taught, observed, and refined for improvement.

Issues of Retention

Less emphasis on: Teacher as an individual based in a classroom

More emphasis on: Teacher as a member of a collegial professional community

The issue of retention of teachers in the profession goes hand in hand with the topic of professional development (NRC, 1996). Simply put, effective professional development can reduce teacher turnover rates (Smith and Rowley, 2005), which are relatively high in comparison to those of other types of employees. Beginning teachers have a very high turnover rate, while rates decline during midcareer years and rise again toward retirement. On average, about 29% of all new teachers leave the profession after three years (Ingersoll, 2003).

In an effort to retain teachers, many new initiatives provide support for beginning teachers. Examples of support that has been implemented within these initiatives include focusing on practical issues like classroom management and discipline, online discussions with professors of education, mentoring, peer assistance, and other forms of guidance and support (DePaul, 2000). The U.S. Department of Education's Survival Guide for New Teachers also lists ways in which beginning teachers can effectively collaborate with veteran teachers, parents, principals, and college and university faculty to obtain the support that they need during the first few critical years of teaching.

Teacher collaboration and mentoring are important aspects of teacher retention. Mentoring is a form of professional development in which a new teacher and an experienced teacher (or sometimes a scientist) collaborate to provide support for the new teacher and enhance the leadership role of the mentor (Loucks-Horsley et al., 2003). Experienced teachers provide new teachers with emotional support. However, in order to utilize mentoring in its fullest capacity, mentors have many other responsibilities. Some of the responsibilities of a mentor toward the new teacher, as pointed out by Dunne and Newton (2003), include enabling new teachers to increase their knowledge of content, guiding them toward ways of including scientific inquiry into teaching, and sharing ideas on making the subject matter comprehensible to others. Mentoring experiences also promote professional development and growth for experienced teachers. Through mentoring, experienced teachers are rejuvenated and renewed by the newer teachers as they reexamine and reflect upon their own teaching practices (Archer, 2002; Brennan, 2003).

Self-efficacy is another promising tool to improve teacher retention. If teachers believe that they have the ability both to present knowledge and to guide students toward learning, then their job satisfaction is likely to increase. In a study by Khourey-Bowers and Simonis (2004), it was found that following professional development programs that focused upon enhancing self-efficacy, there was a significant increase in participants' self-efficacy and that their beliefs significantly improved in relation to their ability to effectively teach science concepts. Additionally, Louis (1998) found that

> *"Enhanced opportunities within the school to use and develop new skills—one of the most important predictors of both efficacy and commitment—was most effectively promoted by all-school, teacher organized inservice activities, teacher mentoring programs, or programs that provided grants to teachers to develop new programs."*

Special Challenges of Second-Career Teachers

Less emphasis on: Teacher as a technician
More emphasis on: Teacher as intellectual, reflective practitioner

Transitioning from one career to the next involves special challenges, particularly concerning the transition into teaching. Scharberg (2005) suggests that for those who are considering making the transition to teaching, a recommended first step is for the decision maker to decide whether he or she has the qualities to become a successful chemistry teacher: love of teaching adolescents, solid knowledge of chemistry, being a team player, excellent communication and organizational skills, and a large supply of patience (NRC, 2006).

The transition is difficult, because most prospective teachers in this category have undergraduate and graduate degrees in the content area; however, they do not have knowledge of instructional strategies or pedagogical content knowledge. Gerald Wheeler, National Science Teachers Association executive director, feels that most scientists cannot just step into the classroom. He believes "it's imperative that the scientist-turned-teacher have a very good handle on the learning characteristics of the students [with whom] they're going to be interacting." However, because these professionals are familiar with the use of inquiry-based methods from their

Best Practice: Second Careers

The Teacher Recruitment and Induction Project (TRIP) is a best-practice program specifically developed for midcareer adults to make the transition into teaching (Resta et al., 2001). Intended for those who have already received their bachelor's degrees, the program allows participants to complete initial certification requirements in one year or less. TRIP focuses on providing participants with strong content and pedagogical knowledge through integrated coursework where instructors model best teaching and instructional practices. In addition to first-semester coursework, participants also spend 2 days per week in the field, observing, tutoring, and teaching students. Participants' field experiences are integrated into coursework. During the second semester, participants become student teachers, complete one more graduate course, and meet weekly with a mentor. After initial certification, the program offers intensive induction support via the mentors during their first two years of teaching.

first profession, they may "be able to take a child into an authentic inquiry exercise" (Henry, 2003). Vicki A. Jacobs, associate director of Harvard's Teacher Education Program, also believes that those making a midcareer transition to teaching will have more life applications and knowledge to draw upon (Henry, 2003).

Recommendations and Conclusions

The nature of science is that it does not stand still; science is ever changing and growing as new theories are formed, challenged, and then either accepted or refuted. Likewise, the nature of professional development for chemistry teachers (and all science teachers) must follow a similar path of growth and discovery, just as teachers themselves must continually adapt and change to meet the needs of their students. Professional development—in all its forms—is perhaps the most important tool in our arsenal for helping and supporting teachers as they shape our future scientists, voters, and decision makers.

As we continue to discover more about the science of the brain and how people learn, our work with teachers will evolve correspondingly. New and emerging technologies will provide new avenues for impacting teachers. Virtual professional development is a significant option for the future. However, most current online offerings do not represent what the future can be: they are passive rather than interactive. True virtual professional development will include high-level problem solving, decision making, interpretation, and analysis through partial or full simulations (Charles and Griffin, 2007).

Professional developers of chemistry teachers are in the position to play a substantive role in shaping this future. A periodic check of your methods against best practices in the field (both new and well established) will help you to best play this role.

Through a combined 70 years of experience in science education, we have established a model for teacher professional development. This protocol has been recognized by the U.S. Department of Education as a "State Model Program," by the National Science Foundation Project Kaleidoscope as a "Program that Works," and by the Chemical Manufacturers Association as a "Recommended Model Program." Ask yourself how well your efforts parallel the best practices in professional development for chemistry teachers shown in Table 1. (These practices are paired with corresponding elements from the Standards for Professional Development for Teachers of Science chapter in the *National Science Education Standards*.)

Table 1: Best Practices in Professional Development for Chemistry Teachers

Program Administration Teachers, administrators, and scientists are included in program development and implementation.	
Less emphasis on	*More emphasis on*
Reliance on external expertise	Mix of internal and external expertise
Teacher as consumer of knowledge about teaching	Teacher as producer of knowledge about teaching
Vision for the Classroom Emphasize a hands-on, minds-on instructional approach; a balance between content and process in classroom instruction; active assessment of important learning outcomes; and the use of materials, strategies, and perspectives sensitive to diversity.	
Less emphasis on	*More emphasis on*
Transmission of teaching knowledge and skills by lectures	Inquiry into teaching and learning
Learning science by lecture and reading	Learning science through investigation and inquiry

Separation of science and teaching knowledge	Integration of science and teaching knowledge
Separation of theory and practice	Integration of theory and practice in school settings
Teacher Development Program Activities Offer a range of instructional strategies, including activity-based instruction, guided and open inquiry, scenario-based investigations, and learning cycles. Model the teaching practices intended to be transferred to the classroom. Engage teachers in activities that provide a foundation for them to actively construct their own knowledge. Use the tools, methods, processes, and real-world challenges of science. Give teachers opportunities to plan ways to incorporate new information into their curricula.	
Less emphasis on	*More emphasis on*
Courses and workshops	Variety of professional development activities
Contribution of Partnering Scientists Collaborate with scientists from industry, government, and the private sector to provide valuable and complementary perspectives to professional development instruction.	
Less emphasis on	*More emphasis on*
Teacher as an individual based in a classroom	Teacher as a member of a collegial professional community
Follow-Up Include both formal and informal follow-up mechanisms both to sustain the creative momentum generated in workshops and to promote the understanding and ability for lifelong learning advocated by the national standards.	
Less emphasis on	*More emphasis on*
Fragmented, one-shot sessions	Long-term coherent plans
Teacher Leadership and Responsibility Empower graduates to assume leadership roles in effecting systemic change within their districts and schools. Involve district teams of teachers and administrators and require the development of action plans to implement programming.	
Less emphasis on	*More emphasis on*
Individual learning	Collegial and collaborative learning
Staff developers as educators	Staff developers as facilitators, consultants, and planners
Teacher as technician	Teacher as intellectual, reflective practitioner
Teacher as follower	Teacher as leader
Teacher as target of change	Teacher as source and facilitator of change
Program Evaluation Include frequent evaluation of professional development efforts in your plans. Use both quantitative and qualitative measures to assess the effects of your program on participant knowledge and attitudes toward science, as well as the effects of the program on students, systemic changes, and second-tier outreach.	

ACS Education Division

Above all, make sure that your professional development efforts involve modeling the pedagogical approaches you hope to impart to teachers. Your successful efforts will lead teachers to more positively impact their classrooms for years to come.

Recommended Readings

Sarquis, A. M. Recommendations for Offering Successful Professional Development Programs for Teachers. *J. Chem. Educ.* 2001, *78*, 820–823. This article shares insights gained by administering three major professional development initiatives. As Director of the Miami University Center for Chemistry Education (CCE), Sarquis developed the CCE teacher professional development model.

Professional Development Leadership and the Diverse Learner; Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2001. This book presents chapters that effectively address the issues of professional development. Each chapter illustrates the utility of professional development for practitioners and addresses general issues and perspectives related to science education reform. The examples provided are valuable models for those conducting professional development activities.

Recommended Web Sites

Triangle Coalition. http://www.trianglecoalition.org (accessed June 30, 2008). The Triangle Coalition is a Washington, D.C.-based nonprofit organization comprising members from business, education, and scientific and engineering societies. Triangle Coalition's Mission is to bring together the voices of these stakeholders to improve the quality and outcome of mathematics, science, and technology education. Triangle Coalition focuses its action in advocacy, communication, and programmatic efforts to advance science, mathematics, and technology education for all students. The Web site provides valuable updates for all who are interested in the state of science education in the United States, as well as news about upcoming professional development opportunities.

The TE-MAT Project. http://www.te-mat.org/ (accessed June 30, 2008). The TE-MAT (Teacher Education Materials) Project supports professional development providers, as they work to enhance the capacity of preservice and inservice teachers to provide high-quality K–12 mathematics/science education. Current national standards for mathematics and science education are based on the premise that K–12 education should provide powerful mathematics and science content for all students and should focus on teaching for understanding. This vision served as a foundation for the design of the TE-MAT database. The site is designed for all levels of experience—from novice to expert—to help in the design, implementation, and evaluation of effective professional development programs to support teachers.

References

Adams, P. E; Krockover, G. H. Concerns and Perceptions of Beginning Secondary Science and Mathematics Teachers. *Sci. Educ.* 1997, *81*, 29–50.

American Chemical Society. Science Education Policies for Sustainable Reform. http://www.chemistry.org/portal/resources/?id=c373e90165f4c0448f6a17245d830100 (accessed Feb. 2007).

Archer, J. Tools of the Trade. *Education Week* 2002, *21,* 30–35.
Arons, A. B. Education Through Science. *J. Coll. Sci. Teaching* 1984, *13,* 210–220.
Ball, D. L. Bridging Practices: Intertwining Content and Pedagogy in Teaching and Learning to Teach. *J. Teacher Educ.* 2000, *51*, 241–247.
Brennan, S. Mentoring for Professional Renewal: The Kentucky Experience. In *Science Teacher Retention: Mentoring and Renewal,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2003; pp 161–169.
Charles, K. J.; Griffin, J. E. Teaching Science in the 21st Century: Virtual Professional Development: The Good, the Bad, and the Future. *NSTA Rep.* Feb 5, 2007. http://www3.nsta.org/main/news/stories/nsta_story.php?news_story_ID=53347.+ (accessed February 2007).
DePaul, A. *Survival Guide for New Teachers: How New Teachers Can Work Effectively With Veteran Teachers, Parents, Principals, and Teacher Educators;* U.S. Department of Education: Office of Educational Research and Improvement, 2000.
Duggan-Haas, D. A Proposed Introduction to the NSTA Standards for Science Teacher Preparation. http://www.msu.edu/~dugganha/intro.htm (accessed May 2004).
Dunne, K. A.; Newton, A. Mentoring and Coaching for Teachers of Science: Enhancing Professional Culture. In *Science Teacher Retention: Mentoring and Renewal,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2003; pp 71–84.
Dyasi, H. M.; Dyasi, R. E. "Reading the World Before Reading the Word": Implications for Professional Development of Teachers of Science. In *Crossing Borders in Literacy and Science Instruction: Perspectives on Theory and Practice,* Saul, E. W., Ed.; NSTA Press: Arlington, VA, 2004; pp 420–446.
Hall, G. E.; Hord, S. M. *Change in Schools: Facilitating the Process;* SUNY Series in Education Leadership; State University of New York Press: Albany, NY, 1987.
Henry, C. M. Back to School: High School Teaching Attracts Both Younger and Midcareer Chemists with Advanced Degrees. *Chem. Eng. News 81*, 47–49.

ACS Education Division

Ingersoll, R. M. Turnover and Shortages Among Science and Mathematics Teachers in the United States. In *Science Teacher Retention: Mentoring and Renewal,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2003; pp 1–12.
Khourey-Bowers, C.; Simonis, D. G. Longitudinal Study of Middle Grades Chemistry Professional Development: Enhancement of Personal Science Teaching Self-Efficacy and Outcome Expectancy. *J. Sci. Teacher Ed.* 2004, *15*, 175–195.
Klentschy, M. P.; Molina-De La Torre, E. A Systemic Approach to Support Teacher Retention and Renewal. In *Science Teacher Retention: Mentoring and Renewal,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2003; pp 161–169.
EDThoughts: What We Know About Science Teaching and Learning; Kruegar, A., Sutton, J., Eds.; McREL: Aurora, CO, 2001.
Lotter, C.; Harwood, W.; Bonner, J. Overcoming a Learning Bottleneck: Inquiry Professional Development for Secondary Science Teachers. *J. Sci. Teacher Ed.* 2006, *17*, 185–216.
Loucks-Horsley, S. Professional Development for Science Education: A Critical and Immediate Challenge. In *National Standards & the Science Curriculum,* Bybee, R., Ed.; Kendall/Hunt Publishing: Dubuque, IA, 1996.
Loucks-Horsley, S.; Stiles, K.; Hewson, P. Principles of Effective Professional Development for Mathematics and Science Education: A Synthesis of Standards. *NISE Brief* 1996, *1,* 1–6.

Loucks-Horsley, S.; Love, N.; Stiles, K. E.; Mundry, S.; Hewson, P. W. *Designing Professional Development for Teachers of Science and Mathematics,* 2nd ed.; Corwin Press: Thousand Oaks, CA, 2003.

Louis, K. S. Effects of Teacher Quality of Work Life in Secondary Schools on Commitment and Sense of Efficacy. *School Effectiveness and School Improvement* 1998, *9*, 1–27.

Luft, J. A. Induction Programs for Science Teachers: What the Research Says. In *Science Teacher Retention: Mentoring and Renewal,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2003; p 35–44.

National Research Council. *National Science Education Standards;* National Academy Press: Washington, DC, 1996.

Pratt, H. The Role of the Science Leader in Implementing Standards-Based Science Programs. In *Professional Development Leadership and the Diverse Learner,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2001; pp 1–9.

Resta, V.; Huling, L.; Rainwater, N. Preparing Second-Career Teachers. *Ed Leadership* 2001, *58*, 60–63.

Sarquis, A. M. Recommendations for Offering Successful Professional Development Programs for Teachers. *J. Chem. Educ.* 2001, *78*, 820–823.

Scharberg, M. A. Teaching High School Chemistry as a Second Career. *J. Chem. Ed.* 2005, *82*, 1281–1285.

Shulman, L. S. Those Who Understand: Knowledge Growth in Teaching. *Ed. Researcher* 1986, *15*, 4–14.

Smith, T. M.; Rowley, K. J. Enhancing Commitment or Tightening Control: The Function of Teacher Professional Development in an Era of Accountability. *Educ. Pol.* 2005, *19*, 126–154.

Spigner-Littles, D.; Anderson, C. E. Constructivism: A Paradigm for Older Learners. *Educational Gerontol.* 1999, *25*, 203–209.

St. John, M.; Pratt, H. The factors that contribute to the "best cases" of standards-based reform. *School Sci. Math.* 1997, *97*, 316–324.

Thompson, C. L.; Zeuli, J. S. The frame and the tapestry: Standards-based reform and professional development. In *Teaching as the Learning Profession: Handbook of Policy and Practice,* Darling-Hammond, L.; Sykes, G., Eds.; Jossey Bass: San Francisco, CA, 1999; pp 341–375.

U.S. Department of Education. The Mission and Principles of Professional Development. http://www.ed.gov/G2K/bridge.html (accessed Feb. 2007).

Wallace, J. D.; Nesbit, C. R.; Newman, C. R. Bringing About School Change: Professional Development for Teacher Leaders. In *Professional Development Leadership and the Diverse Learner,* Rhoton, J., Bowers, P., Eds.; Issues in Science Education; NSTA Press: Arlington, VA, 2001; pp 37–47.