IMPROVING SCIENCE INSTRUCTION IN SOUTHWESTERN ILLINOIS AND METRO EAST ST. LOUIS: STUDENTS LEARNING SCIENCE THROUGH A SUSTAINED NETWORK OF TEACHERS

This article describes the specific methods of a regional partnership that has lasted more than twenty-five years. Southern Illinois University Edwardsville has partnered with public and private schools in the southwestern portion of Illinois, and in metro St. Louis, in the Hands-On Science project, which provides instruction development for chemistry, biology, earth science, and physics teachers in grades 6–12. The project has been modified over the years, and this article explains both modifications and causes, in specific terms such as the effects of funding on classroom equipment and supplies as well as, more importantly, on the turnover among teacher participants. The Hands-On Science project emphasizes classroom assessment techniques, collaboration, and more active learning. Quick Course Diagnosis and Group Instructional Feedback Technique (or Small Group Instructional Diagnosis) are two of the specific methods of assessment used in this successful, long-lived ITQ project—which originally began as an Eisenhower project.

Need for Content Based Professional Development Activities

A key goal of the Illinois Board of Higher Education (IBHE) strategic plan, *Illinois Public Agenda for College and Career Success,* addresses a disturbing and growing "'prosperity gap' that relates to large and widening disparities in educational attainment" and advances a critical role for higher education partners to help create the conditions for prosperity (IBHE, 2008, p. 1). In the 21st century, this must surely include extending high quality Science, Technology, Engineering, and Math (STEM) education to every region of the state. Southern Illinois University Edwardsville (SIUE), the university partner in this case study, is in the southwestern region of the state, near the Mississippi River and metro St. Louis. The rural, urban, and suburban districts of the region have differing needs for professional development and teacher learning overall, but they all require a university partner to prepare and then continuously update the teachers in the region in the dynamic STEM disciplines. This article for the special issue of *Planning and Changing* discusses how SIUE has developed as a regional partner for schools and districts for more than 25 years, originally funded as an Eisenhower program, and now funded as an Improving Teacher Quality (ITQ) state grant program.

We have found that public and private school teachers crave professional development and learning opportunities. It is widely known that we learn about things by teaching about them. Only when they face their own students do our middle, junior high, and high school teachers vividly realize the importance of what they encountered as undergraduate science majors. By then, they have forgotten or incorrectly remembered many core concepts. If they stumble in their teaching, they propagate untruths and inadequate foundations in science, and they also communicate confusion and disinterest. Our project, Hands-On Science, addresses these conditions head-on. As the teachers learn science content and processes for lab and field work from us, we learn about the conditions in schools that allow us as partners to contribute to college readiness on the part of incoming SIUE students through teachers' professional learning.

In his book, *Designing Powerful Professional Development for Teachers and Principals,* Dennis Sparks (2002) describes how professional development of teachers and administrative leadership play central roles in connecting the quality of teaching to the improvement of schools. Professional development became an explicit policy with the No Child Left Behind Act, and Illinois policy mirrors this trend (Desimone, Smith, & Phillips, 2007). Our intent is to work with regional grades 6–12 science teachers to help them improve their science knowledge, gain insight into applications of science, and become aware of available high quality science education resources and regional business partners. These tools and knowledge should assist teachers in preparing their students to meet the standards expected in middle, junior high, and high school science courses. It is anticipated that these activities will eventually lead to students who are better prepared for high school and college science courses, particularly students from historically under-represented and under-served groups. In a study that used a national probability sample of 1027 teachers to determine the effects of different types of professional development on teachers' learning:

> …results indicate that sustained and intensive professional development is more likely to have an impact…. Our results also indicate that professional development that focuses on academic subject matter (content), gives teachers opportunities for 'hands-on work' (active learning), and is integrated into the daily life of schools (coherence), is more likely to produce enhanced knowledge and skills (Garet, Porter, Desimone, Birman, & Yoon, 2001, p. 935).

Garet and his colleagues extended these insights to name five elements of effective professional development: (a) duration (i.e., "sustained" and "intensive); (b) collective participation; (c) content focus; (d) active learning; and (e) coherence with local policies (Desimone, 2009; Garet et al., 2001). This empirically grounded model of exemplary professional development guides the design of partnership structures and influences the implementation and evaluation of all ITQ grants. In recent years, under the auspices of ITQ, this research has been used by the partners in the Hands-On Science project. The Departments of Biology, Chemistry, Physics, and Geography, and the Environmental Sciences Program at SIUE have developed internal partnerships with the SIUE College of Arts and Sciences, the SIUE School of Education, and external partnerships with over 70 partner middle, junior high, and high schools (i.e., grades 6–12) and school districts to improve science education in the southwest region.

History of the Project

This partnership began in 1985 as a professional development project for high school chemistry teachers with funding from the federal ESEA Title II Dwight D. Eisenhower Professional Development Program. A consortium of partners from SIUE, Southern Illinois University Carbondale (SIUC), and Eastern Illinois University (EIU) provided chemistry workshops for high school teachers from districts throughout southern Illinois. SIUE project directors were Emil Jason and Sadegh Khazaeli. Over time, SIUC and EIU partners no longer participated, leaving SIUE as the only university partner. Chemistry workshops were offered as once-a-week evening classes in spring semesters, and as all-day classroom and laboratory experiences for a week in summer semesters. Sadegh Khazaeli continued as project director after Emil Jason's retirement.

In 2004, the partnership continued in the form of the Hands-On Chemistry project, funded by the No Child Left Behind (NCLB) Title II program. Eric Voss joined as project co-director of the Hands-On Science project, to also include middle and junior high school science teachers in a two-week summer professional development workshop. Starting in 2007, high school physics workshops in summer and fall were added with assistance from Abdullatif Hamad, and then in 2010, fall high school biology workshops were added with Dennis Kitz as the content expert. Currently, ten SIUE faculty Contribute to the content expertise for this project.

Project Description

The goal of this project is to provide hands-on professional development for high school chemistry, physics, and biology, and middle and junior high school science teachers with an emphasis on science subject matter related to the Illinois State Board of Education's Illinois Learning Standards (ISBE, 2010a) and Illinois Professional Education Standards (ISBE, 2010b). Project directors, an external evaluator, other SIUE faculty, and administrative leaders work with regional teachers to help them improve science content knowledge, gain insight into applications of science, and increase awareness of available high quality science education resources and innovative student learning assessment techniques.

Working in collaboration with regional partner educators, we have devised the Hands-On program, with these key goals: (a) development of participants' understanding of the basic principles of science to a sophisticated level; (b) development of participants' laboratory and/or field skills; (c) sharing of resources, ideas, and experience among the participant educators; (d) establishment of a sustained teacher and school administrator network among participants; and (e) a considered, flexible response to educators' needs for determining the future direction of the project.

We have provided area science teachers with the opportunity to develop a deeper understanding of science content, to integrate this understanding into their 6–12 curricula, and to implement simple yet effective tools to assess student learning in science. The overarching goal of all of these activities is to improve the learning of science content and application by Illinois students in the region we serve.

Project partners each year include about 150 teachers representing more than 70 school districts, and both public and private schools. We estimate that 20,000 students are impacted by program activities each year. Table 1 summarizes partners in the project over the past four years as an ITQ project.

Table 1

Partners in the Project for the Past Four Years

Year	Workshop	Total number of teachers	Teachers from public schools	Teachers from private schools
2007	Middle school science	42	33	9
	High school chemistry	68	66	2
	High school physics	27	27	0
2008	Middle school science	50	39	11
	High school chemistry	66	62	4
	High school physics	35	35	0
2009	Middle school science	51	38	13
	High school chemistry	66	64	2
	High school physics	27	27	0
2010	Middle school science	43	34	9
	High school chemistry	57	52	5
	High school physics	27	27	0
	High school biology	16	13	3

Special Features

SIUE programs have been successful in encouraging networking and sharing of resources among a core group of teachers in the area, some who have known each other for many years. For example, one Granite City High School chemistry teacher, Amy Heath, was a first year teacher when the partnership began in 1985, and continues to be an active collaborator 25 years later. Current activities reach many educators, including those serving financially disadvantaged and/or mainly minority districts. Ongoing collaborations have produced highly qualified and effective science teachers who serve in urban, suburban, and rural districts.

School educators and administrators are responsible for implementing curricular materials, experiments, and demonstrations in their science courses. As part of the partnerships' formal agreements, each school or district is required to commit to providing lab space and offering hands-on science to students, although the quality of these accommodations varies widely. This policy ensures some understanding by administrators and a baseline of commitment to support teachers in implementing what they have learned. The partnership includes formal planning, oversight, direction-setting, and decision-making by a range of partners. Throughout the year, a Program Board meets on a regular basis (approximately every other month). The Program Board consists of the project director (Sadegh Khazaeli), co-project directors and science faculty (Eric Voss, Dennis Kitz, Abdullatif Hamad, and Cathryn Springer), a representative from the SIUE College of Arts and Sciences (William Retzlaff), a representative from the SIUE School of Education (Randy Smith), the external evaluator (Douglas Eder), ten "liaison" teachers, and two science department heads from partner schools, both active Hands-On teachers as well. The Program Board acts as a "sounding board" for communication in both directions between SIUE partners and 6-12 partners. Each "liaison" in turn communicates with five to six districts, follows up on their evaluation processes and represents their views at all meetings. This is believed to be an effective method for continuous feedback and serves as one tier of a network that provides material, personal, and professional support in the schools and districts.

Nine high need school districts are targeted as principal partners of this program: East St. Louis #189, East Alton #13, East Alton-Wood River High School #14, Belleville #118, Cahokia #187, Madison #12, Venice #3, Centralia High School #200, and Centralia #135. Local data obtained from four other school districts identify them as high need districts: Belleville East, Edwardsville, Roxana, Granite City, and SIUE East St. Louis Charter School. Other public schools that have participated in previous programs are: Highland, Okawville, Valmeyer, Greenville, Mt. Olive, Triad, Mascoutah, Gillespie, Belleville West, Carlinville, O'Fallon, Staunton, Civic Memorial, Waterloo, Lebanon, Livingston, Collinsville, New Athens, Freeburg, Divernon, BCCU #2, Jersey, Mulberry Grove, Bond County, Coolidge, Damainsville, Grantfork, High Mount, Highland Elementary, Hillsboro, Irvington, Liberty, Lincoln, Pocahantas, Pontiac, Ramsey, Smithton, Belleville West Junior High, Bunker Hill, Fulton, Garant, Virden, Nashville, Mary Schaefer, Joseph Arthur, Grigsby, Fox, Mel Carnahan, North Green, Red Bud, and

Southwestern. The private schools that have participated in this program are: Trinity Lutheran, Holy Trinity, St. Anthony, Governor French Academy, Holy Rosary, Holy Childhood, Christian Academy, St. Ambrose, St. Clare, St. James, St. John the Baptist, St. Rose, Mater Dei, Christ Light of the Nation, Gibault Catholic, St. Elizabeth, and St. Michael.

Challenges

The SIUE network of partnerships has several strong features, two of which are longevity and network density. The two features are naturally related, and several of our challenges are the result of successes. First, the number of participants is growing each year. A very real challenge is finding appropriate laboratory space on campus to accommodate all participants. Hands-on science requires that teachers have genuine lab and field experiences themselves so that they can witness their value and learn how to provide comparable experiences to students. Because of safety considerations, the number of teachers in a given laboratory room should not exceed 20. SIUE provides several laboratory spaces for each workshop, even though these rooms are at a premium, as a sign of SIUE's commitment to the network of partnerships. We also split groups larger than 20 into subgroups doing different activities in different laboratories at the same time. This kind of coordination requires planning and university support. For these sessions, we have two faculty and two teaching assistants supervising the subgroups. If growth continues, we will offer more workshops and find ways to address the costs. On the average the cost for each participant is about $2,000. Stipends, enrollment fees, demonstration kits, and commodities for use in the schools amount to about 2/3 of the total cost.

Second, there is a great diversity in the experiences of teachers attending project sessions. Some teachers have just started their careers, while others are veteran teachers with more than 20 years of experience, and there is great variation in the content knowledge they bring with them. The ongoing challenge here is whether to focus on basics or to focus on advanced content. Unlike most ITQ projects, we have so many school partners that we must offer content without having a specified curriculum or school improvement initiative. So far, we have tried to maintain a balance between basic and advanced material guided by science standards, and in general, school partners have liked our approach. We also plan workshops considering new developments in science of which teachers may be unaware. For example, advanced techniques such as gas chromatography and mass spectrometry experiments have been included in each summer session so that teachers are exposed to techniques currently used at universities and in industry. Although these techniques are not part of the basic curriculum and current standards for middle, junior high, and high school science, they are a part of modern science, and they provide examples of how science is used to improve the lives of people in society.

Third, teachers have suggested that we offer similar science content-based programs in other disciplines, but it is challenging to form the internal partnerships at SIUE that would make this possible. A related challenge is extending all the sciences to middle, junior high, and high school teachers. The first population we served was chemistry teachers, one group covered by the current project. The middle and junior high school science teacher program has been in place for six years, and continues to attract a diverse group of teachers. Starting in 2007, our project also includes workshops for high school physics teachers. We expanded project activities to include earth science and environmental science components in our middle school science and high school chemistry workshops. We started similar offerings for high school biology teachers in fall 2010. Because of identified school needs, we would like to add mathematics workshops in the future.

Fourth, the IBHE has encouraged all NCLB projects to include assessment and evaluation feedback loops among all partners involved. To address this challenge, we now have meetings throughout the year of the Program Board described above. With the growth we have experienced in recent years, we expanded the Program Board in 2010 to include two high school physics teachers, three high school chemistry teachers, and five middle and junior high school science teachers. We also invited four school administrators to one of our Project Board meetings in hopes of securing commitments from two administrators to become Project Board members. We currently have the commitment of two science department chairs, one from a suburban community and another from a high school that serves several rural communities. Taken together, these science administrators serve a southern Illinois population of approximately 60,000 people. We aspire to adding two building level administrators, principals or assistant principals from project schools, to the board in the future. Internal partners at SIUE, including representatives of both Arts and Sciences and Education Deans, serve on the board as well, providing means to secure support for program changes based on evaluation results and input from school partners.

Fifth, we have used SIUE School of Education contacts and formal agreements with area school districts and have expanded interactions between project partners and area school administrators. This additional participation by administrators is crucial to bringing about significant systemic change and better access to schools for student learning assessments. Leadership matters at all partnership intersections, between and among university internal partners and school partners. Originally, our partnerships were single-tier professor-to-teacher structures that have been evolving into multi-tier arrangements with leadership engagement and a shared awareness of what a sustainable partnership requires (Baker, 2011; Gardner, 2011a). Leadership stability and commitment is a source of persuasion and buy-in for improving science education that translates into the five professional development features in the IBHE policy (Desimone, 2009; Garet et al., 2001). SIUE science faculty are the content experts who design summer workshops and school year follow-up programming to ensure sufficient active learning, duration, and collective participation to make the project viable and sustainable. However, the school leaders must include these features and ensure that this science professional development initiative is coherent with other school improvement policies and does not represent a source of fragmentation in the busy lives of teachers. In schools where the goals of the project can be supported by collective participation in school-based teams, leaders are critical to the functioning and sustainability of these teams.

Finally, some of the schools do not have even basic pieces of equipment and commodities for implementing program activities. As part of formal partnership agreements, schools must commit to do what they can to provide basic infrastructure for hands-on science, but we are sensitive to the different contexts in our large regional network. Without the partnership, frankly, SIUE faculty in the sciences might be unaware of school conditions that affect college readiness. Additional funds provided by IBHE in 2009 enabled us to purchase equipment and materials for schools in the partnership. Other more expensive pieces of equipment purchased using project funds are stored at SIUE and are available for loan to teacher partners. The library of equipment benefits all the schools and increases the strength of the network because teachers confer about the equipment, the logistics of sharing it and ideas about its uses in hands-on science.

In the process of meeting these and other challenges, the partnership reveals its strengths and exposes places where partners could be more responsive to each other. The Program Board is a critical structure for implementation, for evaluation and evaluation capacity building, and a forum for the development of evaluation instruments and application of evaluation results to planning and improvement (Haeffele, Hood, & Feldmann, 2011). As a longstanding science education regional partnership, meeting these challenges has helped us to realize that we do have a strong regional network that could not be easily or quickly developed. We can now continue to strengthen and use our network. We continue with some of the lessons learned about supporting science education through school-university partnership.

Lessons Learned

Demand is high for professional development among middle, junior high, and high school science teachers. We have tried to accommodate the growing number of participants within the constraints of classroom and laboratory size, available staff, and monetary support. We are proud to have never turned away any interested participant. This was possible since SIUE supplied partial salaries for program personnel. Both partners have to commit, and the commitment of staff, space, and time for collaboration all serve to support partnership functions. In addition, our partnership has taught us several lessons that might help in forming new partnerships as well as in improving longstanding ones like ours.

First, partners must be responsive. For example, we learned that among high school chemistry teachers and middle and junior high school science teachers, there is very high interest in core academic content related to environmental science linked to state standards. Based on feedback from earlier years of the project, we initially added one day of environmental science to each workshop. Teachers wanted even more environmental science, so we recruited Judy Zhang from the SIUE Department of Chemistry and Environmental Science Program to collaborate on the project. As a result, we were able to provide two days of environmental science activities in 2009 and 2010 for high school chemistry teachers and middle and junior high school science teachers.

Second, partners continue to demand a focus on core science subject content rather than pedagogy or educational methods. Our expertise is as content providers, and this is the real strength of this program. But content is never divorced from the ways in which science is done. Active learning, a core feature of exemplary professional development, is what we do as scientists in our own lab and field work. By inviting science teachers to do authentic lab and field work, we model the overlap between content and pedagogy. This is an exemplary professional development practice as pedagogical processes taught in isolation do not improve teaching effectiveness (Desimone, 2009). Assessment is also a critical feature of good instruction and since Douglas Eder, (project external evaluator) joined the project, we have included more explicit pedagogical and assessment techniques in project activities. In particular, Doug has developed assessment activities that are used in the schools, and we discuss these below. As teachers increase the assessments of learning and share assessments developed through the partnership, teachers not only learn about assessment, they develop evidentiary sources for the partnership to use in its ongoing cycles of evaluation and project improvement.

Third, many partner teachers have recently changed teaching assignments to new disciplines, a fact of life in schools stressed under economic and other pressures that create instability. We must be sensitive to the needs of those who may be teaching a subject for the first time with little or no prior formal training in that subject. In other cases, rural schools may have just one science teacher who will not have comparable levels of content knowledge or comfort in all the different scientific disciplines. This is an ongoing challenge to support teacher partners as they must retool and perhaps teach out of their comfort zones. It is important to have activities geared to both new teachers and seasoned veterans who may be teaching solo or out of their field of preparation, with or without recent updating in content knowledge, or experience with the content pedagogy of the field. This mixture of experience levels and content or content-pedagogical experiences makes for interesting interactions. When asked, partners prefer to keep the group heterogeneous rather than separating into groups based on experience or other factors. This matches the five-part model that encourages collective participation and builds a support network wherein teachers can benefit from the strengths of others and mutual support in situations where there are no science colleagues.

Fourth, we have found that an emphasis on basic and advanced math skills is essential to successful applications of science, but not all regional science teachers are comfortable with mathematics. In our workshops and supports, we help participants gain confidence in their math skills, which will certainly improve their effectiveness in teaching how to solve scientific problems. In addition to math as a basic prerequisite for science, there is great need for content on science basics, including logistics. We have included training in laboratory safety and stockroom management for high school chemistry teachers, as one example. Also, we have chosen to go beyond the basics in some selected advanced topics, and introduce topics related to the management of specialized laboratory experiments. Recently, organic chemistry synthesis was included as just such an advanced topic.

Fifth, we have learned the value of structured discussion time during workshops. In 2007 we added more time for roundtable discussions that were popular, but this was not enough. Since then, we have included more time at the conclusion of laboratory and field activities to discuss data analysis, interpretation, comparisons, purposes, improvements, missing pieces, adaptations, and other topics. This provides an opportunity for the development of critical thinking skills. At the end of each workshop, participants are invited to share favorite resources (e.g., experiments, web pages, or teacher made print resources), and this provides another opportunity for discussion and network-building.

In addition, some partners suggested inclusion of the Illinois Science Assessment Framework (ISBE, 2010c) that was implemented as part of the Illinois Standards Achievement Test (ISAT) beginning in spring 2006. We then incorporated the framework for grades 4 and 7 and the framework for grades 9–12 (ISBE, 2010c) from the Illinois State Board of Education into all program activities. We encourage teachers involved in the program to be aware of new standards that are in preparation, particularly the common core standards. Looking ahead, international standards and the Programme for International Student Assessment (PISA) will increasingly affect science educators in this standards-based environment (Organization for Economic Cooperation and Development, 2009). Teachers and students must think ahead to the ways in which STEM education will continue to shape standards and expectations.

Also, we learned that science field trips by teachers not only benefit them in improving their knowledge, but also the trips give them an edge in the classroom in explaining complicated scientific techniques. Recent field trips include the Anheuser-Busch brewery, the Sigma-Aldrich Chemical Company, Argonne National Laboratory, the LEED Platinum certified Alberici Corporate Headquarters, and TekLab, an environmental testing laboratory. More could be done in this area as we explore the role of science in regional development, including the universal need for science background for 21st century employment and how it potentially affects our region. Not all 21st century STEM employment will require advanced education. The region needs lab and pharmacy technicians, physical therapy aides, and other jobs that contribute to regional economic health and opportunities for students, college bound or not.

Finally, the outside evaluator for this grant, Douglas Eder, makes the observation that strict memorization of facts is not how practicing scientists “do” science. Nevertheless, a focus on facts and content has become a default approach in science teaching, one that is remarkably resistant to change. A lesson learned—or at least reinforced—is that one cannot skip steps during progress toward a long-term goal. Until teachers are comfortable and confident with what they want to learn, which is content-oriented, they are resistant to moving toward what we want them to learn. Even though the big payoffs for student learning may exist outside the strict boundaries of science content, the teachers won’t reach for these payoffs until they understand the prerequisite material. Stated in assessment terms, the best academic predictor of what students will learn is what they already know. If the teachers aren’t comfortable with content, they have great difficulty in going to the next level and requiring a greater cognitive demand of their students.

Evaluating Content-Based Professional Development in a Regional Network

The IBHE ITQ projects evaluate and use evidence about each project for ongoing improvement at the project level and for evaluation capacity within and across projects (Haeffele et al., 2011). Hands-On Science at SIUE has a theory of change rooted in the value of content expertise and discipline-specific approaches that include investigative laboratory and field work. Critical to the partnership is the content expertise offered by the university, which now includes multiple science departments, as well as the value of the network in making the project viable and sustainable (Gardner, 2011b). IBHE further requires that projects create logic models to make theories of change explicit for a variety of audiences, as an aid to planning and implementation, and as a guide to evaluation (Frechtling, 2007). In this section, we offer the SIUE logic model and some comments on evaluation.

Logic Modeling

In 2008, we began to use logic modeling with the tools, examples, and training provided by the Illinois Board of Higher Education (IBHE; see Figure 1). ITQ projects are required to evaluate teacher learning, implementation, and student learning using the logic model as a representation of intended outcomes and a set of pathways for evaluation. Using our logic model, we started to explore new ways of gathering evidence about what the project has accomplished. Logic models link inputs or resources, activities, outputs, and outcomes in a linear fashion to provide a road map for evaluation (Frechtling, 2007). Our project's theory of change emphasizes professional development in content knowledge and science practice and has done so for 25 years. What logic modeling suggested to us was the role of the regional network as part of our theory of change for both school partners and the university that accrues the benefit of science readiness in first year students. We include some of these emerging measures and means of observing project outcomes we are developing.

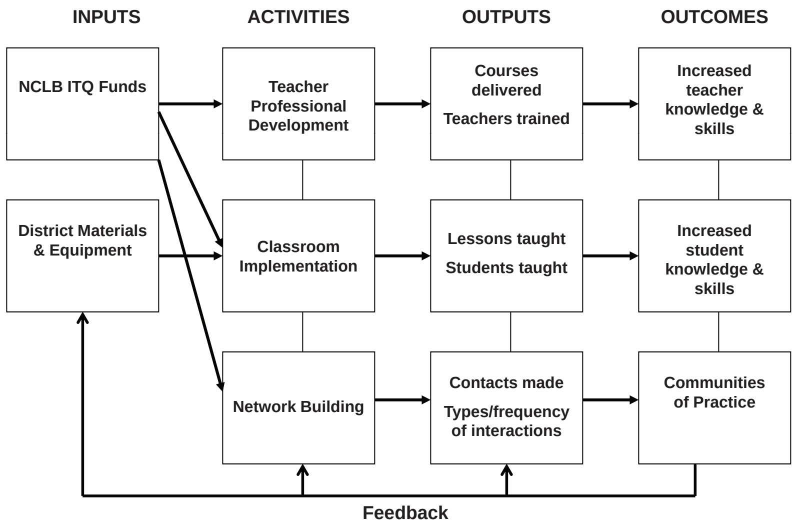

Figure 1. Program theory/logic model—Part 1: teachers and students.

Evaluation: Observations and Measures

The Hands-On Science logic model (Figure 1) is a road map for understanding our approach to designing, implementing, and evaluating. The evaluation methods employed within this project were aimed chiefly at the outcome level, and most often at examining student learning, although we looked also at teacher learning and implementation using several methods that we share below. We also used a survey to yield findings about the Hands-On Science regional network and communities of practice. Because of our interest in student learning and helping teachers use classroom assessment to inform instruction, many assessments were drawn from, or were variations of, classroom assessment techniques (CATs), and we piloted the use of CATs by a small group of teachers (Angelo & Cross, 1993). Four additional instruments we used included: an on-line survey; embedded questions from a common exam; the Quick Course Diagnosis (QCD) (Lansing Community College, 2010); and evaluations of teacher learning. We summarize these topics and methods below.

In addition to science content, teachers received instruction on a dozen classroom assessment techniques (CATs), such as the one-minute paper, directed paraphrase, memory matrix, rapid organizer, and double entry journal. These and other CATs were selected because they required little teacher preparation, yet they did require student reflection and could make learning visible as it happened, expanding a teacher's assessment repertoire. As a result, a dozen teachers out of the 150 or so involved in this project in 2010 voluntarily reported CATs results. This is a small number, but this interest in CATs was suggestive and served to pilot several approaches for future use and to identify areas for further investigation. Issues raised by this small sample revealed that students: (a) did not focus reliably on what their teachers said was important; (b) too often omitted important material that was essential for understanding and frequently rated as important material that was largely irrelevant; and (c) desired more active learning experiences and fewer pure lectures. One implication of these findings from this small sample is that the project could use CATs more systematically and help teachers to make reflective use of student communications. Teachers can have the classroom feedback they need to alter instruction, clarify goals for themselves and their students, and to communicate about learning goals, including learning standards. Students need to be conversant in the world of standards and use them to take charge of their own learning (Black & Wiliam, 1998), so CATS are potentially useful tools for all units of analysis in our evaluation.

CATs are emerging as useful formative assessment tools, but we use other methods of evaluation that are not as closely linked to instruction. Surveys are an important evaluation of Hands-On Science. Participating teachers are invited to complete 9-question, on-line surveys at the end of each fall semester. Response rates each year were between 58–70%, and we strive to improve this rate but still find results instructive. Unlike attitude surveys, which ask about impressions, feelings, and interpretations, these surveys elicit factual information about teacher behavior. For example, one question asked teachers to count the number of contacts (e.g., telephone, e-mail) they made with other teachers each week on project-related topics. The contacts could be to check facts, exchange supplies, acquire pedagogical assistance, borrow equipment, or something else so long as it was grant-related. The most important finding was the prevalence of networking. Participating teachers were communicating with each other on grant-related topics at the rate of an average of four contacts per school day across the network. Given the isolation that teachers often profess—e.g., "I'm the only chemistry teacher in my school"—these contacts were important and would not have existed except for the project. The contacts themselves facilitated the borrowing and exchanging of ideas, equipment, and supplies. Through the surveys, teachers also reported subject areas in which student learning was improving and those in which it was not. This information informed the principal investigators so that they could tailor future workshops and interventions: Would teachers benefit from more emphasis on hypothesis forming and testing? Or more insights on colligative properties? Less emphasis on weights and measures? In this way, we used surveys to address teachers' needs directly and to understand how the project was being implemented.

The Program Board meets two to three times each semester to promote evaluation and use of evaluation results. One important advance from this group was the construction of two student exams, one in chemistry and one in physics. The exams were designed to be used as stand-alone assessments of content learning or as questions to be embedded in other exams and then retrieved for item analysis. Remarkably, the questions were designed for use by teaching participants in the project and by non-participants as well, in order to assess student learning in "intervention" and "control" situations. Pledges were received from participating teachers to solicit cooperation (and future participation) by non-participants. These exams were administered throughout the Hands-On network in spring 2011, but results of this assessment were not yet available at the time of publication. We believe that this method is promising for evaluation at all levels of analysis from the classroom to the Program Board.

As a further investigation of classroom learning, we trained teachers in the Quick Course Diagnosis (QCD), a derivative of the longer and more complex Group Instructional Feedback Technique (GIFT), sometimes called Small Group Instructional Diagnosis (SGID). The key element is for groups of four to six students to respond to two questions: (a) what aspect of this course helps you learn? (b) What aspect hinders your learning? The reason for using groups is so that no one student voice dominates. If each group can return only one response to each question, then group agreement becomes essential. For a typical class of approximately 30 students, this means that each question produces five to seven group responses. In addition, the emphasis of the questions is on the learning environment, not on the teacher's behavior. This is a learning assessment, not a teaching evaluation. The major difference between the GIFT/SGID and the QCD is that the GIFT is done through a one-half-to-1-hour classroom interview process whereas the QCD is accomplished via a 10-minute 3x5 card process. In both processes, a trusted teaching colleague conducts the class with the host teacher absent in order to assure student anonymity. The trusted colleague also transcribes and summarizes the data and presents it privately to the host…hence the idea of a "gift." We found considerable agreement observed across teachers, subjects, and schools. Students said that they learned better when given active learning situations, such as lab exercises, opportunities for group processes, repetition and practice, slower talking by the teacher, and time in class for reflection. Things that students reported to hinder their learning included too much lecture, fast talking by the teacher, no time during class for practice and reflection, and both aural chatter and visual clutter in the classroom.

Finally, all participating teachers completed evaluations during and after each workshop or follow-up session. The evaluations asked for feedback regarding pedagogy as well as content. Workshop facilitators took the feedback to heart and now more consistently model effective and engaging teaching practices. Moreover, the principal investigators paid special attention to those topics that teachers said they would find most useful in their own classrooms: Does chromatography of flower pigments sufficiently engage students to convey an important point at low expense? Does making ice cream get across the idea of a colligative property (i.e., freezing point depression), or is the exercise merely distracting? (To make ice cream, one doesn't need a traditional barrel with dasher. There are inexpensive, colorful, plastic balls available with an inner compartment in which cream can be cooled by icy slush laced with salt in an outer compartment. Agitation occurs when students roll the ball on the floor. To what extent is the thermodynamic mechanism of salt depressing the freezing point of water, thereby freezing the cream, made clearer and memorable by making ice cream?) The workshop evaluations prompted these sorts of questions, and the answers were used to reinforce or restructure subsequent grant-supported interventions. Thus, the participating teachers' own knowledge base was reinforced (and sometimes recast!) in a manner aimed to yield subsequent improvements in student learning.

Some Challenges

From an external evaluator's viewpoint, five challenges emerge. First, in an era of financial distress, it was discouraging to observe that some of the most committed teachers were laid off and could not serve the schools that had sent them to Hands-On Science. Teachers who are bright and energetic applied to become, and were accepted as, participants in the training afforded by this project. If coherence, duration, and collective participation are hallmarks of effective professional development, the factors that work against them are discouraging. These factors included the fragmentary nature of state support and lack of instructional program coherence in the schools (Newmann, Smith, Allensworth, & Bryk, 2001). Looking first at the state, the IBHE administered this program and supported evaluation looking to improve schools and districts, but the state legislature reduced funding for schools. In this way, grant funding can be a source of support, but it is seldom integrated into a system that helps schools use fiscal and human resources to their best effects. A second source of fragmentation comes from the districts. The lay-off decisions that affected Hands-On Science were unrelated to who was seeking meaningful professional learning and who was not. Failure to align staffing decisions with a coherent approach to school improvement compounded our frustration as good science teachers leave project schools and districts, although recent legislation in Illinois may change teacher lay-off priorities as a matter of policy.

Second, evaluation efforts are hampered by confusion about the nature of formative evaluation. During the course of using the GIFT/SGID, some school administrators learned about it and decided that it would make a useful teacher evaluation tool. They inserted themselves into the process in the role of GIFT-giver. This misuse of the GIFT converts evaluation from non-judgmental, formative assessment of learning based on trust into a judgmental presumption about teaching based on doubt. Administrative misapplication of the GIFT process happened more than once during the project period, and both the fact and surrounding rumors curtailed use of this method. From an evaluator's perspective, formal administrative support for the project must come with an explicit understanding that teachers must be allowed experiment with instructional methods free from premature summative evaluation and the personal and professional risks it entails.

Additionally, preliminary findings from the GIFT/QCD raise questions about what helps and hinders learning in the science classroom. The idea that the best way to convey science content is through animated lectures packed with facts may not align with how middle, junior high, and high school students learn best. Students reported slower-paced, active learning as more effective. Students also reported that rapid talking and rapid presentation hindered grasp of new material. Their reports also suggested that quiet, in-class reflection time was an important contributor to deeper learning. Teachers may well produce better student achievement simply by slowing down and resisting pressures to "cover" more content superficially, providing gaps of time for students to reflect and consolidate their knowledge, and managing sensory stimuli in the classroom and laboratory. Some of the GIFT/QCD findings are easily implemented; others are not. But in all cases, evaluation of factors that affected the classroom were raised to consciousness and made available for reflection and renewal.

A Final Thought on Assessment

Many students who attend SIUE come to campus from high schools served by the activities of this project. Some of those students have been taught by project teacher-participants. This presents us with an opportunity to explore the college readiness that the network generates. Although doing so is not straightforward, the principal investigators have followed students in first- and second-semester general chemistry courses that are engaged in the project through the involvement of their teachers. The results of this tracking assessment are shown in Table 2. This is exploratory data for us to consider how the university partner is affected by the network. These performance percentiles are not ideal as measures of learning, but the table is suggestive and encourages us to find ways to observe how a regional network of science teachers may support science education for both school and university partners.

Table 2

SUIE First and Second Semester Chemistry Performance Percentiles by Student Origin

Origin of students	Number of Students	Average final chemistry performance percentiles
Took high school science	359	71.94%
Took high school science in school served by Hands-On project	97	74.85%
Took high school science in school and from teacher served by Hands-On project	29	80.75%

Taken together, the multiple assessments of this grant-supported project provide some evidence that the Hands-On project produces improvements in student learning as students from project teachers appear to do better in first year chemistry courses. We do not understand the mechanisms for this, but we intend to follow-up with first year students from the three groups. This project is the only current ITQ project that has been in place long enough to begin to evaluate long-term effects, and because it is a high school project in part, we can follow-up and see how the project benefits both partners. We believe that long-term, realistic improvements in student science learning are achievable and that with a regional network system where partnerships exist, the university and schools can be of mutual benefit.

Conclusion

Of the ITQ projects, Hands-On Science for middle, junior high, and high school teachers at Southern Illinois University Edwardsville is the longest-lived, beginning more than 25 years ago as an Eisenhower grant. The Eisenhower grants were one late 20th century policy aimed at improving science education. In 2011, the emphasis on improving STEM education in the United States grows and shows no sign of subsiding. There is a general recognition that STEM matters in the hot, flat, and crowded 21st century (Darling-Hammond, 2010). The SIUE project has changed leadership several times, from Emil Jason to Sadegh Khazaeli, and now including Eric Voss, demonstrating the SIUE commitment as a partner and contributing to the stability that has made professional learning among science teachers in regional networks possible. University professors worked directly with school teachers and developed a network of science teachers in settings as diverse as suburban St. Louis on both sides of the Mississippi, urban East St. Louis, and dozens of rural communities hard hit by economic and demographic trends. Through IBHE support and encouragement, the project now uses evaluation for project planning, implementation, and improvement.

The project began as a single-tier structural configuration with simple professor-to-teacher implementation through content-focused summer institutes. No deans, superintendents, principals, or other constituencies were involved except as administrative functionaries. Early on, there were no particular requirements or supports for evaluation from IBHE. The professional development picture now emerges as more complex than just content expertise offered by professors to teachers. We can look back over the quarter century of the project, and consider how the five empirically-grounded features of professional development have contributed and hindered our success: content focus, active learning, duration, collective participation, and coherence.

We began with the first two of these: content focus and active learning, and continue to see their value. Sciences, technology, and engineering are dynamic fields always altered by new findings and directions. The emphasis on test scores and prescribing what must be "covered" work against the best practices for STEM teaching and professional development. Years of school improvement focused on literacy and math have left science out in the cold. Science is not emphasized in state testing, so it does not get the recognition its significance in the 21st century suggests it should receive. We also have attended to duration as a factor, offering summer workshops and year round study, always allowing teachers to continue, new teachers to join, and never turning anyone away. In the course of the last three years under IBHE's new and emerging evaluation policies, we recognize the value of the regional networks that have developed and that provide necessary supports within schools or through ongoing contacts for those without science colleagues at work, recognizing how we had encouraged collective participation. We have no coaches who work in the schools, as many ITQ projects do. The teachers are networked to support each other, and we have done this long enough that this seems to be working. We know that the potential can be more fully tapped. We continue to explore ways to make the network function and to increase its supportive features.

Of the five features, the most challenging for Hands-On Science is coherence with policies that cause fragmentation at each level of the system, from the state legislature into the districts and schools, where leaders may or may not recognize or understand how the project can support their educational renewal and school improvement goals. As a result, we recognize the need to be increasingly intentional about adopting a multi-tier configuration that brings regional leaders into the project (Baker, 2011). We have the reputation of the program in our favor, but challenges remain. The creation of the Program Board was a step in this direction. We garnered internal support on the SIUE campus from both the Arts and Sciences and Education units, with representatives of the two deans serving on the board. We have science teachers who serve in formal and informal leadership roles serving on the board and working in the larger schools and districts to expand the program, which attracts more and more applicants each year. We have the trust of teachers and teacher leaders in the region. These are our most valuable assets.

Implications for the future include development of teacher leadership and networking school and district leaders. In addition, we are beginning to consider the effects of the project on the university partner through new evaluation. The project began as a faculty-to-teacher configuration that added several sciences to the original chemistry program, improved the chemistry performance of students, and linked two colleges in a science education partnership. We also have preliminary connections to business partners with an interest in STEM and graduates from high school and college. Ideally, these graduates enter the workforce, and further education with a STEM foundation can serve them well.

We are in a position to reap the rewards of years of partnership between professors and teachers, recognizing that we are already reconfiguring the structure of our partnership and helping everyone from the school and university to evaluate results. We take this special issue of *Planning and Changing* as an opportunity to do some stocktaking and acknowledge what we have accomplished by working as partners with the science teachers in our region.

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