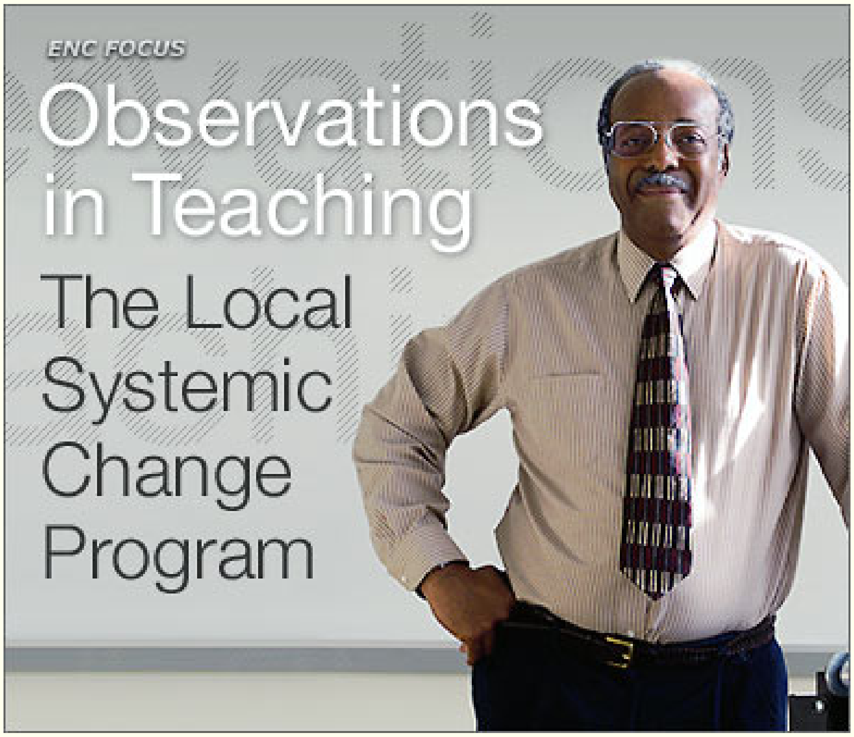

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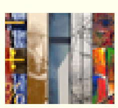
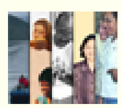
 by Topic

 by Audience

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Improving Math and Science Instruction Through Improved Professional Development

The results of 10 years of research and evaluation of the Local Systemic Change professional development program point to some useful insights and promising practices for improving mathematics and science instruction.

by Joan D. Pasley, Horizon Research, Inc

The Local Systemic Change (LSC) program, begun in 1995 with funding from the National Science Foundation, was designed to improve instruction in science, mathematics, and technology by focusing on the professional development of teachers within whole schools and school districts. It placed an emphasis on preparing teachers to implement exemplary mathematics and science instructional materials in their classrooms. Projects targeted elementary and secondary grades, as well as K-12 grade spans, and addressed mathematics, science, or both subject areas. LSC started with a cohort of eight projects and grew to a total of 88 projects across the country by 2002.

The LSC theory of action argued that providing teachers with opportunities to deepen their content and pedagogical knowledge in the context of high quality instructional materials will result in better-prepared teachers. The theory also predicted that these teachers, with on-going support, would be more inclined to change their instruction in ways advocated by national standards, and would have more capacity to do so. Improved instruction would in turn lead to higher student achievement.

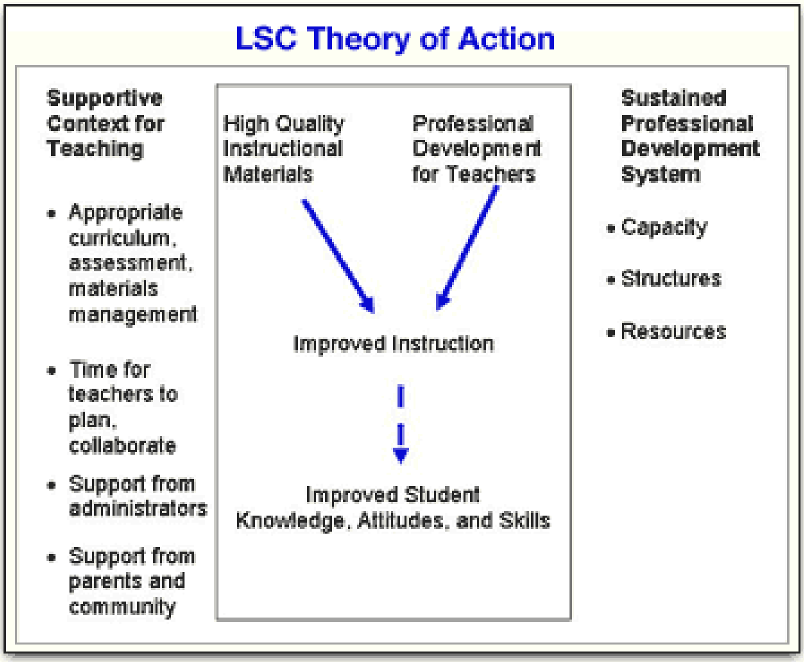

Figure 1. LSC Theory of Action.

Guiding Principles

While the design of LSC projects varied based on their local contexts, LSCs were guided by a common set of principles to achieve their overarching goal of improving mathematics and science instruction. These principles included the following:

- Providing experiences that deepen teachers' knowledge of the mathematics and science content in the curriculum and the pedagogy needed to teach this content
- Providing opportunities for teachers to explore and become conversant with exemplary instructional materials and the appropriate pedagogy for using these materials in their classrooms
- Providing support for teachers in the areas of content, pedagogy, and materials over the course of implementation
- Providing access to well-prepared professional development providers whose backgrounds include in-depth content understanding and expertise in KÂ–12 mathematics and science education
- Establishing a supportive and collegial professional development culture that facilitates teacher learning

Evaluating the Program

Horizon Research (HRI), the LSC program evaluator, created a core evaluation system that allowed information to be aggregated across the diverse LSC projects. Local project evaluators collected data using common instruments designed to answer core evaluation questions and rated the quality of LSC professional development programs.

Data collection activities completed by evaluators of each LSC project included:

- Observations of professional development activities
- Classroom observations
- Teacher questionnaires
- Principal questionnaires
- Teacher interviews

This information was analyzed and compiled by HRI into a set of key findings about the successes and challenges of the LSC program. This article highlights some of the major findings regarding designing and implementing high-quality professional development. It serves a dual purpose. For designers of professional development, it provides a set of criteria to use in creating programs. For teachers, it provides a lens through which they can view or measure the nature and quality of professional development opportunities available to them.

Why Was the LSC Program Significant?

While the evaluation results point to strengths of the LSC program, it also raises questions about deep or sustained impact, and these questions pose additional challenges for educators working in mathematics and science improvement.

LSC professional development had a powerful impact on teachers' beliefs and attitudes toward their teaching. Workshop evaluations and interviews revealed that teachers left professional development activities with:

- greater sense of enthusiasm for teaching,
- heightened awareness of how students learn,
- willingness to modify their teaching practices and collaborate with colleagues, and
- increased confidence in their ability to teach mathematics or science.

Teachers attributed new beliefs about how students learn--through questioning, discovery and reflection--to their exposure to inquiry-based instruction in LSC professional development.

> *I look at students' work completely different now. It opened my eyes to how many different ways there are to come to the same answer.* (Teacher, K-12

mathematics LSC)

In addition, they indicated changes in their beliefs about who can learn mathematics and science. LSC professional development helped dispel low expectations that teachers had for some of their students.

> *After the (LSC) summer school, I began to see myself as a teacher who cares very much about rich content matter (such as science) and about scaffolding that content in ways that LEP children can really grasp ideas and language.* (Teacher, elementary science LSC)

LSC Professional Development: Design, Implementation, and Impacts

LSC professional development was based on the premise that content and pedagogy are most accessible when learned in the context of student instructional materials. LSCs attempted to find a balance of content, pedagogy and materials--where content is not sacrificed, where new practices are both modeled and explicitly discussed, and where teachers have opportunities to reflect on new practices. The most effective LSC professional development programs reflected a design that was conceptualized and implemented as an overall program of work, not as a laundry list of offerings. As a consequence, exemplary LSC professional development design targeted three areas in a coherent, integrated fashion:

- Deepening teacher content knowledge
- Enhancing teacher pedagogy and use of exemplary materials
- Supporting teachers during implementation

Teacher content knowledge
Teachers, especially at the elementary level, have substantial needs in mathematics and science content. While this was accepted as common knowledge among the LSCs, many struggled with providing sufficient emphasis on content. Given the newness of the instructional approaches and hands-on materials, training was often targeted at module-specific content needed to implement the materials. Over time, many LSCs came to recognize the need for increased content-based sessions and enhanced their focus in this area by providing mini-courses, study groups, and university courses to enhance teachers' content knowledge.

Often, the quality and usefulness of content sessions depended on the professional development provider. The provider's ability to effectively translate key concepts and offer the right level and pace of content was critical to teachers' understanding and to avoid overwhelming the teachers. At the same time, the provider needed to challenge teachers beyond the module-based content so that they could use the content to build student understanding.

LSCs encountered many barriers in meeting the content needs of teachers within their districts. Most LSCs could not mandate participation in professional development, so they needed to design sessions that teachers perceived as interesting, relevant and accessible using a range for formats. Attempts to offer in-depth coverage of content were sometimes derailed by state demands for breadth of coverage. Teacher leaders were often not well enough prepared in content areas to effectively lead study groups. As LSCs refined their ability to gauge and respond to teacher needs, teachers came to recognize their content deficits and request more content-based sessions.

Based on questionnaire data, participation in LSC professional development had a substantial impact on K-8 teachers' content preparedness, with those having 80 hours or more of training showing a marked difference over those who had none. However, classroom observation data suggest that teachers may not have been as well prepared to teach content as they perceived themselves to be. Examples of how insufficient content knowledge impacted instruction are presented in the math and science cases that accompany this article.

Teacher pedagogy and use of exemplary materials
The LSCs put a heavy emphasis on pedagogy and use of materials across all of the projects. In the early stages, training focused on module familiarity, materials management and logistics. As teachers moved beyond the introductory sessions, activities gave greater emphasis to inquiry, student thinking, assessment strategies, and teaching for understanding. One local project evaluator noted,

> *The program has been developmental; it has embraced the research on ways to best address teachers' needs based on their level of use of a new educational innovation.* (Evaluator, elementary science LSC)

The most highly rated LSC professional development offered a coherent and focused design in its offerings rather than a random smorgasbord of opportunities.

LSCs attempted to instill in teachers a real sense of what it is like for students to experience the instructional materials. As a result, professional development facilitators needed to model the instructional strategies. This increased teachers' understanding of what an inquiry-based lesson looked like, demonstrated how to engage students, and helped teachers make sense of the materials. This modeling approach was a strength of the LSC professional development; however, the most effective providers went beyond simply modeling to explicit discussions of what they were doing and why. This strategy enabled teachers to become students themselves, reflecting on the pedagogical implications for their own classrooms.

Again, as with the content area, the skills of the professional development facilitators were important in making explicit connections between the session activities and the larger goals or intent of the strategies being demonstrated. Highly rated facilitators provided adequate opportunity for teachers to reflect in order to see how they could incorporate new techniques into their own lessons.

As teachers attended more LSC professional development sessions, they also steadily increased their use of the designated instructional materials. Teachers commented on their increased comfort level with hands-on and inquiry-based approaches to teaching. Although teachers were using the materials more extensively in their classrooms, there was a wide variation in how well they were implementing these materials. Teachers often omitted rich activities, skipped over steps and jumped to higher-level concepts, or left little time for students to make sense of the lessons. Teachers who were new to these types of materials and pedagogy had difficulty implementing the materials as intended by the developers. Classroom observations indicated that lessons taught as the developers intended were more likely to provide students learning opportunities than those that were adapted by teachers unfamiliar with the pedagogy.

Teacher support
The LSC design was built on sustained professional development that provided year-round opportunities for teacher learning. Summer trainings offered intensive opportunities for teachers to explore new materials and instructional practices over periods of a week or longer. School-year sessions offered additional in-depth follow-up as teachers were implementing programs.

LSCs used both small group sessions and individual support through coaching and mentoring to address specific teacher needs. Cross-grade and grade-specific seminars, study groups, action research, roundtable groups, and local learning communities were among the many approaches used by LSCs. Providing teachers with the support and time to collaborate and engage in reflective practice generated enthusiastic responses from many LSC teachers.

> *One of the most meaningful experiences was the opportunity for a group of teachers to meet and reflect on our teaching. It is rare (or uncommon) that we have the time to do this. As teachers, we are under time constraints and don't take time to reflect. These reflections helped me in my teaching in science and all subjects.* (Teacher, elementary science LSC)

While these opportunities to engage in group learning were critical for teacher development, one-on-one coaching and mentoring support was also a positive force for helping teachers make meaningful changes in their practice.

> *The coaches have helped me, clarifying where I can improve my teaching methods. They are very positive and non-threatening.* (Teacher, elementary mathematics LSC)

Top Ten Challenges for LSCs

Many LSCs were successful in creating effective systems for teacher professional development and growth, but the work was not without significant challenges. While each project took its own route to addressing challenges, the issues are likely to be similar for any school or district attempting to implement a mathematics or science improvement initiative. Each challenge may not have an inherent or identified solution, but school districts can benefit from careful consideration of the issues in their design of teacher development activities. The following are 10 important challenges (not necessarily in order of importance) that emerged from the LSC history and lessons learned.

1. Addressing the extent of teacher needs for content and pedagogy professional development in a culture of voluntary participation

2. Striking a balance in professional development activities between theory and practice; content, pedagogy, and materials; and depth and breadth of coverage

3. Moving teachers beyond module-specific and logistics discussions to deeper conversations around conceptual learning and student understanding

4. Moving teachers beyond superficial changes in practice to implementing high-quality materials as intended

5. Providing adequate guidance and structure for teacher professional development choices

6. Anticipating the turnover among the teaching staff and providing different levels of professional development targeted to teachers at different stages of experience

7. Identifying, training, and supporting a sufficient number of qualified and skilled teacher-leaders, mentors, coaches, and professional development providers

8. Establishing quality standards for professional development providers, especially their capacity to model and discuss

effective instructional practices and address content in ways that are both rigorous and accessible

9. Establishing a school culture that values collaboration and provides adequate time and resources for collaboration to occur

10. Maintaining momentum beyond the grant, using available resources for ongoing, high-quality professional development

If schools are successful in addressing these challenges in their professional development design, they can increase the likelihood that teachers will have the requisite knowledge and skills to offer high-quality mathematics and science instruction. And our students will be the ultimate beneficiaries of this effort.

Joan D. Pasley, a former high school science teacher and administrator, is a Senior Research Associate at Horizon Research, Inc. Dr. Pasley received a Bachelor's Degree in Biology from the University of Cincinnati, a Master's Degree in Educational Administration from Xavier University, and a Ph.D. in Curriculum and Instruction, from the University of North Carolina at Chapel Hill. She coordinates the standardized evaluation system for NSF's Local Systemic Change through Teacher Enhancement Project. She also directs the evaluations of a number of Mathematics and Science Partnership projects. Correspondence concerning this article may be sent to jpasley@horizon-research.com.

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A Case Study: Teaching the Game of Pig Provides Professional Development Insights

Through teacher observations and professional development, high school math teachers improve instruction for an *Interactive Mathematics Program* unit that explores probability.

by F. Joseph Merlino, The Greater Philadelphia Secondary Mathematics Project

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This case examines professional development in the context of teaching the Game of Pig, a unit in the first year of the high school curriculum *Interactive Mathematics Program* (IMP). The game is an introduction to the core concepts of probability and expected value as well as the supporting ideas of randomness; equally likely events; independent events; probability in the long run; theoretical versus experimental probability; and mean, median, and mode.

These concepts are contextualized in the unit problem, determining the best strategy to win the most points in the Game of Pig. The game is simple. Players roll a die as many times as they wish adding up the number rolled each time until they choose to stop rolling or until they roll a 1. If they voluntarily stop *before* rolling a 1, players get to keep all their cumulative points for that turn. But if they should roll a 1 at any time during their turn, they don't earn any points for that round. The problem is to determine a decision rule for when to stop rolling so as to maximize the player's total points over many turns.

Learning materials represent the concepts used in solving the Game of Pig in various ways, such as histograms, tree diagrams, area models or "rugs," and sample spaces. The teacher may also use additional activities and games during the course of the unit. Gaming materials include dice, coins, playing cards, and spinner games. Several "Problems of the Week" or POWs are also included within the unit and require students to ponder how to solve a situational problem individually or in groups. Students individually submit a written explanation of their solutions to the POWs and the reasoning behind their answer. POWs are in addition to regular class work and homework assignments.

The Game of Pig is designed to be completed in approximately 30 school days assuming a 50-minute class period, a trained and experienced IMP teacher, and on-grade-level students. Using a direct instruction approach, a teacher could pose the Pig unit problem to students in a single period, show them an algorithm for solving the problem, and arrive at the answer. The teacher could then test the students using a slightly different problem and move on to another problem rather than spending 30 days on the game as IMP does. While the latter instructional method appears more efficient, it produces virtually no conceptual understanding or cognitive capacity within the student for new problem solving.

Addressing Challenges Through Professional Development

To help teachers successfully implement IMP, the professional development design consisted of a variety of training components rather than just a workshop-type in-service. New IMP teachers:

- received 12 hours of in-service in each IMP unit, roughly two full days per unit, taught by a fellow teacher experienced in IMP.
- were encouraged to teach the unit in which they had been trained for at least one semester.
- were provided a mentor who visited their classroom and conducted pre- and post-conferences with the teacher via email and in person. Teachers were mentored for 20 hours the first year.
- were offered a five-day, IMP-based, graphics calculator course.

Each mathematics department was encouraged to:

- arrange peer teacher visitation within the school.
- meet weekly to discuss common concerns, insights, and experiences in the

program.

- allocate resources and time for teachers to attend IMP-related professional conferences, regional IMP conferences, and National IMP teacher leadership conferences.

Observing Teachers

Three ninth-grade teachers volunteered to be observed teaching lessons from the Game of Pig unit; two from suburban schools and the third in an urban setting. All three teachers were new to the IMP program.

First Observation
The first teacher, from one of the suburban schools, began the unit by working on a homework problem on expected value. In the problem, the students were to imagine that they had two pockets and that each pocket contained a penny, a nickel, and a dime. They were asked to determine the possible total values of two coins if they reached in and removed one coin from each pocket. The teacher devoted the first half of the lesson to having the students present their solutions to the homework problem. For the second half of the lesson, the teacher instructed students on how to use their graphing calculators and how to do a frequency bar graph on the graphing calculator.

While there was a mathematical segue between the homework problem and frequency bar graphs on the graphing calculator, the teacher made no attempt to tie the two together. For students, there was no apparent purpose to why she was teaching them how to use the graphing calculator to make frequency bar graphs. The teacher reviewed other questions from the homework assignment, but did not probe students further with extensions to determine if they understood the concepts. Nor did she tie the problems to previous activities. The teacher directed students toward the correct answer to the homework questions in a lockstep manner.

Second Observation
The second teacher observed was also from a suburban school. The students, who were lower in ability level than the first class observed, sat in rows facing the teacher. The lesson was also from the Game of Pig but was about a different homework problem on expected value. The teacher had written questions on the board and students came up to the board and filled in the answers. In going over the questions, the teacher played the major role, doing most of the talking while trying to get students to answer his questions using the "fill in the blank" format that he had set up on the board. The questioning was task-oriented, aimed at arriving at a product or a

result and not at developing students' conceptual understanding.

Third Observation
The final teacher observed was in an urban school. In this lesson students were working on expected value by playing the spinner game. In this game, Ann and Julio were playing a game with a spinner. Ann had 25% of the board and wins $4 from Julio each time the spinner stopped on her portion of the board. Julio had 75% of the board and wins $1 from Ann each time the spinner stops on his portion of the board. The students were asked determine who is more likely to be the winner of this game, and if Ann and Julio played 100 times who would be the expected winner. The students worked on the problem with the spinners for the entire period, and the teacher did not provide any sense-making help during the lesson. As in the previous lessons, the aim was to get the answer to the problem of Ann and Julio, not to get students to understand that probabilities can have weighted values that affect your decisions. In addition, there was no tie between this activity and related activities the students had previously experienced. In hindsight this gap was foreshadowed by the instructional purpose written on the board at the beginning of the day: "Learn how to play the spinners game."

In all three lessons observed, the teachers did not demonstrate that they understood the content or how the concepts in the lessons they were teaching fit into the overarching concepts of the unit. They tended to focus on the minutiae of each particular lesson and did not consider how the lessons fit into the bigger picture of the unit.

Learning from Teaching

Based on these observations and other informal observations and interviews, it seems that most teachers made a good faith effort to implement the curriculum as intended. By the end of their first year, many teachers made great strides in both content knowledge and pedagogy, but it can take five years or more for teachers to become truly comfortable and confident with the IMP program and skilled at managing a student-centered classroom. Future professional development efforts should take into account this development process and provide the necessary support for teachers as they acquire the knowledge and skills necessary to effectively implement a unit such as the Game of Pig. Specifically, professional development should:

- *Help teachers understand the mathematical purpose of the complete unit*
  New IMP teachers often have difficulty linking the individual parts of a day's

lesson into a coherent whole, and then linking the many daily lessons into a larger unit. Moreover, they don't see the relationship of the Game of Pig unit to other IMP units and how student understanding is progressively scaffolded in succeeding units. Teachers often become so preoccupied with simply getting through the day's lesson that they present it devoid of its original motivating purpose. As a result, lessons can degrade into mere exercises and miss the overarching educational goal.A companion problem for new teachers is to see how a particular concept is developed over time and related to other concepts within the unit. Teachers do not as yet have a "cognitive map" of either the flow of the unit or its content. As a result, they tend to teach each day's lesson in isolation without providing students opportunities for insight into the interconnections of activities and topics.

- *Help teachers use the available technologies in their lessons*
  Teachers must effectively and efficiently learn to use graphing calculators, manipulatives, chart paper, games, and the overhead projector within the Game of Pig unit.
- *Develop teachers' skills in effective group management*
  Some teachers rarely place their students in groups; others feel they must do so all the time. Thus, a challenge for teachers is to understand the purpose of student learning groups. They are meant to promote individual conceptual development and mathematical communication skills. The groups allow students to discuss their ideas while affording the teacher an opportunity for individualized, small group instruction. Like hands-on activities, student groups are not ends in themselves.
- *Develop teachers' skills in conducting effective classroom discussions and lead students' discovery*
  Another challenge for IMP teachers was to organize instruction around complex, open-ended questions. They must learn to pose questions that are not immediately answerable but that are open for discussion. The Game of Pig unit is essentially a 30-day, open-ended

question. Teachers are accustomed to posing a problem and immediately showing students how to solve it. Guiding students through a directed discovery approach requires new pedagogical skills, a deeper grasp of the course's mathematical content, a heightened sensitivity to the learner's state of mind, and increased patience.

F. Joseph Merlino is director and principal investigator of the Math Science Partnership of Greater Philadelphia, which is housed at LaSalle University.

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Improve Your Practice Using Lesson Study

In this article, teachers observed other teachers' lessons and helped them improve their practice. You can do the same. In this issue of *ENC Focus on Lesson Study*, learn about an innovative model of professional development where teachers connect with one another to focus their energy on student learning in the classroom. Articles in this issue describe the lesson study technique in which teachers observe colleagues and participate in peer to peer coaching. The collaboration challenges the status quo that teachers and their classrooms are islands--relatively unaware of events on other islands--with students floating in between. Lesson study legitimizes the work that teachers do in classrooms, giving teachers authority in making the instructional decisions necessary for their students.

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A Case Study: Professional Development Workshops for a Science Module

Schools using the Full Option Science System develop workshops and classroom observations to increase teachers' ability to convey balance and motion concepts to elementary school students.

by Ben Sayler, Black Hills State University

The Black Hills Science Teaching (BLAHST) Project serves 430 K-8 teachers from 10 school districts in western South Dakota. All participating districts have used FOSS (Full Option Science System) modules developed by the Lawrence Hall of Science to varying degrees. Project leaders include district representatives plus faculty members from two universities. The project has provided workshops on science content, the use of specific instructional materials, and topics such as the integration of science across disciplines. In addition to workshops, the project has facilitated site-based study groups and provided classroom coaching.

This case study describes professional development specifically geared to the teaching of one module, Balance and Motion, as well as observations and analysis of classroom teaching using the module.

The Balance and Motion Module

Balance and Motion is a first- and second-grade module. Ten activities require roughly fifteen 45-minute sessions. The teacher's guide describes the activities:

> *Students explore stable (balanced) and unstable systems, using*

> *counterweighting to change the center of mass of the system. They explore two classes of motion--spinning and rolling--first through trial and error, and later through systematic explorations. Students begin to develop a sense of variables, which they control to produce desired outcomes.*

Activities include: (1) balancing tagboard shapes on a narrow platform with the aid of clothespins; (2) balancing a pencil on its point using a flexible wire and a clothespin; (3) building a mobile using straws, paperclips, rubber bands, and index cards; (4) constructing and spinning tops; (5) rolling paper cups down a ramp; and (6) rolling marbles along plastic foam runways.

Project leaders anticipated that teachers would need practical experience assembling and manipulating the instructional materials, opportunities to discuss how the lessons work and build on one another, and time to consider the physical science concepts associated with the module.

Introductory Workshop

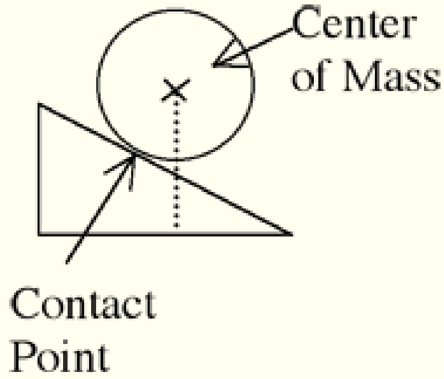
The professional development sequence began with a five-hour introductory workshop. The lead teacher was a full-time classroom teacher who had taught the module many times. The lead scientist was a physical science professor with considerable experience in K-12 science education reform. Most of the teachers had never taught the module.

The structure of the workshop adhered closely to the structure of the module itself. Using materials directly from the kit, participants worked in pairs or groups of three to conduct each of the 10 activities. Following each activity, the lead teacher led a discussion of the lesson and how it typically plays out with students. She also discussed books that tie in well with the unit and related favorite extensions.

The lead scientist helped participants think about connections between lessons and fielded participants' content questions. Content interjections were intentionally brief (perhaps 30-45 minutes total spread throughout the day). Their purpose was to challenge participants, particularly those who had taught the module before and were ready to think more deeply about the science. The interjections were also intended to whet participants' appetites for content-focused workshops that the project was offering.

Discussions of content helped

participants understand the conceptual flow of the module. Why, for example, are the topics of balance and motion combined into a single unit? One answer is evident in the following example: If a ball's center of mass lies directly above its point of contact with a surface, the ball will remain stationary; if not (as depicted), the ball will roll. This connection is not addressed in the teacher's manual (and it is developmentally inappropriate for first and second graders) but may help teachers appreciate the logic and flow of the complete module.



The lead scientist also guided a discussion of how the module aligns with state standards. The unit directly addressed many of South Dakota's nature of science and physical science standards at grades 1 and 2, and with some creativity, it was possible to connect with some less obvious ones as well. Because many project teachers expressed concern about being able to cover all of the standards using kits (and in the time available), the project took every opportunity to share ideas for maximizing coverage of standards using the kits.

Classroom Follow-Up

The project manager for BLAHST, a veteran K-8 science teacher, offered classroom coaching and taught model lessons (in some cases a series of lessons).

Level 2 Workshop

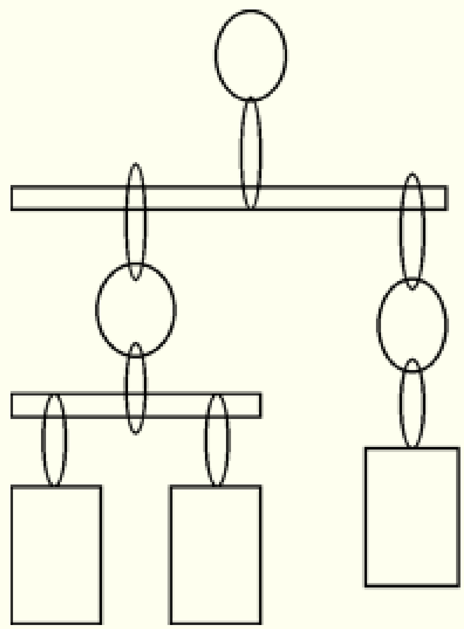
During the summer following the workshop, the project offered a level 2 workshop that targeted teachers who had taught the module at least once. Participants met with the project manager and a lead scientist to examine the concepts within the module in greater depth, to become more familiar with assessment tools, and to discuss cross-disciplinary connections. The workshop was an additional five hours of professional development.

Observing Teachers

Three teachers who had participated in a workshop volunteered to be observed teaching part of the module. The teachers worked in different settings: a country school with six students in grades 1 to 4; a traditional first grade; and a grades 1 and 2 split. Two of the three teachers had served as lead teachers for a Balance and Motion workshop. In all three cases, lessons came from the "balance" portion of the module.

Traditional First Grade --Teacher Leader

The primary activity in this lesson was building a mobile using straws, paperclips, rubber bands, and index cards. The lesson started with all 16 students sitting on the floor while the teacher led a discussion of previous activities from the unit (e.g., the balancing pencil). She asked volunteers to demonstrate the activities and describe their discoveries. The teacher then introduced the mobile activity by holding up a sample. She unbalanced the mobile twice and asked for suggestions about how to fix it. Students offered suggestions, and the teacher made the adjustments.



Students then returned to their desks, each with a small bag of supplies and a photocopy of the mobile design, and set to work. The teacher and the observing project representative assisted students having trouble. After completing the assembly, students were encouraged to decorate their mobiles with seasonal designs. For most, the decorating took at least as long as the assembly.

The teacher followed the instructions for the lesson quite closely. She demonstrated an understanding of the underlying content and did a particularly nice job of reviewing previous activities. She was somewhat less successful, however, at drawing out connections between the activities. Also, the teacher may have shortcut students' discovery of how to get their mobiles to balance. In essence, once students were set to work with their own materials, their task was merely to verify a known result, lessening the extent to which they grappled with the underlying concept of balance.

Mixed Grade Class--First, Second, and Fourth Grade

This class of six students in a small country school also did the mobile activity. After prompting the students to recall previous lessons, the teacher explained the mobile task, displayed a sample, and paired the students. Though paired, students worked independently in a race to finish first. The teacher aided those having trouble, and as each student finished, the teacher asked, "Is your mobile stable?" Each student responded affirmatively and demonstrated the stability with the tap of a finger. The teacher seemed to miss an opportunity to challenge students to make their systems balance in more than one way. This may have been an indication of the teacher's own lack of understanding of the concepts involved in the activity.

During the mobile instruction, a few students had trouble attaching paperclips to the straws. This was the teacher's first time teaching the lesson, and she did not realize until near the end of class why students were having these problems. The older students had balanced their mobiles within about ten minutes, and the teacher asked them to work on another assignment, rather than helping them to extend the intellectual content of the lesson.

First Grade / Second Grade Split--Teacher Leader

This observation took place on the first day of the Balance and Motion module for this mixed-grades class of 16 students. The second graders had done the same module the previous year with the same teacher, but when given the option, they chose overwhelmingly to repeat the activities with the first graders. The teacher told the second graders not to spoil the discovery for the first graders and arranged the room so that the grades sat at different tables. The teacher allocated 90 minutes for science on the day of the observation, and the students did three lessons (balancing a tagboard crayfish, determining if various configurations of shapes and clothespins would balance, and balancing a pencil on its tip). A teacher's aide was present during the lesson, and both the aide and the teacher demonstrated strong understanding of the content.

The teacher asked a number of high-quality questions during the lesson. For example, when students were determining whether or not the various configurations would balance, the teacher prompted the class to look at all of the systems they said balanced and asked, "Where are the weights?" She asked the same question about configurations that did not balance. These two questions guided students toward a general rule about systems that balance. The teacher also monitored the work closely looking for discrepancies between groups. Each time she discovered one, all students were asked to recreate that configuration and arrive at a consensus. While the teacher did not provide a conceptual wrap-up after the last activity, she did tie all of the activities to the overarching concept of stability.

Lessons Learned

In the five-hour introductory workshop, the teachers could experience most of the student activities, gain some practical tips, and deepen their understanding of the underlying scientific concepts. From there (and relying heavily on the manual), teachers could teach the module at least at a mechanical level. This was evident in all three of the observations. The two veteran teachers were quite adept with the materials, while the new teacher had some difficulty with the mechanics of the mobile construction. Additional skill would likely come with repeated teaching of the module, with classroom coaching, and in discussing the module with peers.

The extent to which the observed teachers demonstrated their understanding of the content of a single lesson and how that content fit into the larger unit varied. The teachers of the mobile lessons reviewed the previous activities and concepts with their students but did not emphasize relationships between the activities. In the third observation, the larger concept of stability was discussed, but it was done in the context of each individual activity rather than across the activities. The use of questions to engage students with the concepts also varied. In two of the three observations, there was little questioning that would prompt students to think deeply during the activities. All three lessons lacked a strong wrap-up.

How teachers understand the content in the unit, how a lesson fits conceptually into the unit, and how this understanding is translated into practice represent important issues in the professional development of teachers, especially at the primary grades. In this FOSS module, the emphasis is on providing rich experiences, rather than teaching concepts explicitly. Teachers need to understand this distinction, but they must also recognize that a lesson can be implemented in a manner that maximizes emphasis on the central concepts (e.g., asking "what would happen if" questions when balancing objects, asking about similarities and differences between different activities within the unit, discussing observations both during an activity and at the end). This level of implementation requires a teacher to understand the unit and its content just as deeply as teachers in higher grades who are charged with addressing the same concepts more explicitly. This level of implementation also requires development of highly refined pedagogical skills.

It was clear to project leaders that teachers needed additional content development beyond a five-hour introductory, kit-based workshop. Having someone with a strong grasp of the content (e.g., a scientist) participate in an introductory workshop was a useful start. The contributions of the scientist were particularly valuable for those participants who were ready to think deeply about the science concepts embedded in the module. At the same time, it is essential that the participating scientist be well acquainted with the module and be highly attuned to the level of the audience. Ancillary benefits of having a scientist participate in an introductory workshop are that it provides an opportunity for the scientist to glean topics for future content-focused workshops as well as to gain a richer appreciation of issues related to the teaching and learning of science.

In addition to needing a deeper understanding of the content, most teachers would also benefit from further development of pedagogical skills related to a particular unit. It would be valuable, for example, to discuss specific questions that teachers could ask their students to focus attention on the central concepts. It would also be valuable to place more emphasis on characteristics of an effective launch, on connecting one lesson to another, and on wrapping up. Lead teachers and scientists need to model these components themselves and discuss explicitly their importance within a learning cycle. This would be a valuable departure point for future lesson studies as well.

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