

Interventions that Involved STEM Disciplinary Faculty in Deepening Teachers' Science Content Knowledge

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The Summer Institute

During the summer of 1999, 22 middle and secondary teachers participated in the integrated science and mathematics institute. Of these 22, 10 had previously participated in an integrated science and mathematics program at WSU. The teacher participants had diverse backgrounds ranging from 2 to 35 years of teaching experience and from no professional development experience to master's degrees. Additionally, the areas in which the teachers specialized were quite different: four special education teachers, four mathematics and four science high school teachers, and 11 middle school teachers. The three districts involved were a large urban district, a suburban district, and a smaller urban and rural mixture. Student populations ranged from 75% African American students to 85% Caucasian students. These districts were chosen because they are local to the university, and WSU's preservice teachers are often placed with these districts for field experiences.

The summer institute was intensive with 72 contact hours of class over a 4-week time period, meeting 8 hours a day for 3 days a week. We immersed the teachers in inquiry-based learning environments, in which they worked on integrated science and mathematics units in cooperative groups of three or four. The general structure of the institute involved teachers spending two thirds of each day working on content units and the remainder of the day considering pedagogical issues and developing such units for use in their own classrooms.

Two different cooperative groupings were used. For the science and mathematics investigations, teachers were grouped heterogeneously with the requirements that the teachers in the group could not all teach the same grade level, or be in the same district, or teach the same subjects. For the development of units, cooperative groups were formed by same, or similar, grade-level teachers, since these teachers shared similar curricula and were often from the same district. Including both elementary and secondary science and mathematics teachers within the same groups for content investigations effectively expanded the resources and expertise available to groups in both content and pedagogical knowledge. Rich discussions resulted from these heterogeneous groups, often involving topics of vertical curriculum alignment and effective pedagogical strategies. Heterogeneous grouping typically developed mutual respect and cooperation among the different grade level and topic teachers.

To best model standards-based integrated science and mathematics teaching practices, we team-taught the institutes. In this way, teachers experienced teaching from both the science and mathematics perspectives and gained pedagogical knowledge of both disciplines. Master's degree program students who were also secondary science and mathematics teachers helped facilitate the institutes. These "resource" teachers provided real classroom connections that aided participants in transferring the institute experiences to the precollege classroom.

Due to the diverse backgrounds, teaching assignments, and teaching environments of the teachers, the content of the institute was matched to grade 4-12 strands of the science and mathematics standards, with topics chosen for their importance and integration aspects. Content investigations started with the most fundamental concepts, usually encountered in the earlier grades, and built up to

the concepts and applications of the upper grades. Even though the content was consistent with grades 4-12 standards, the teacher participants analyzed the content at an adult level in order to develop the conceptual understanding necessary to teach effectively.

We used a combination of commercial curricula and curricula we designed. Commercial resources included *Mathematical Modeling in Our World* (The Consortium for Mathematics and Its Applications, 1998a) and physics education materials (Arons, 1997; McDermott, 1996). The integrated science and mathematics units we designed ourselves were adapted from preservice teacher course activities (Basista, 1998a, 1998b). When designing the units, we took great care to maintain conceptual development for both disciplines. Indeed, we chose many of the specific science and mathematics topics not only for their importance in the teachers' curricula, but also because the topics lent themselves to a high degree of integration. In every case, we made no assumptions about the backgrounds of the teachers. Each unit started with the most fundamental concepts and built teacher understanding from that basis. Since 1997, we have utilized units such as motion and graphing; shadows and proportional reasoning; and simple machines and proportional reasoning. Refer to Table 1 for the topics covered in 1999.

The integrated science and mathematics units were of a guided discovery format, with facilitator checkpoints included after conceptually connected sections. At the checkpoints, we utilized questioning techniques not only to deepen the teachers' understanding, but also to model effective questioning strategies. At these checkpoints, we often discussed pedagogical issues related to teaching the material in grades 4-1 2 classrooms. We assigned daily homework over the sections completed to help solidify the teachers' understandings of the content and to provide further examples of applications of the concepts.

The pedagogical issues addressed during the institutes related directly to the standards, their implementation, and assessment. These topics included comparisons between inquiry and traditional environments, assessing students' prior understandings, methods of modifying and/or developing inquiry-based activities, cooperative learning techniques, development of in-depth conceptual understanding, development of problem-solving skills, integration of science and mathematics, reflection on one's teaching, and authentic assessment techniques. For a sample of pedagogical content covered in the summer institute, see Table 1.

About halfway through the institute, the class was divided into groups of teachers who taught similar grade levels so that they could develop integrated science and mathematics units for use in their classrooms. At this point, the teachers began to apply the science, mathematics, and pedagogical content knowledge they had acquired during the institute to their own classrooms. During the final two days of the institute, the teachers team-taught lessons from their developed units for the class and received peer and instructor feedback.

Academic Year Support Activities

We visited the teachers' classrooms three times during the academic year to observe them, to model teaching methods, and to provide feedback about their teaching practices. During the academic year, the teachers attended three workshops, in which they shared the results of their efforts. During the workshops, pedagogical issues and district issues were frequently discussed. We encouraged teachers to maintain contact with us through phone and email.

Throughout the academic year, the teachers built portfolios documenting their efforts in modifying their teaching practices. These portfolios included lessons they had taught in their classroom, together with reflections, student feedback, and results. Teachers documented their efforts in implementing inquiry and cooperative teaching practices, developing their students' in-depth content understanding and problem-solving skills, and utilizing forms of authentic assessment.

Table 1
Summer 1999 Topics

Science Content	Mathematical Content	Pedagogical Content
Shadows	Proportional reasoning	Science and mathematics standards
Measuring heights and distances	Geometry	Inquiry
Levers	Multiple representations (graphs, diagrams, symbols)	Integration of science with mathematics
Hooke's Law	Logistics modeling	Developing problem solving skills
Population growth	Modeling vs. problem-solving	Authentic/alternative assessment
Population growth	Exponential growth	Cooperative learning
		Modifying and developing inquiry lessons
		Questioning techniques
		Reflective teaching practices
		Facilitating inquiry lessons

Excerpted from Irving, M. M., Dickson, L. A., Jr., & Keyser, J. (1999). Retraining public secondary science teachers by upgrading their content knowledge and pedagogical skills. *Journal of Negro Education*, 68(3), 409–418.

To break the didactic teaching-learning-teaching cycle, a professional development collaboration is needed between government education professionals; university-based schools, colleges, and departments of education (SCDEs); and public school systems that emphasize the importance of merging content knowledge with constructivist teaching practices (Stofflett & Stoddart, 1994). With funding from the National Science Foundation, the School of Education and the Department of Biology of an urban, historically Black university joined with a large, diverse public school system (encompassing urban, suburban, and rural areas) in such a collaboration. University faculty and public school educators assumed leadership roles in designing unique professional development courses for secondary school science teachers. The resulting courses were established to upgrade the targeted teachers' content knowledge, skills, and instructional strategies, and focused on blending content with constructivist teaching strategies.

The university and school district collaborators developed four graduate-level courses for secondary school science teachers whose undergraduate areas of concentration were in either biology, chemistry, or physics. Each course, which required 45 contact hours and provided three graduate credits, utilized the following approaches:

- (1) interactive lectures and laboratory experiences to update and enhance teachers' science content knowledge;
- (2) exercises that expanded teachers' pedagogical knowledge by showing them how to implement alternative teaching and assessment strategies addressing the needs of diverse student populations; and
- (3) demonstrations that guided teachers to synthesize content information and laboratory experiments into teaching activities that are consistent with state performance guidelines and the participating school district's constructivist model for teaching science.

Classes met over eight weekends during the fall and spring semester at the participating university and for two weeks (six-and-a-half hours per day) during two summer semesters. Classes were held at the participating school district's science resource center.

The four professional development courses focused on strategies for incorporating the school district's constructivist model and cooperative learning approaches into science instruction. This model, called the "5 E's," utilizes an inquiry-based approach that provides students with concrete learning experiences and a starting point from which to construct science concepts. In this model, learning is viewed as an active rather than a passive process. Teachers are encouraged to become facilitators of learning in their classrooms and to guide students to find their own answers within their own experiences so that the knowledge they acquire becomes meaningful to their lives.

The professional development courses designed for the science teachers provided opportunities for the modeling of constructivist approaches and other alternative teaching and assessment strategies to encourage teachers to transfer science skills, materials, and activities to the classroom. A School of Education professor presented the instruction on pedagogical strategies, and a Department of Biology professor presented the content-specific instruction. A science specialist from the school district's science resource center assisted with the laboratories and

facilitated collegial sharing among the course participants. Each of the instructors created an environment wherein participants were allowed the time and the resources they needed to learn, share, and reflect on an array of activities, materials, and strategies that enhanced both teaching and student achievement.

For the most part, the teachers worked in groups; however, they were required to write three individual lesson plans based on the 5 E's model of conveying content knowledge through pedagogical instruction. Many of the other written assignments included group oral presentations, and the teachers were encouraged to work collaboratively on a group lesson focusing on content application as well as on the laboratory experiments. These collaborative inquiries provided them with opportunities to share ideas and expand their knowledge of science content and pedagogy. Additionally, collaborative brainstorming and the use of concept maps helped them to acquire content and pedagogical knowledge from each other.

The sample was comprised of 63 secondary school science teachers (40 female and 23 male) from the participating school district who enrolled in one or more of the four courses. The district paid their tuition and provided them with stipends. Of the total, 73% were African American and 27% were European American. The participants entered the program with varying certification statuses for teaching science: 21% held provisional certification, 21% held standard certification, and 58% held advanced professional certification. Their teaching experience ranged from less than 1 year to 24 years. Forty-three percent had 5 or fewer years of experience, 7% had between 6 and 10 years, 29% had between 11 and 15 years, and 21% had 16 years or more experience.

Excerpted from Jones, E. E. (1997). Organization, implementation, and results of an Eisenhower systemic elementary science reform project. *Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science*, 1-11.

The project includes 72 teachers and 3 administrators who attended a three-week summer workshop organized into three separate grade level groups, K-1, 2-3, and 4-5, with an average of 25 participants in each group. Each grade level workshop included 15 days of formal instruction, laboratory and field experiences. Formal instruction (generally 9:00 a.m. to 12:00) covered physical, biological, and earth science concepts appropriate for the district's new science curriculum. During laboratory time (12:30 to 3:30 p.m.), participants worked in small groups with hands-on materials and learning centers to provide them with grade level activities that supported the adopted program. Laboratory time allowed teachers to carry out individual projects and undertake long-term activities and observations that would be used in their classrooms. Project workshops supported the revised curriculum and emphasized hands-on inquiry activities, selected science content, the integration of science with other subjects, and alternative hands-on assessment. Learning by inquiry included activities emphasizing a search for solutions rather than answers revealed directly by the teacher. Particular emphasis was placed on the processes of investigations. Teachers gained an operational knowledge of integrating investigative activities with mathematics, language arts, fiction and non-fiction trade books.

Summer workshops were led by classroom teacher-leaders who worked with the same group for the entire three weeks and for the follow-up Saturday seminars. The teacher-leaders have had extensive success using investigative, hands-on approaches to science instruction and have previous experience instructing hands-on science projects for MU. They provided stability and methodology, working with teachers of their own grade level expertise. One of the professors is a botany professor providing expertise in biological science. The other is a professor of science education providing expertise in the physical sciences and science education. The two professors rotated from one grade level group to another, spending time with each as their subject matter area is scheduled.

A workshop follow-up includes inservice activities and classroom visits by the director and curriculum coordinator to assure the appropriate implementation of workshop activities and methods. Participants are observed teaching hands-on science in their classrooms, and they receive oral and written feedback. Observers offer suggestions on teaching methods, science content, materials management, learning centers, and displays. Three six-hour follow-up seminars are conducted during the 1996 fall semester by the project staff. These include instruction in science content and methodology, sharing ideas and experiences, and planning and conducting inservice activities. Workshops, seminars, inservice activities, and classroom observations are integrated for continuity.

Inservice activities enable participants to share ideas and experiences with teachers who did not participate in the project by presenting at least two inservice programs each. Possible formats include regularly assisting another teacher in the building for one full semester; grade-level inservice for building or district; and inservice for buildings other than those of the participants.

The district hosted a half-day science inservice for K-5 teachers, Friday, Nov. 1, 1996. All K-5 teachers in the district and in selected Archdiocese schools were released to attend.

Each applicant's principal must confirm instructional competence and assure that the teachers are provided with the necessary hands-on materials. Selection criteria included appropriate certification, grade level, history of honors, service to district committees, and demonstrated efforts for self-improvement.

Teachers without previous experience with hands-on workshop opportunities but are eager to employ this approach in their classrooms were considered prime candidates. A special emphasis was placed on recruiting teachers from underrepresented and underserved groups and on teachers in schools with higher poverty level enrollments. Applicants from the same school who applied as a team were also given extra consideration in order to establish cooperative teams of teachers and administrators. An attempt was made to balance grade level representation.

Excerpted from Lord, T. R. & Peard, T. L. (1995). Scientist-teacher summer workshops can enhance constructivist views about science and science instruction. *Education*, 115(3), 445–447.

Twenty science teachers from high schools in Philadelphia were selected. Thirteen of the teachers were male and seven were female and the average length of service for the participants groups was 15 years. The teachers attended a three-week long summer institute at a mid-size university in Pennsylvania. Each participant was given their room and board, materials, and a stipend. The teachers followed a rigorous agenda each day. Mornings and afternoons were spent with practicing scientists in the physical, biological and geological disciplines. Activities were primarily hands-on in nature and field work was often included. Several of the scientists actually involved the participants in their research. As the teachers saw how scientists examined problems, they were encouraged to consider what implications this had on their teaching. Examples were provided to demonstrate how a systematic approach involving experimentation and discussion could guide students through the process skills of hypothesis generation, experimental design, and communication of results. For example, the geologist in the project took the teachers to a huge boulder near campus which had been sheered in two by natural forces. Breaking the teachers into small teams, he asked how such a clear division could have occurred. Smaller rocks sheered in a similar manner were brought back to the lab for microscopic examination. Following this the teams gathered for a class discussion of their hypotheses. Through such inquiry the groups determined the history and identity of the sample.

After dinner, the teachers met with science education faculty to discuss pedagogical and practical applications of what they had learned during the day. Efforts were made during these sessions to explore how the content of science might be delivered to their students while, at the same time, emphasizing the reality of science as a way of knowing, thinking, and investigating.

The primary emphasis of the workshop was on the process of science and the constructivist approach to teaching. The various experiences promoted understanding of the nature of the scientific enterprise and prompted considerations of ways to translate this understanding into instruction. Furthermore, group work focused on how strategies the teachers currently used could be modified to include practicing critical thinking skills. Teachers were stimulated to think about teaching science as a process of discovery and not a collection of terms and facts to be supported only by deductive laboratory experiences.

Excerpted from Odom, A. L. (2001). Inquiry-based field studies involving teacher-scientist collaboration. *Science Educator*, 10(1), 28–37.

The project was initially based on the 21 Questions to Conclusions model for teacher enhancement (Calabi, 1997). The 21 Questions to Conclusions model was selected because it was reported to be an effective way to team teachers and scientists in research, and it was consistent with the pedagogy and content stipulated by the Missouri Show-Me Standards (Missouri Department of Elementary and Secondary Education, 1996) and National Science Education Standards (NRC, 1996) as requested by the urban school district.

Prior to seeking Eisenhower funding, university professors and school district teachers and administrators were provided training on 21 Questions to Conclusions by Dr. P. Calabi, who developed the model. Continued communication between university and school district personnel resulted in numerous planning meetings, from which we developed a basic framework for a professional development program that teamed teachers and scientists.

The project was designed to help teachers develop a better understanding of scientific inquiry. Reflection on how these skills could be integrated in the classroom was not formally addressed, although informal discussions occurred throughout the project. The primary goal was to establish productive, collaborative relationships between teachers and scientists and give teachers the opportunity to ask authentic scientific research questions of scientists. This goal was subsumed by the following objectives: to model the skills of asking and answering research questions; to encourage teachers to ask questions and to formulate hypotheses; to increase teachers' self confidence in doing scientific research; to make instruction more student-centered; to model and encourage analytical thinking in science or any subject; and to awaken learner curiosity. In addition, we planned to include the following content and pedagogical skills but maintained open lines of communication about content to enable teachers "...to have a significant voice in decisions about content..." as stipulated by National Science Education Standards Teaching Standard E (NRC: 1996, page 46).

Subject Content:

1. Science as Inquiry
 - a. Identify questions and concepts that guide scientific investigation.
 - b. Design and conduct scientific investigations.
 - c. Use technology and mathematics to improve investigations.
 - d. Formulate and revise scientific explanations and models, using logic and evidence.
 - e. Recognize and analyze alternative explanations and models.
 - f. Communicate and defend a scientific argument.
2. Characteristics and interactions of living organisms.
3. Changes in ecosystems and interactions of organisms with their environments.
4. Processes (such as water cycle, airflow) and interactions of earth's biosphere, atmosphere, lithosphere and hydrosphere.
5. Impact of science, technology and human activity on resources and the environment.

Pedagogy Skills:

1. Model the planning of an inquiry based science program for their students.
2. Guide teachers in active and extended scientific inquiry.
3. Design and manage learning environments that provide teachers with time, space, and resources needed for scientific inquiry.
4. Model the intellectual rigor and standards of evidence of scientific processes.

Twenty-one Questions-to-Conclusions was used to introduce teachers and scientists to approach scientific research in simplistic terms. It provided a platform to develop a scientific research project (Calabi, 1997). This method contained four steps: asking questions discussing the questions, utilizing “triage,” and developing a research project. The process was led by a facilitator assigned to the research site.

The first step, asking questions, introduced the study area by helping participants focus on the details of the field site. Study sites selected were: a woodland, a grassland, a creek, and an urban site in a field adjacent to a local high school. Participants were asked list questions until they had reached 21 in total or the time limit had been reached (30 minutes). During this stage, the participants immersed themselves in the assigned area. They were asked to work alone while keeping in sight of another person, and write down the first 21 questions that came to mind. Once they were finished with 21 questions, or the time limit had been reached, participants came back into a group.

During step two the participants’ questions were discussed. They were requested to choose one question for which they were really interested in knowing the answer; this was called a “burning question.” Other questions were prioritized during this process, in case two people had the same “burning question.” Then, facilitators and participants were arranged in a circle, and participants shared their questions. Facilitators led a discussion of the questions by asking additional questions such as, “How would you go about studying this question?” and “What do you think is going on with the phenomenon?”

Step three, the “triage” portion of this technique, was to used re-evaluate the questions as possible research questions. Each “burning question” was written on a portable tablet carried into the field for all to see and discuss. Each topic was dissected into sections: what is the question, how would you answer the question, and what methods would you use? During this stage, questions were focused and clarified.

Step four, developing the research project, involved choosing a question. The participants decided which question they wished to pursue during a specified timeframe. They worked in groups limited to four members, to plan and conduct their respective research projects with the aid of a facilitator.

The project had three specific phases, designed to facilitate development of specific skills and knowledge. Phase 1 involved introduction to field research sites using 21 Questions to Conclusions and introduction to research methodology with a facilitator. Phase 2 focused the development of scientific processes through field study, data collection, and communication of

research findings with 3-day research projects, culminating in a poster session of findings. Phase 3 involved an extensive long-term field based research project by teacher-scientist teams, culminating in a poster session which university and school district faculty and administration were invited to attend.

Phases 1 and 2 occurred during a two-week summer institute in June 1998, for a total of 80 contact hours. During phase 3, teacher-scientist teams conducted long-term research for a total of 80 hours of independent study, including 4 follow-up meetings during Fall 1998 and Winter 1999. In addition, teachers attended a half-day preliminary meeting May 1998, to provide an overview of the project, and discuss equipment, procedures, and safety concerns of scientific field-work.

Most of the research activities were focused at J.A. Reed Wildlife area; a 2500+ acre site located a half-hour drive from the university campus. The project specifically included some work in an urban setting close to campus, to demonstrate that scientific research was not the exclusive domain of exotic wilderness settings, but worthwhile field projects can be done in any setting.

During the first four days of the summer institute, teachers were introduced to the four different study areas. Teams of teachers rotated among the four study areas each day and were introduced to field based research by facilitators, using the Twenty-one Questions to Conclusions model. The facilitators were 2 high school teachers who had completed a similar program. During the four one-day mini-projects, teachers asked questions, selected questions of interest for research, designed experiments to answer questions, collected data, and drew conclusions. At the end of each day all of the teacher teams returned to a central location to share research findings.

On the fifth day of the summer institute, teacher teams began three-day research projects, which were self-designed research projects culminating in a formal poster session. A half-day was spent on campus in the computer lab organizing research and constructing posters. At the poster session, scientists were introduced to the teacher teams. Subsequently, each of the scientists made a formal presentation of his/her personal research efforts. Informal discussions followed the presentations, serving as a mechanism for teachers and scientists to discover common interests that led to the formation of teacher-scientist research teams. Teacher-scientist teams then jointly designed long-term research projects, with teachers taking the lead and participating scientists providing guidance. The remaining two days of the summer institute were used to identify and chose research questions for the long-term research projects, plan how the 80 hours of independent study would be used to conduct the research, and begin data collection.

Phase 3 began after the summer institute was completed. Some teacher-scientist teams immediately took advantage and conducted much of their research during the summer. Other teams had previous commitments and did not begin long-term research projects until the fall. During the fall and winter, teacher-scientist teams attended three half day and 1 full day follow-up meetings. Teams provided progress reports; continued planning; shared ideas and techniques; trouble-shot problems, and began working on posters. The final follow-up meeting was used to complete and present research in a poster session which university and school district faculty and administration were invited to attend.

Excerpted from Radford, D. L. (1998). Transferring theory into practice: A model for professional development for science education reform. *Journal of Research in Science Teaching*, 35(10), 73-88.

The Project LIFE program had four major components: a 3-week summer course; an independent science research project; academic year follow-up through workshops, classroom visits, and newsletters; and a leadership institute during the second summer for selected program participants.

Teachers were recruited through brochures sent to the science supervisors in each school system in the target area and through presentations at the annual science teachers state conference. Interested teachers applied for 1 of the 30 positions funded annually. The initial target population was life-science teachers in northern Louisiana with a focus on middle-grades teachers. The participants included 34% upper elementary, 55% middle grades, 3% high school, and 8% teachers of multiple grades. Thirty teachers participated in the project each year, for a total of 90 participants. The sample was 88% female, 12% male; 79% white, 21% black. The years of teaching experience ranged from 1 to 29 years, with a mean of 10.7 years.

The 3-week summer course was an intensive team-taught program focusing on integrating concepts from life/environmental science, chemistry, and mathematics. The science concepts and skills taught in the course are listed in Table 1. The course was conducted in a university lab classroom. Field activities were conducted at a nearby park having a variety of habitats including a lake. The instructional team consisted of a biologist, a chemist, a science educator, and an exemplary middle-grades teacher who served as the project site coordinator. All four were in the classroom or at the study site throughout the course. The learning environment was highly interactive and supportive of hands-on/minds-on learning. During investigative activities the instructors circulated continually among groups of teachers modeling the role of the teacher as facilitator. They asked probing questions that encouraged participants to problem solve and to pose and test possible solutions for their own questions. The team-teaching approach allowed project staff to closely monitor participant discussions and understanding of the science concepts being taught, thus providing better formative assessment and evaluation of the program. The project staff met daily following the class to discuss their observations and adjust the program to meet the needs of the participants.

Participants engaged in learning science and science process skills by experiencing the techniques they were being asked to use with their students. Problem-centered learning (Wheatley, 1991) was frequently used during the course. Course instructors described a situation that naturally generated a question that needed to be answered. The participants were then provided basic materials and asked to work in small groups to answer the question. The questions were crafted so that explorations led to more than one possible interpretation. Within their small group, participants explored, discussed, and explained their interpretations to each other and continued their explorations until they reached a solution that was supported by all group members. The groups then presented their data and the interpretation of those data to the class. This often led to further explorations on the part of the small groups as they attempted to validate their own or others' conclusions.

The small-group work situations were highly structured models of cooperative learning. Participants worked in one of two types of cooperative learning groups throughout the course. One type of cooperative grouping was based on the Johnson and Johnson model (Johnson & Johnson, 1987) in which groups of four students worked cooperatively to accomplish a task, with each student having a specific job and each student having individual responsibility for the learning of all group members. Participants were assigned to a cooperative group for 1 week, rotating into a new group at the end of each week. Groups were designed to be heterogeneous with respect to gender, ethnicity, years of teaching experience, science background, grade level taught, and experience with reform-based teaching strategies. Job assignments were rotated with each activity. Specific activities throughout the course used a second model of cooperative learning, the jigsaw model (Slavin, 1980), in which members of the home group moved to expert groups to develop expertise in a particular area. The experts then returned to their home group and were responsible for sharing their knowledge with other group members.

Alternative, authentic assessment was integrated with instruction throughout the course. Participants experienced multiple assessment techniques as project staff modeled the use of card sorts, concept maps, projects, learning logs, journals, higher-level questioning techniques, gallery walks, and performance assessments to monitor participant understanding. The use of science demonstrations to assess conceptual understanding is a technique developed by project staff that was used throughout the program (Radford, Ramsey, & Deese, 1995).

Functioning as scientists and writing about science were integral parts of the summer course. Throughout the course, teachers acted as scientists as they were immersed in hypothesizing, designing experiments, and collecting, recording, and analyzing data. Each participant recorded daily observations of ongoing experiments in a learning log that was reviewed each evening by project staff. The logs provided the staff opportunities to pose probing written questions to individual teachers that stimulated them to think more deeply about their observations as they provided a written response. The learning log also included teachers' responses to questions that asked them to apply their learning in a new situation or to make connections among science concepts through concept mapping, diagrammatic representations, graphing, or other graphic organizers.

The participants' affective domain was addressed through journals that were reviewed and responded to each day by the instructor who is a middle-grades teacher. The journals provided participants a mechanism for reflecting on the program, its impact, and the changes in their own attitudes toward science and science teaching. The other members of the project staff were provided copies of journal comments each day after all personal identifiers had been removed. This allowed the staff to monitor and adjust the program on a daily basis to meet the needs of the participants.

Throughout the course, participants were asked to reflect on what they were experiencing and to consider how they might integrate the pedagogical techniques and the hands-on, minds-on activities into their teaching. Upon completion of each activity or investigation, participants completed a science activity sheet that summarized the activity and included a place for participants to enter how they might use the activity in their classrooms. Participants discussed how they might modify the presented activity to meet the needs of their students and to suit their

specific teaching situation. Discussions of classroom applications were often led by the middle-grades teacher instructor who drew upon her extensive classroom experience with this type of teaching. Participants brainstormed creative solutions to problems of space, appropriate facilities, and time. Tips on classroom management, assertive discipline, and working with parents were provided by the science educator and teacher instructor.

The curricular materials used during the summer course and at follow-up workshops were adapted from many nationally known programs such as GEMS, AIMS, OBIS, SEPUP, Bottle Biology, and Wisconsin Fast Plants™. Participants also received training in Project WILD and Project Learning Tree. Specific science concepts (Table 1) were taught using a spiral approach in which the concepts were revisited several times during the course. An outline of the activities in a typical day of the course is presented in Table 2.

The curriculum was not designed to be a comprehensive curriculum for all of the science that the participants teach to their students. The essence of the project was allowing teachers to experience the reform teaching methods and work as scientists while learning some science concepts. These methods are adaptable to any science curriculum. When they returned to their classrooms, the participating teachers integrated many of the course activities into their current curriculum, and as they became more experienced with reform-based teaching strategies, they applied those strategies to other areas of their science teaching (McGee-Brown, 1995b, pp. 13-15).

During the 4 weeks following the summer course, participants designed and conducted an independent science investigation. Investigations were designed by the teachers to be appropriate models for their students and feasible given the time and resources available. Examples of topics selected for investigation included water quality in local streams, effects of nicotine on guppy behavior, salt pollution, environmental preferences of sow bugs, regional differences in owl diet as revealed by owl pellets, and the effect of acid rain on plants. At the end of the 4 weeks, the results of the investigations were presented at a science expo. Administrators, other teachers, and the public were invited to attend. Handouts that described their investigation were produced by each participant and made available to all who attended the expo. Many participants also presented the science investigations at the state science teachers association annual conference.

Immediately before the start of the school year, participants attended a reflective reunion at which they reflected on their experiences in the course and presented a yearlong plan for integrating the teaching methodologies, science investigations and activities, and alternative assessment methods that they had learned in the project into their current curriculum.

Academic year instructional support consisted of 5 day-long workshops, attendance at the state science teachers conference, multiple visits to each participants' classroom by the project site coordinator, and regular project newsletters.