There are ongoing discussions about the best way to teach science to young children during the preschool and early elementary school years. What practice is most likely to contribute to children's development and learning while cultivating exploration, questioning skills, and revision of thinking to accommodate new ideas in science? The Head Start on Science and Communication (HSSC) Program is based on collaborative research from the fields of science education and language development. Program objectives have been aligned with the curriculum and are based on the national science standards for young children. The HSSC Program evolved over four years of research and implementation at schools in Pennsylvania, New Jersey, and Washington, DC. The initial phase of the program included input from parents, teachers, and teaching assistants to help develop lessons and shape the inquiry-based strategies for young children learning about life science, earth science, and physical science. The second phase of the program incorporated curriculum materials and investigative experiments to promote inquiry-based, hands-on science as a vehicle for promoting young children's language development. Children learned to match, discriminate, categorize, sequence, and associate information as they worked with peers to understand science concepts, relate facts, and solve scientific problems. As a result of participating in the HSSC Program, teachers employed collaborative learning strategies, engaging in small-group problem-solving teams with verbal interactions among teachers and students. Outcomes also included positive changes in teachers' questioning strategies. Teachers became proficient in asking more open-ended questions at increasing levels of difficulty instead of basic factual and yes-no questions. Preliminary data from a study of 85 first-grade students who engaged in a series of 12 science experiments indicated that prior to the program, they answered an average of 58% of the factual-type questions correctly and 15% of the application-type questions correctly. After learning about topics such as earth surfaces, minerals, changing colors, seeds, and plants, these children answered the factual-type questions with 96% accuracy and the application-type questions with 92% accuracy, indicating a significant gain in knowledge beyond the $p < .05$ level for both types of questions. Students improved their knowledge of science concepts along with their ability to answer questions requiring higher-level cognitive skills. Teachers noted students' improved knowledge of science and enhanced language development.

Abstract

There are ongoing discussions about the best way to teach science to young children during the preschool and early elementary school years (Bell & Gilbert, 1996). What practices are most likely to contribute to children's development and learning is the question that parents, teachers, and the research communities want answered. We know that young children's thinking is expanded through their cognitive development as well as their personal experiences. Children must explore, ask questions, and revise their thinking to accommodate new ideas (Mundry & Loucks-Horsley, 1999). This article describes a model that fosters science learning through a systematic approach to understanding language at increasingly higher levels of abstraction by using questioning skills to elicit factual and application information. Language skills are supported with hands-on, visually engaging materials for learning about life science, earth science, and physical science during the primary grades. At the Mid-Atlantic Laboratory for Student Success headquartered at Temple University Center for Research in Human Development and Education, science educators and speech-language specialists have developed a science curriculum that promotes the content of and process for learning about science in contexts that young children can experience and understand.

Introduction

There are ongoing discussions about the best way to teach science to young children during the preschool and early elementary school years (Bell & Gilbert, 1996). What practices are most likely to contribute to children's development and learning is the question that parents, teachers, and the research communities want answered. We know that young children's thinking is expanded through their cognitive development as well as their personal experiences. Children must explore, ask questions, and revise their thinking to accommodate new ideas (Mundry & Loucks-Horsley, 1999). This article describes a model that fosters science learning through a systematic approach to understanding language at increasingly higher levels of abstraction by using questioning skills to elicit factual and application information. Language skills are supported with hands-on, visually engaging materials for learning about life science, earth science, and physical science during the primary grades. At the Mid-Atlantic Laboratory for Student Success headquartered at Temple University Center for Research in Human Development and Education, science educators and speech-language specialists have developed a science curriculum that promotes the content of and process for learning about science in contexts that young children can experience and understand.

Instructional Methods

Most early childhood programs incorporate both explicit teacher-led activities, in which the students follow the teacher's directives; and exploratory, teacher-facilitated activities, in which students guide instruction based on their interests and curiosity (Fradd & Lee, 1999). These two practices stem from different theories and philosophies of how young children learn and the role adults play in the learning process. Explicit curriculum models for preschool are based upon behavioral learning principles. This theory is linked to learning theories in which cognitive competence is assumed to be transmitted through the process of repetition and reinforcement (Stipek & Byler, 1997). The explicit models use a highly structured teaching approach for acquiring academic skills. The skills emphasized tend to be those assessed by general intelligence and achievement tests. Teachers may lead small groups of children in structured question-and-answer lessons and drills. Teachers also spend much time correcting errors to keep children from learning incorrect answers. Workbooks and paper/pencil-oriented activities are generally included in the learning process (Schweinheart & Weikart, 1997).

The other approach incorporates the exploratory model of learning and suggests that children construct their knowledge by confronting and solving problems through direct experience and use of manipulative objects (Stipek & Byler, 1997). The goal of the exploratory teaching model is to create an environment in which...
children may explore, learn, and develop when involved with naturally interesting materials and events. In such a setting, there are no structured responses. Rather, activities lend themselves to creativity and exploration (Stipek & Byer, 1997). In exploratory models, the teacher's role is to serve as a facilitator for the children by providing them with opportunities to engage in activities and interact with their peers. Teachers who are unfamiliar with the "facilitator role" may be uncomfortable and feel as if they are not teaching according to the curriculum.

Long-term and short-term studies have looked at the different outcomes of these two approaches toward early childhood education and their impact on cognitive and social-emotional development (Becker & Gersten, 1982; DeVries, 1991; Gersten, 1986; Schweinhart, 1997; Schweinhart & Weikart, 1997).

Some researchers believe the explicit-directed type of teaching is management driven. Cuban says, "The basic imperative of elementary schooling is 'to manage large numbers of students who are forced to attend school and absorb certain knowledge in an orderly fashion'" (as cited in Goldstein, 1997, p. 5). Cuban explains that this demand has led to the development of a curriculum approach that is linked directly to the challenge of managing children. Other researchers believe this type of curriculum is superior to exploratory, child-centered models, especially for children of low-income families. Deloit (1995) maintains that the explicit-directed type of curriculum values basic skills over creative thinking and is necessary because of the value society places on highly structured skills-oriented programs. Schweinhart and Weikart (1997) state that explicit, teacher-directed instruction may lead to a temporary improvement in academic performance at the cost of missed opportunities for long-term growth in personal and social behavior. They support the use of an exploratory, child-centered curriculum to further develop social responsibility and enhance interpersonal skills. Additional research reports that children in exploratory, child-centered programs display better language development and verbal skills (Dunn & Kontos, 1997).

Both approaches have value in educating young children. Some of the questions that have been asked include the following: Which is better for the teacher? Which is better for children in developing cognitive competence? and What curriculum models are best for enhancing the social-emotional development of young children? We know that students can benefit from both the explicit and exploratory approaches. "Instead of viewing these approaches as opposing camps, they could be conceptualized as complementary opportunities for teachers to move between perspectives" (Frad & Lee, 1999, p. 16).

One of the goals of this paper is to provide an example of an effective program for developing science knowledge and language skills with young children that incorporates both explicit, teacher-directed methods and exploratory, teacher-facilitated methods.

Head Start on Science and Communication (HSSC) is the early science program that has been implemented in classrooms that use the Adaptive Learning Environment Model (ALEM) (Wang, 1992), a cornerstone of the Community for Learning (CFL) comprehensive school reform model. This instructional program provides the infrastructure for blending exploratory and explicit learning to support children's unique abilities and individual differences. The program has been highly influenced by over two decades of research and broad, field-based implementation of innovative school programs (Wang, Haertel, & Walberg, 1995). CFL "draws itself from the field-based implementation of an innovative instructional program that focuses on school organization and instructional delivery in ways that are responsive to the development and learning needs of the individual child, the research base on fostering educational resilience of children and the youth beset by multiple co-occurring risks, and the forging of functional connections among school, family, and community resources in coordinated ways to significantly improve the capacity for the development and education of children and youth" (Wang, 1998, p. 10).

**Developmentally Appropriate Practices**

In connection with the instructional model, the National Association for the Education of Young Children (NAEYC) recommends that developmentally appropriate practices be adopted. Developmentally appropriate practices (DAP) are not a curriculum; however, they provide standards for identifying high-quality early childhood education programs. DAP emphasizes the treatment of children as individuals with the ability to make choices about their educational experience (Bredekamp & Copple, 1997).

The HSSC Program has implemented NAEYC's suggestions in the classroom to meet children's individual needs. These recommendations include, but are not limited to, (1) ensuring that classrooms function as caring communities so they can help children learn how to establish positive and constructive relationships with adults and other children; (2) providing opportunities for the children to accomplish meaningful tasks and experiences in which they can succeed most of the time; and (3) preparing a learning environment that fosters children's initiative, active exploration of materials, and sustained engagement with other children, adults, and activities. Further recommendations include planning a variety of concrete learning experiences that are relevant to children and providing opportunities for children to plan and make choices about their own activities from a variety of learning centers.

Appropriate opportunities for learning are further supported by providing an environment that cultivates receptive and expressive language and cognitive development. As preschoolers proceed through stages of language development and cognitive growth, they gain skills in acquiring vocabulary, understanding simple stories, following directions of increasing complexity, and learning about causal relations. Their expressive skills expand to use grammatically appropriate sentences, and they learn to exchange ideas in discussion, discuss why something happened, ask questions related to a topic, and retell a simple story by kindergarten age. As young children expand their vocabulary, they begin to differentiate likeness and differences and to match, discriminate, and categorize objects and events through paired comparisons. Such emergent skills are precursors to later reading and writing. As young children gradually refine their visual perception and explore their environment, they learn to sequence events in logical order. They begin to make associations and can compare objects on the basis of different attributes. These abilities lead to higher-level skills of planning, making judgments, and solving problems. Throughout this time, children learn that their communication has an effect on others and on their own ability to get what they want (McLean & McLean, 1999).

**Classroom Dynamics**

The manner in which the teacher structures learning opportunities and the methods used to foster interaction among students while learning are critical to supporting language and cognitive development. Howes and Phillipson (1998), in their study on the effects of preschool interaction, found that low levels of child-teacher closeness when a child is 4 years old lead to social withdrawal in second grade and that prosocial ratings in second grade were best predicted by preschool classrooms that were high in children spending time interacting with peers. This finding supports the recommendation of NAEYC that teachers serve as facilitators to children's self-initiated activities. Teachers can not only provide instruction but also provide opportunities for children to explore concrete materials and interact with peers (Bredekamp & Copple, 1997). Teachers can circulate around the room responding to students' requests, giving individual instruction, or offering feedback and reinforcement (Wang, 1992).

Students' internal motivation to succeed is further fostered by a classroom environment that incorporates cooperative learning activities. In such classrooms, students tend to be less focused on how they are doing relative to their peers and are more focused on learning for its own sake. According to Nicholls (1990), students in classrooms with a cooperative learning structure focus more on how to accomplish tasks, and they view making mistakes as part of a process towards learning. "Depending on the type of classroom structure teachers choose, they are communicating a view of success or failure to their students that can have a critical impact on children's beliefs" (Bempechat, 2000, p. 12).

**A Best Practice Model**

In deciding how to encourage students to explore the nature and meaning of science while developing their comprehension and expression, science educators and language development specialists have developed a curriculum that is both explicit and exploratory in nature, taking the best qualities of each. The curriculum is based on the (1) American Association for the Advancement of Science Project 2061 science benchmarks (AAAS, 1993); (2) developmentally appropriate practices; and (3) language skills for classroom communication (Farber & Klein, 1999).
The developers of the HSSC Program have based their thinking on a few guiding principles. Young children have a natural tendency to explore. Children's daily playtime activities engage them in "science." Science education in school unites cognitive development and children's prior knowledge and experience with intuitive scientific theories to formulate new ideas. As they develop explanations about the world around them, they are learning broad scientific concepts. While they are discovering their world, they are questioning and investigating. Rather than looking at isolated science concepts, science for the early childhood student is an introduction to the "big picture." Newer approaches also emphasize learning that maximizes students' individual competencies. Using an interactive process to enhance students' questioning abilities (Stone, 1994), the HSSC Program encourages social interaction, discourse, and questioning during science lessons. This interactive, analytic approach tends to improve kindergarten children's planning and problem-solving skills. Students are asked to describe and communicate their ideas as they make sense of their own learning, drawing from prior knowledge and asking questions to acquire information. This interactive inquiry-based perspective is supported by the National Science Education Standards (National Academy of Sciences, 1996).

**Program Description**

The Head Start on Science and Communication (HSSC) Program was initially conceived to unite parents and teachers to promote current and future success in science for children in preschool, kindergarten, and first grade. The HSSC Program emphasizes the development of children's language skills through an explicit, teacher-directed approach and an exploratory, child-centered approach to acquiring science knowledge. The program aims to achieve three very specific goals:

- broadening participants' science knowledge and conceptions around three science domains: life science, earth science, and physical science;
- enhancing age-appropriate abilities through scientific inquiry for observing, hypothesizing, predicting, investigating, interpreting, and drawing conclusions; and
- integrating science with communication to recall, identify change, generalize, analyze, judge, and solve problems.

The two phases of the HSSC Program are described below. Phase I included outreach and planning with parents and teachers in the community; phase II was an instructional scaling-up attempt to incorporate specific science experiments in classrooms.

**Phase I**

The participants in phase I of the study represented Head Start programs from 18 schools in Philadelphia and New Jersey. Participants included 18 teachers, 11 classroom assistants, and 10 parents, ranging from 19 to 53 years of age, and included three ethnic groups: African American (68%), Caucasian (29%), and Latino (3%). Eighty-five percent of the Head Start programs represented were based in large urban settings, and 15% were based in suburban or rural settings. Although the educational background of participants varied, none of the participating parents held college degrees.

All participants received interactive inquiry-based training to broaden their general science knowledge about life science, earth science, and physical science, and to create strategies to establish learning environments that encourage an inquiry approach to everyday learning in school and at home. A basic design principle of the HSSC Program is the inclusion of parents in the learning process. This element was critical to the success of the planning phase.

**Program Components**

Phase I of the HSSC Program included three components: (1) a summer institute that provided intensive, hands-on instruction and learning experiences for participants; (2) ongoing follow-up technical assistance and training support for program implementation; and (3) extended implementation of the HSSC Program with the first cohort of participants in community-based science-rich centers such as area museums, as well as moving into phase II of the program.

The focus of the two-week summer training program was to provide professional development and an opportunity to promote collaboration among teachers and parents for improving problem-solving skills. The primary goal of the summer institute was to create a lifelong interest in science for participants and the children with whom they interact. In keeping with the intent of the National Science Education Standards, the HSSC curriculum materials were developed to assist participants in fostering their own and the children's "natural curiosity" to learn about the world.

The curriculum materials and experiments were designed to promote inquiry-based, hands-on science as a vehicle for language development with young children. Each experiment begins with background information about the topic under investigation and a teacher demonstration module that provides an opportunity for teachers to engage students with manipulative materials and ask guided questions to gain more information about what students know and what they need to learn. As the project participants implemented these plans that were developed during the summer, the technical support became increasingly site-specific, based on individual classroom needs. For example, one teacher expressed the need to learn about various inferential questioning techniques, while another teacher requested strategies for promoting student collaboration.

**Data Collection**

Data on program implementation were obtained through surveys, on-site observations, and interviews. Participants (teachers, teaching assistants, and parents) were rated as either "encouraging inquiry," because the participants asked questions that helped students gain needed information to solve problems, or "giving away," because the adult immediately answered questions asked by students. In addition, on-site observations were conducted to determine each classroom's primary mode of interaction. Classrooms were classified as "collaborative" or "competitive." The post-implementation surveys were followed by semi-structured, open-ended interviews to learn more about classroom interaction.

**Phase I Findings**

**Changes in Questioning Strategies**

Preliminary findings from the post-implementation surveys indicated that 50% of the teachers relied solely on the use of questioning to encourage students' problem solving, 33% encouraged problem solving as well as giving away the answers, and 17% tended to simply "give away" answers as opposed to using questions to get children to try to solve the problems themselves. The majority of parents (83%) engaged in both questioning to encourage problem solving and giving away answers; 17% engaged in giving away answers only; and "none" engaged in only using questioning to encourage problem solving. Almost half of the classroom assistants reported that they tended to give away answers. In summary, classroom assistants gave away substantially more answers to students when compared with teachers and parents, who encouraged more problem solving through questioning.

**Changes in Classroom Interaction**

A teacher's philosophy and his or her interaction with students have been found to have a major impact on how students view success and failure. Nicholls (1990) has shown that traditional, competitive classrooms produce children who are overly concerned with how they are doing relative to their peers. This competitive
style makes children anxious about mistakes, and students tend to equate their mistakes with failure. This anxiety has been found to affect children's beliefs about themselves and their abilities. Conversely, cooperative classrooms foster a sense of learning through accepting mistakes as experiences for growth. Nicholls further points out that the challenge for teachers is to help students maintain a healthy balance among accepting mistakes as opportunities to learn, believing they have the ability to learn, and knowing that effort will help them maximize that ability. Prior to training, the 12 observed classrooms lacked collaborative interaction among teachers and students. Following the training (spring 1997), the classrooms were observed to determine if there was a change in their primary mode of interaction. Eight of the 12 classrooms were rated as collaborative, engaging in small-group problem-solving teams with verbal interactions among teachers and students. Teachers not only asked questions of students but also encouraged students to ask questions for clarification, to understand that learning takes time, and to understand that mistakes are accepted when followed up with new information to solve problems. Three classes were found to be both collaborative and competitive, fluctuating in interactions during the course of the day. Only one class remained predominantly competitive in nature. Collaborative interactions included working together on projects, with students assuming varied and complementary roles as they worked on problem-solving activities in science. Characteristics of classroom interactions included listening, waiting, acknowledging comments, inviting questions, accepting others' points of view, and encouraging students to express ideas. Competitive interactions included activities that focused on performance with a form of grading attached.

Changes in Classroom Focus

When interviewed after program implementation, participants indicated that they changed their classroom focus to be primarily inquiry-based (75% of classes). The participants said they used more open-ended questions with their students instead of asking yes-no type questions. They asked “why”-type questions (i.e., who, what, when, where, why, and how) with much greater frequency (encouraging recall, application, and problem solving). Some teachers set up science centers and other exploratory learning centers within the classroom setting. Generally, parent involvement reinforced classroom learning. Teachers sent letters to parents, explaining what would be discussed in class and encouraging parents to visit the classroom. Teachers and assistants discovered that the use of language that targeted vocabulary development and questions was integral to enhancing learning and engagement of young children. Teachers reported making a difference in the children's scope of cause-effect knowledge. At the completion of phase I, participants had many ideas for the future of the HSSC Program. Some teachers planned to engage other faculty members in brainstorming questions that tapped inferential thinking for science experiments. Other teachers looked forward to involving more parents, noting that parental involvement is one key to successful program implementation. Overall, participants anticipated implementing the techniques and using the ideas they learned. Because of the success of phase I, the program was expanded from preschool children to those in the early elementary years (kindergarten through grade 2). Phase II of the program included further implementation, refinement of program materials, and expansion to kindergarten through grade-2 classrooms.

Phase II

Phase II of the HSSC Program involves the formal development of 30 science experiments and a manual covering three science domains: life science, earth science, and physical science (see the appendix). The experiments are based on benchmarks written by the National Science Foundation (National Academy of Sciences, 1996). Using specific language concepts and scientific background information, the teacher initially tests students individually using the pre-test to assess the student's knowledge base. Following the pre-test, the teacher introduces each science experiment to a small group of students or to the entire class. Students also have an opportunity to engage in exploration using the manipulatives and directions within science activity kits. After the experiment is completed, the post-test is administered to assess a student's content knowledge gains.

The HSSC Program encourages children’s natural inclination to explore by providing an early learning environment that is conducive to scientific literacy. The HSSC Program incorporates the use of individualized hands-on science learning activity boxes as well as small-group and whole-class instruction. Providing hands-on learning experiences fosters curiosity in young children and engages them in the social and cognitive processes that promote language and communication skills essential to continued academic success. The combination of explicit, teacher-directed methods and exploratory, child-centered methods allows young children to obtain information, explore their surroundings, and develop meaning, thus honing their communication and problem-solving skills.

The explicit role of the teacher is an important component of this early childhood program. As a facilitator, the teacher assists individual students in gaining new scientific knowledge by relating experiences and answering personal questions when appropriate. Initially, teachers facilitate the demonstration lesson that introduces the scientific concepts embedded in the students' individualized activities. The classroom teacher provides background information and supports students as they learn newly introduced science material. Manipulative materials and supplies for the science activities are all included in 150 individually boxed learning activity kits.

After each science demonstration, the teacher asks probing questions to determine students' general concept understanding. Based on the lesson taught during the science demonstration, the students will have the opportunity to use their knowledge to work through a series of science activities that are organized into five levels. The science activities are arranged hierarchically by cognitive level from basic matching tasks to higher-level associations based on understanding relationships.

The first level in the hierarchical structure of the program is matching. While the students work on the first science activity, they are encouraged to identify likenesses among objects. This level is followed by level 2, a discrimination task. This level focuses on the student's ability to not only identify similarities but to also distinguish differences. These activities help foster the ability to compare and contrast, a basic scientific process (Hammrich, 1998). Level 3 focuses on categorization. Children use their ability to discover similarities and organize information into like units. Level 4 requires the ability to order information for sequencing. Students arrange various items according to patterns or gradations, noting specific stages and order. The final level, level 5, involves an association activity. These activities incorporate previous knowledge levels and challenge students to transfer information, understand relationships, and make new connections.

To demonstrate understanding of scientific concepts, students answer six post-experiment questions that directly relate to the five activity levels. The post-assessment questions are based on a modified taxonomy derived from Bloom (1984). To determine if children have acquired knowledge from engaging in the experiments, students must initially recall factual information. This type of question draws on the student's knowledge of previously introduced information. Table 1 provides a brief look at the six questioning levels that tap increasingly more demanding cognitive abilities.

### Table 1: Six Levels of Post-Experiment Assessment Questions

<table>
<thead>
<tr>
<th>RECALL</th>
<th>CHANGE</th>
<th>GENERALIZE</th>
<th>ANALYZE</th>
<th>JUDGE</th>
<th>PROBLEM SOLVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>facts</td>
<td>added information</td>
<td>units of thought</td>
<td>think it through</td>
<td>speculate</td>
<td>apply to new situations</td>
</tr>
<tr>
<td>Tell what…</td>
<td>Tell what X means</td>
<td>Describe how X is used in example</td>
<td>Tell how X and Y are alike or different</td>
<td>Explain why X is better or worse than Y</td>
<td>Explain how you could make it better</td>
</tr>
<tr>
<td>Tell when…</td>
<td>Tell why (reason or purpose)</td>
<td>Tell what is an example of…</td>
<td>Explain why you think X did Y</td>
<td>Tell why you agree or disagree</td>
<td>Explain what you plan to do</td>
</tr>
<tr>
<td>Tell where…</td>
<td>Tell how X felt</td>
<td>Tell why it happened</td>
<td>Tell what is true/not true</td>
<td>Describe which you choose first/last</td>
<td>Explain what you think will happen next</td>
</tr>
</tbody>
</table>

*Read down
Twelve experiments are discussed in this section. Because of the late start of the program within the school year, not all 30 experiments could be completed by teachers and students. Generally, one demonstration experiment with follow-up activities was conducted weekly.

The science and language concepts for each of the 12 experiments of life science, earth science, and physical science include the following:

- Changing Fish: change, adaptation, and variations among fish and their environments
- Coloring Celery: levels of water and absorption of plants
- Evaporating Liquids: wet, dry, and moisture associated with events
- Blowing Across: movement, distance, air, and wind
- Gathering Nature: plant and animal features for comparison and classification
- Finding Earth: varieties of environmental surfaces
- Growing Seeds: patterns, similarities, and differences in growth
- Making Plants: parts and wholes of plants and their functions
- Moistening Seeds: sunlight, moisture, and development of the seed
- Organizing Rocks: grouping characteristics and textures
- Bouncing High: height, movement, and force
- Bubbling Air: space, observation, and size

**Implementation of the HSSC Program**

The first-grade teachers in this study were chosen by the school principals after the teachers indicated an interest in participating in a science program. The first-grade teachers in the experimental condition followed the HSSC Program, providing standards-based curriculum with learning activity boxes for life science, earth science, and physical science. In addition, these teachers received technical support in their classrooms from an implementation specialist on an average schedule of two times per month. During the fall of 1999, 14 first-grade teachers in the targeted schools were observed to determine the degree of implementation in their classrooms on the 12 critical dimensions of the Adaptive Learning Environments Program (ALEM) of the Community for Learning Comprehensive (CFL) School Reform Model developed by Wang (1992). Degree of implementation scores are reflected in percent form, referring to the number of dimensions met within each category. The 12 areas for degree of implementation are (1) arranging space and facilities, (2) creating and maintaining instructional materials, (3) establishing communication and refining rules and procedures, (4) coordinating and managing support services and extra personnel resources, (5) record keeping, (6) diagnostic testing, (7) prescribing, (8) monitoring and diagnosing, (9) interactive teaching, (10) instructing, (11) motivating, and (12) developing student self-responsibility. An average score for all 12 areas is referred to as the degree of implementation (DOI) composite. Results indicate that in the fall, the average DOI composite for the 4 experimental classroom teachers was 67.30, and the average DOI composite for the 10 control classroom teachers was 81.44.

In the spring, following implementation of the HSSC Program, the average DOI composite for the experimental group increased to 87.50, whereas the control group DOI composite remained steady at 81.73.

**Table 2**

<table>
<thead>
<tr>
<th>Group</th>
<th>Experimental Fall 1999</th>
<th>Experimental Spring 2000</th>
<th>Control Fall 1999</th>
<th>Control Spring 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Classes</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Mean</td>
<td>67.30 (25.16)</td>
<td>87.50 (11.99)</td>
<td>81.44 (18.53)</td>
<td>81.73 (25.19)</td>
</tr>
<tr>
<td>Change</td>
<td>+20.20</td>
<td>81.73 (25.19)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results indicate that teachers from the experimental classes increased degree of program implementation by approximately 20%, whereas the control classroom teachers made negligible change. Although the teachers in the experimental classrooms started out lower in degree of implementation, they achieved higher scores by the end of the school year than the control classroom teachers for arranging space/facilities, establishing/communicating rules, coordinating/managing support, record keeping, diagnostic testing, prescribing, monitoring/diagnosing, interactive teaching, instructing, and motivating students. The final two assessed areas, creating/maintaining instructional materials and developing student self-responsibility, were similar in degree of implementation scores (less than one point difference) between the two groups by the end of the school year.

**Program Gains**

The areas that indicated a gain in DOI from fall to spring for teachers with experimental classes included arranging space and facilities (8%), creating and maintaining instructional materials (40%), establishing and communicating rules (20%), coordinating and managing support (30%), record keeping (50%), prescribing (40%), monitoring and diagnosing (25%), interactive teaching (30%), instructing (17%), motivating students (15%), and developing student self-responsibility (4%). In the control classes, the following increases were noted: creating and maintaining instructional materials (4%), establishing and communicating rules (7%), record keeping (10%), prescribing (7%), monitoring and diagnosing (1%), interactive teaching (14%), and developing student self-responsibility (8%). Experimental classrooms made superior gains when compared with control classrooms in 11 of 12 DOI areas assessed.

Curriculum-based Pre- and Post-test Results
The "Unit Pre-Post Tests for Life, Earth and Physical Sciences" (Hammrich & Klein, 2000) were administered to first-grade children in five classes to determine growth in content knowledge. There were two questions asked for each experiment prior to and following program instruction. The first question for each experiment, labeled "A," was factual, based on factual recall of information. The second question for each experiment, labeled "B," was application, based on students’ explanations of information. For each question, students received a score of "0," indicating an incorrect response, or a score of "1," indicating a correct response. All pre-tests and post-tests were administered individually to students by the classroom teachers with the support of program staff during pre-test time. Table 3 provides a breakdown of scores for each type of question (A and B) for the 12 completed experiments.

Table 3
Gains from Pre- to Post-test Scores for Science Content Knowledge with 12 Experiments

<table>
<thead>
<tr>
<th>Experiment Name</th>
<th>Number of Students</th>
<th>Mean Pre-test Score</th>
<th>Mean Post-test Score</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing Fish–A</td>
<td>56</td>
<td>.38</td>
<td>1.00</td>
<td>.62</td>
</tr>
<tr>
<td>Changing Fish–B</td>
<td>56</td>
<td>.00</td>
<td>.91</td>
<td>.91</td>
</tr>
<tr>
<td>Coloring Celery–A</td>
<td>31</td>
<td>.35</td>
<td>.91</td>
<td>.55</td>
</tr>
<tr>
<td>Coloring Celery–B</td>
<td>31</td>
<td>.45</td>
<td>.97</td>
<td>.52</td>
</tr>
<tr>
<td>Evaporating Liquid–A</td>
<td>12</td>
<td>.17</td>
<td>.92</td>
<td>.75</td>
</tr>
<tr>
<td>Evaporating Liquid–B</td>
<td>12</td>
<td>.00</td>
<td>.92</td>
<td>.92</td>
</tr>
<tr>
<td>Blowing Across–A</td>
<td>17</td>
<td>.71</td>
<td>1.00</td>
<td>.29</td>
</tr>
<tr>
<td>Blowing Across–B</td>
<td>17</td>
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</table>

Results indicate that there was a significant difference between pre-test and post-test knowledge beyond the \( p < .05 \) level for all experiments tested. Students in the HSSC Program made significant gains in content knowledge at both factual and application levels.

**Gender Differences**

There were a total of 53 female first-graders and 45 male first-graders who took the pre-test. Students engaged in self-paced investigations to complete the five levels of each experiment following teacher demonstrations. Post-testing took place when the student completed the entire experiment. Figure 1 indicates that the girls generally scored lower than the boys at pre-test time. In fact, there were only two experiments (#6—finding earth and #9—moistening seeds) in which they scored higher than the boys initially. However, post-test results revealed that the girls matched the boys on factually based questions for 7 of the 12 completed experiments and surpassed the boys on one experiment (#10—organizing rocks).

Figure 1. Factual pre- to post-test question means for girls and boys.
Table 4 indicates that although the girls in the study scored slightly lower than the boys on both factual and application questions at pre-test time, their scores approximated the boys at post-test time with both girls and boys evidencing mastery of the material.

### Summary of Head Start on Science and Communication Results

Results indicated that the HSSC Program had positive achievement effects for students who participated in the program. Overall, there was a significant difference between pre-test and post-test knowledge beyond the \( p < .05 \) level for all 12 completed experiments. Gains ranged from a low of 0.00 (an incorrect score) to a high of 1.00 (a correct score). Table 4 below reveals significant pre- and post-test changes beyond the \( p < .05 \) level of significance.

**Table 4**

<table>
<thead>
<tr>
<th>Factual Pre-test Means</th>
<th>Factual Post-test Means</th>
<th>Application Pre-test Means</th>
<th>Application Post-test Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls ( n=53 )</td>
<td>.937* ( n=44 )</td>
<td>.992* ( n=41 )</td>
<td>.912* ( n=44 )</td>
</tr>
<tr>
<td>Boys ( n=45 )</td>
<td>.992* ( n=44 )</td>
<td>.944* ( n=41 )</td>
<td>.912* ( n=44 )</td>
</tr>
</tbody>
</table>

* Significance beyond \( p < .05 \).

Teachers reported improvement in their methods of instruction and classroom management after using the HSSC Program. Results indicated that in the fall, the average DOI composite for the four HSSC experimental classroom teachers was 67.30, and the average DOI composite for the 10 control classroom teachers was 81.44. In the spring, following the HSSC Program, the average DOI composite for the experimental group increased to 87.50, whereas the control group DOI composite remained steady at 81.73.

The HSSC Program significantly benefited teachers in (1) arranging space and facilities, (2) establishing communication and refining rules and procedures, (3) coordinating and managing support services and extra personnel resources, (4) record keeping, (5) diagnostic testing, (6) prescribing instructional material, (7) monitoring and diagnosing individual needs, (8) interactive teaching, (9) instructing, and (10) motivating students. Students benefited in their comprehension of language and level of knowledge acquired as evidenced by the gains they made when answering both factual and application types of science questions previously unknown.

### Conclusion

Gaining knowledge about scientific processes and principles while increasing cognitive, linguistic, and literacy skills is a challenging and important task. Not all children learn in the same way, and they may not learn equally well using only one method. Often, we find that it is best to combine more than one teaching method to help children learn to their maximum potential. To motivate children to explore, understand, analyze, and create, teachers may want to combine both explicit, teacher-directed methods and exploratory, child-centered methods. In this way, students are given basic information from which to begin and to peak their curiosity for continued exploration. The Head Start on Science and Communication Program unites language development and science inquiry with a multifaceted curriculum to meet the needs of teachers and children within our diverse educational arena of the 21st century.

### References


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Anika Ragins
Appendix
Science Activity Index

The following index lists the activities and a brief description of the major concepts covered. Activities are grouped by life, earth, and physical sciences.

**Life Science**

1. **Listening Inside**: Things that make sounds vibrate.
2. **Guessing Boxes**: Using your senses, you can describe physical properties of different objects.
3. **Coloring Celery**: Water can be absorbed.
4. **Pouring Shapes**: You can change some materials' properties, but not all materials respond the same way.
5. **Melting Materials**: Water can change back and forth from a liquid to a solid and from a liquid to a gas.
6. **Feeling Water**: Using your senses, you can feel temperature for variations from hot to cold.
7. **Evaporating Liquids**: Water and moisture can disappear if left in an open container.
8. **Changing Fish**: Animals have external features that help them adapt and survive.
9. **Ordering Nuts**: You can describe and organize objects by their physical properties.
10. **Sensing It**: You can use your senses to identify properties of objects.

**Physical Science**

11. **Bouncing High**: You can vary movement of something by force.
12. **Falling Objects**: You can change the position of something by pushing it.
13. **Sticking Objects**: Magnets can make some materials move.
14. **Spilling Over**: Things can be done to change a material's properties.
15. **Bubbling Air**: Most living things need air.
16. **Floating Food**: Some objects can float, while other objects sink.
17. **Creating Pitch**: Sounds can be low or high in pitch.
18. **Coloring Line**: You can change colors by adding other colors to them.
19. **Measuring Sound**: You can use your senses to hear different sounds.
20. **Moving Hands**: You can create heat from friction.

**Earth Science**

21. **Finding Earth**: Different surfaces have different textures.
22. **Making Plants**: Plants are comprised of various parts that have different functions.
23. **Blowing Across**: Force of air can make objects move various distances.
24. **Organizing Rocks**: Rocks come in different sizes, shapes, textures, and colors.
25. **Moistening Seeds**: Plants need water and light to grow.
26. **Running Liquids**: Physical properties can be changed.
27. **Growing Seeds**: Plants share similarities and differences in features and growth.
28. **Sinking Boats**: Buoyancy and weight are factors in flotation.
29. **Gathering Nature**: Materials in nature have similarities and differences.
30. **Observing Objects**: Some objects' physical properties can be changed and others cannot.