Language Development and Science Inquiry:
A Child-Initiated and Teacher-Facilitated Program

by

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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 best practice is 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 development as well as through their personal experiences. Children must explore, ask questions, and revise their thinking to accommodate new ideas (Mundry & Loucks-Horsley, 1999).

The purpose of this article is to discuss a model that fosters science learning through a systematic approach to language development. At the Mid-Atlantic Laboratory for Student Success headquartered at Temple University Center for Research in Human Development and Education, scientists and language specialists have developed a science curriculum that promotes the content and process for learning about life, earth, and physical sciences.

Instructional Methods

Current trends in early childhood programs tend to incorporate explicit teacher-led activities or exploratory, teacher-facilitated activities (Fradd & Lee, 1999). These two different practices stem from different theories of how children learn and the role the 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). Explicit models use a highly structured teaching approach for acquiring academic skills. The skills emphasized tend to be those assessed by intelligence and achievement tests. Teachers lead small groups of children in structured question and answer lessons. 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 (Schweinhart & Weikert, 1997).

Exploratory curriculum models suggest that children construct their knowledge by confronting and solving problems through direct experience and use of manipulative objects (Stipek & Byler, 1997). The goal is to create an environment in which children may explore and develop naturally. In such a setting, there are no structured responses. Rather, activities lend themselves to creativity and exploration (Stipek & Byler, 1997). In exploratory models, the teacher's role is to serve as a facilitator for the children by providing them with the opportunities to engage in activities and interact with their peers.

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

Some researchers believe the explicit-directed type of teaching is management driven. Cuban (1993) 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." 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. Delpit (1995) maintains this type of curriculum values basic skills over creative thinking and is necessary for this population because of the value society places on highly structured skills-oriented programs. Schweinhart and Weikart (1998) 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 further support the use of an exploratory, child-centered curriculum to further develop social responsibility and interpersonal skills. Additional research reports that children in child-centered programs display better language development and verbal skills (Dunn & Kontos, 1997).

Both approaches have value in educating young children. Some of the issues that have been raised include: which is better for the teacher, which is better for children in developing cognitive competence, and which curriculum model is best for developing the social-emotional development of children. We know that students can benefit from both the explicit and exploratory. “Instead of viewing these approaches as opposing camps, they could be conceptualized as complimentary opportunities for teachers to move between perspectives,” (Fradd & Lee, 1999, p.16).

A cornerstone of the Community for Learning (CFL) comprehensive school reform demonstration program is the Adaptive Learning Environment Model (ALEM) (Wang, 1992). This instructional program provides the infrastructure for blending exploratory and explicit instruction as it supports individual differences in learning and provides effective education to improve schooling outcomes. The program was 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

Regardless of the model, it is recommended by the National Association for the Education of Young Children (NAEYC) that developmentally appropriate practices be adopted.

Developmentally appropriate practice (DAP) is not a curriculum, however; it is a single set of standards encompassing 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 NAEYC suggests several ways in which DAP can be implemented in the classroom to meet each child's individual needs. These include but are not limited to: 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; providing opportunities for the children to accomplish meaningful tasks and experiences which they can succeed in most of the time; and 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 which are relevant to the children's own lives and providing opportunities for children to plan and select many of their own activities from a variety of learning areas.

Appropriate opportunities for learning are further supported by providing an environment that cultivates language development and cognitive development. As preschoolers proceed through stages of pre-operational growth from 2 to 7, they initially use words to represent broad categorization. They begin to categorize objects through direct paired comparisons and engage in such activities as matching and discriminating. As they gradually refine word meanings they also begin to perceive situations from their own perspective and they can focus on one dimension of problem solving. Children learn that their communication has effects on others and on their own ability to get what they want (McLean & Snyder-McLean, 1999).

Classroom Dynamics

Classroom dynamics involves both the manner in which the teacher structures learning opportunities and the methods used to foster interaction among students while learning.

NAEYC recommends that teachers serve primarily as facilitators to children's self-initiated activities. Teachers should provide opportunities for children to explore concrete materials and interact with peers (Bredekamp & Copple 1997). Wang (1992) has effectively described what a typical classroom should look like.

> Teachers and students are all busy, with many different activities occurring simultaneously. A teacher is conducting a lesson with a group of six students at a large, round table. Seven other students are working with various learning centers and the materials in front of each student are different types and from different levels of curricula. While two students are engaged in an experiment about light at a science center, another is putting together a puzzle map at a social studies center.

The teacher circulates around the room either responding to students' requests, giving individual instruction, or offering feedback and reinforcement (Wang, 1992).

Students' internal motivation to succeed is further fostered by a cooperative classroom environment. In cooperative classrooms, students tend to be less focused on how smart they are relative to other students. They tend to be more focused on learning for its own sake. According to Nicolls (1990), students in cooperative classrooms focus more on how to accomplish the task and they view mistakes as a process towards learning. "Depending on the type of classroom structure teachers choose, they are communicating a view of success and 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, and based it on (1) American Association for the Advancement of Science Project 2061 Science Benchmarks, (2) Developmentally Appropriate Practices, and (3) cognitive-linguistic concepts for classroom communication (Farber & Klein, 1999).

The major thrust behind scientific thinking in young children is a natural tendency to explore and discover one's surroundings. 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 the isolated science concepts, science for the early childhood student is an introduction to the "big picture."

Some newer approaches emphasize adaptive learning that maximizes students' individual competencies. Using an interactive process to enhance students' questioning abilities has been explored by Stone (1994), who encourages social interaction, discourse, and questioning during science lessons. This interactive, analytic approach has led to increased planning and problem-solving skills for kindergarten children. Students are taught to view the world in a continuous process of changing ideas. They are asked to describe and communicate those ideas as they make sense of their own learning, drawing from prior knowledge and asking questions to acquire information. Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations. This interactive inquiry-based perspective is supported by the National Science Education Standards (National Research Council, 1996).

Program Description

In order to foster science literacy development, the Head Start on Science and Communication Program (HSSC) was initially conceived to unite parents and teachers to promote current and future success in science for children in preschool, kindergarten, and first grade. HSSC emphasizes the development of children's language skills through an explicit teacher-directed and 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 answer questions relating to recall of information, identification of change, generalization, analysis, making judgment, and problem-solving information.

Phase I

The participants in phase I of the study represented Head Start programs from 18 schools throughout Philadelphia and New Jersey. Participants included 18 teachers, 11 classroom assistants, and 10 parents ranging from 19 to 53 years of age, and including 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, 15% in suburban or rural settings. While the educational background of participants varied, none of the participating parents held college degrees.

All participants received interactive inquiry-based training on broadening their general science knowledge in topics of life, earth, and physical science, and creating 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 was a critical element to the success of the program. The link between what a child learns at school and how it is reinforced outside school is key to a child's ability to generalize and apply new information.

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) extending the implementation of the HSSC program in the first cohort of participants to 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 a variety of factual and inferential questions important to promoting collaboration among teachers and parents for greater 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. The experiments began with a teacher demonstration module providing an opportunity to manipulate materials and ask questions to gain more information. Ongoing technical assistance provided research-based support, on-site visitation and consultation, and staff development workshops. As the project participants implemented the 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 student collaboration.

Method of Data Collection

Data on program implementation was obtained through surveys, on-site observations, and interviews. Participants were rated as either encouraging inquiry to gain information and solve problems or "give-away" answers. In addition, classrooms were rated for their primary mode of interaction as being collaborative or competitive. On-site observations were conducted to determine each classroom's primary mode of interaction with students. 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 problem solving with the students, 33% encouraged problem solving as well as giving away the answers, and 17% tended to simply give away or provide answers as opposed to using questions to get children to try to solve the problems themselves. The majority of parents (83%) indicated that they engaged in both questioning to encourage problem solving as well as giving away answers, while almost half of the classroom assistants reported they only gave away answers. In summary, classroom assistants gave away substantially more answers to students when compared to teachers and parents, who encouraged more problem solving through questioning.

Changes in Classroom Interaction

Prior to training, the 12 classrooms observed lacked collaborative interaction among students and faculty. Following the training (spring, 1997), the dynamics of the classrooms were observed to determine their primary mode of interaction. Eight of the twelve classrooms were found to have become collaborative, engaging in small-group problem-solving teams with verbal interactions among teachers and students. Three classes engaged in tasks that were both collaborative and competitive, and only one class was determined to remain predominately competitive. Collaborative interactions included working together on projects, with students assuming varied and complementary roles. Classroom characteristics included listening, waiting, acknowledging comments, inviting questions, accepting others' points of view, and encouraging students to express ideas. Competitive interaction included activities that produced a winner or individualized work with a grade attached.

Changes in Classroom Focus

When interviewed after program implementation, participants indicated that they changed their classroom focus to primarily inquiry-based (75% of classes). The participants said they used more open-ended questioning with their students instead of asking "yes/no"-type questions. They asked "wh"-type questions (who, what, where, when, why, and how) with much greater frequency (encouraging recall, application, and problem solving). Some teachers set up science 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 encouraged parents to visit the classroom. Teachers and assistants discovered that the use of language for vocabulary development and the use of questions were integral to enhance 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 the brainstorming questions that tapped more inferential thinking for science experiments. Other teachers looked forward to involving more parents, noting that parental involvement is one key to success of program implementation. Overall, participants anticipated implementing the techniques and using the ideas they learned. Because of the success of phase I, the program has expanded from preschool aged children to those in the early elementary years (K-2). Phase II of the program will include further implementation with cohort one, refinement of program materials, and expansion to K-2 classrooms.

Phase II

Phase II of HSSC has involved the formal development of 30 science experiments and a manual covering three science domains (see appendix A): life science, earth science, and physical science. The experiments are based on benchmarks written by the National Science Foundation (National Research Council, 1996). Using specific language concepts and scientific background information, the teacher introduces each science experiment to a small group of students or to the entire class.

The HSSC early childhood science program encourages children's natural inclination to explore by providing an early learning environment that is conducive to science literacy. The HSSC program incorporates the use of individualized hands-on science learning activity boxes as well as 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 and exploratory child-centered methods allows young children to gain 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 to this early childhood program. As a facilitator, the teacher assists individual students to gain 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 the 150 individually boxed learning activity kits.

After each science demonstration, the teacher asks probing questions to determine 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 five-leveled science activities. The science activities are arranged hierarchically in cognitive levels 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 challenged to identify likeness among objects. This is followed by 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). The third level 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. The final level involves an *association* activity. These activities incorporate previous knowledge levels and challenge students to transfer information 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 Bloom's Taxonomy (Bloom, 1984). To determine if children have acquired knowledge from engaging in the experiments, students must *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.

Conclusion

Gaining knowledge about scientific processes and principles while increasing cognitive, linguistic, and literacy skills is a challenging and important task. Whether information is acquired through explicit, teacher-directed methods or through exploratory, child-centered methods, it cannot be assumed that one method of learning is better than the other. Not all children learn the same way. Nor do they learn equally well using one method. Often, we find that it is best to combine more than one method to help child learn to their maximum potential. In efforts to motivate children to explore, understand, analyze, and create, teachers are encouraged to combine both explicit and exploratory teaching methods. 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.

Table 1: Six Levels of Post-Experiment Assessment Questions

RECALL ↓	CHANGE ↓	GENERALIZE ↓	ANALYZE ↓	JUDGE ↓	PROBLEM SOLVE ↓
Tell what…	Tell what X means	Describe how X is used in example	Tell how X & Y are alike or different	Explain why X is better or worse than Y	Explain how you could make it better
Tell when…	Tell why (reason or purpose)	Tell what X is an example of…	Explain why you think X did Y	Tell why you agree or disagree	Explain what you plan to do
Tell where…	Tell how X felt	Tell why it happened	Tell what is true/not true	Describe which you choose first/last	Explain what you think will happen next
Tell who or whose…		Explain what can be done	Tell what you learned	Explain what you think will happen	Describe a new thing that can be done
Tell which…					Describe what you created
Tell how…					Describe how you did X
Tell how many…					

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