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Engaging Young Children in Science and Mathematics

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The purpose of this article is to present various techniques that will engage young children, ages 3-8, in learning science and mathematics. Children actively engage in acquiring basic science and mathematics concepts as they explore their environment. The methods presented are intended to meet the developmental levels of young learners as they make connections with science and mathematics. Also included is a review of science and mathematics content and process skills appropriate for early childhood age learners.

Introduction

A key element for children in understanding science and mathematics knowledge on the early childhood level (preschool-primary grades) is through active, creative, intellectual engagement (Charlesworth & Lind, 2003). Children actively engage in acquiring basic science and mathematics concepts as they explore their environment: "Science and mathematics fit together in a natural and very functional way. Mathematics is an essential component of communication for scientists and also provides an effective way for children to process and share their discoveries" (Winnett, Rockwell, Sherwood, & Williams, 1996, p. 7).

In this manuscript, a review of science and mathematics content and processes appropriate for early childhood age learners are presented. In addition, various techniques are shared that are appropriate for engaging young children in science and mathematics. The methods presented are intended to meet the developmental levels of young learners as they engage in science and mathematics.

Jerome Bruner's Representation of Knowledge

According to Jerome Bruner (1966), the course of intellectual development for children or adults learning new material progresses through three stages: (1) enactive (concrete – actions on objects), (2) iconic (pictorial – visuals/images), and (3) symbolic (abstractions – words, numerals) (Sperry Smith, 2001). Bruner focused on how children think as well as how children learn and how they can best be helped to learn (Howe & Jones, 1993; Martin, 2003).

At the concrete level—Bruner's first stage of learning—teachers need to provide children with numerous opportunities to act on objects (manipulatives). Providing appropriate hands-on, minds-on, relevant learning experiences in both science and mathematics can fuel this learning level. It is extremely important to remember, however, that manipulatives by themselves do not teach. Manipulatives must suit the developmental level of the child and close the gap between informal and formal school mathematics and science (Sperry Smith, 2001). Connections between informal and formal science and mathematics understandings are critical. Teachers can facilitate these connections by carefully observing children while they work with manipulatives and other materials.

At the transitional or pictorial level, which is described by Bruner as the second stage of knowledge representation, learners can express their understandings through conversation or by creating a mental image or picture of their concrete understanding (Sperry Smith, 2001). Children should be encouraged to draw a picture/image of what they previously acted on and then explain their drawings. Educators should listen carefully to children's explanations and ask them to justify their responses. Simply allowing children to participate at the concrete level by acting on objects is not enough: "Careful and deliberate connections between manipulatives and the underlying concepts they are designed to illustrate are crucial to the construction of useful mathematical understanding" (Ginsburg & Baron, 1993, p. 15).

Children need to be provided with many opportunities to share their understandings at the transitional/pictorial level. Real objects, used in conjunction with pictorial representations, would assist learners during this transition. Teachers can use commercially made pictorial materials, or they can create their own from magazine pages, picture books, etc. Teachers need to be aware of children's understandings about each concept or topic in order to provide appropriate guidance that will enable learners to construct knowledge. When children have experienced success at the transitional level, they can experience the third level, which Bruner labeled the abstract or symbolic level.

At the abstract/symbolic level, children are introduced to the symbols that represent their mental understandings such as numerals and mathematical signs (+, -, x, =, etc.) for number concepts and letters for words. According to Bruner, both the concrete and pictorial stages must be nurtured before moving to the symbolic stage (Sperry Smith, 2001). Yet, many teachers working with young children begin at the symbolic stage by introducing numerals, letters, and other symbols that can create confusion within children's minds.

According to Sperry Smith (2001), "Bruner's three modes are found in today's mathematics instruction: physically doing math with manipulatives; doing mental math by thinking in terms of memories of visual, auditory or kinesthetic clues; and finally being able to use number symbols with meaning" (p. 15). By allowing children to progress through all three stages of learning, teachers provide children with opportunities to take ownership of their knowledge and understanding by recreating, reconstructing, and redefining concepts on their own. At this point, children should have a personal understanding of the concepts that accompany symbols.

Bruner believes that instruction should include a variety of appropriate materials that would enable students to represent their new knowledge through actions, drawings, or words (Howe & Jones, 1993). Additionally, he advocates providing children with opportunities to discover concepts for themselves. Bruner promotes various benefits to discovery learning. First, discovery learning provides opportunities for children to increase their intellectual potency by learning how to learn. Children develop skills in problem solving, which enable them to apply what they have learned to new situations. Second, discovery learning focuses on satisfying oneself rather than others. There is a shift from being rewarded extrinsically to being rewarded intrinsically. Third, knowledge that results from discovery learning is more easily recalled and remembered (Kellough et al., 1996).

The Connection of Content and Process Skills in Early Childhood Science and Mathematics

Children's construction of science and mathematics knowledge involves both content and process skills. Concepts, considered to be the building blocks of knowledge, are developed through the use of process skills (Charlesworth & Lind, 2003). According to Charlesworth and Lind, the basic mathematics concepts of comparing, classifying, and measuring are basic process skills of science. Science is both knowledge (content) and ways of finding out (process). Science process skills of observing, communicating, inferring, and controlling variables are important for solving problems in both science and mathematics. Additionally, basic mathematics concepts such as comparing, sorting, counting, estimating, measuring, and graphing are used when solving science problems. As children deal with new situations, they begin to apply basic content and process skills such as observing, counting, recording, and organizing to the collection and organization of data.

What Is Early Childhood Science?

We are living in an era often labeled as the "Information Age." With the advancement of technology and means to communicate, scientific information is increasing at an unprecedented rate (Martin, 2003). Scientific facts and discoveries are recorded in abundance, but with advanced means to acquire knowledge, more data continue to be uncovered, revealing the tentative nature of science.

The challenges that we face today may differ greatly from those our children will face when they reach adulthood. As a result, educators must view science as more than a body of knowledge. Educators must prepare today's children to question, think critically, problem-solve, and make well-informed decisions that will affect society. Along with the development of thinking skills, educators must also foster scientific attitudes such as curiosity, open-mindedness, a positive approach to failure, and a positive attitude toward change in regard to the nature of science. In order to do so, scientific inquiry, through the use of process skills, must be promoted with early childhood-age children.

Process skills are the "doing" parts of science that early childhood educators must promote in order for children to have opportunities to explore and discover science knowledge. The process skills most appropriate for early childhood-age children are observation, comparison, measurement, classification, and communication (Charlesworth & Lind, 2003). These skills are developed through hands-on (concrete) experiences that encourage children to question and investigate phenomena. These skills will later enable students to perform more advanced process skills as they gather, organize, and record data; infer relationships; predict outcomes; hypothesize; and identify and control variables.

Hands-on/minds-on science teaching methods at the early childhood level promote thinking and communication through talking, drawing, drama, puppetry, and writing. With additional opportunities to question and communicate, children's development of language and reading skills improve as well as their science knowledge, resulting in the beginning stages of a scientifically literate population. School science programs must provide experiences for all students to become scientifically literate and prepare the next generation of scientists (Martin, 2003).

According to the National Research Council (1996), "The *National Science Education Standards* present a vision of a scientifically literate populace. They outline what students need to know, understand and be able to do to be scientifically literate at different grade levels" (p. 2). The report *Science for All Americans* (Rutherford & Ahlgren, 1990) emphasizes the need for scientific literacy by defining a scientifically literate person as "one who is aware that science and technology are human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and, uses scientific knowledge and scientific ways of thinking for individual and social purposes" (p. ix). Educators need to provide children with opportunities to experience this developmental process when they are very young for it to be present throughout each individual's life. Science is for ALL students and must be designed to actively engage learners of all ages so they are successful in today's and tomorrow's world.

Early childhood teachers should create a learning environment that is designed to support children's curiosity and questions. When teachers help children learn about their world through hands-on/minds-on activities, they reinforce children's natural interests and curiosity as well as strengthen children's reasoning abilities. Early childhood teachers should present science activities in ways that are natural and interesting for children.

Rutherford and Ahlgren (1990) recommend that science be taught by reducing the amount of material covered and devoting more time to developing thinking skills. They also promote making connections among science, mathematics, technology, and other curriculum areas; teaching with questions rather than with answers in order that students can be actively engaged in designing and implementing investigations; encouraging students' creativity and curiosity; and focusing on the needs of all children. As a result of activities in grades K-4, all students should develop an understanding of the following science content standards: Science as Inquiry, Physical Science, Life Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspectives, and the History and Nature of Science. Specific concepts appropriate for young learners can be found in the *National Science Education Standards* (NRC, 1996).

When designing educational science experiences that focus on learning in a social context, teachers need to remember that there may be more activity and noise in the classroom than when content is presented in a direct instruction format. Although a classroom of science learners need not sound like a circus, nor should silence be expected. The ultimate goal is for children to construct their own science knowledge and become productive, contributing, scientifically literate citizens.

What Is Early Childhood Mathematics?

Mathematics is a part of children's daily lives; therefore, they should be provided with a strong foundation. According to the National Council of Teachers of Mathematics (NCTM) (2000), "[M]athematics learning builds on the curiosity and enthusiasm of children and grows naturally from their experiences" (p. 73). From birth to grade 2, cognitive growth in children is strong (Bredekamp & Copple, 1997). Children learn by thinking, doing, collaborating, sharing, and communicating about their experiences. Educators need to have high expectations of children and be aware of the many ways they learn mathematics (NCTM, 2000).

Many mathematics concepts develop informally before children enter school. Once children reach school age, mathematical concepts become solidified as children continue to explore their world through informal (play) and formal experiences. Children experience the concept of time as their daily routines follow certain sequences and patterns. They experience order as they discover and practice patterning. Children experience distance as they travel to and from school, and move about their classroom and school building. They experience sorting, comparing, creating sets, matching, one-to-one correspondence, classifying, counting, problem-solving, and graphing as they determine how many students are present each day; how many napkins are needed for a group of students; the number of girls in their classrooms versus boys; the number of sunny, rainy, and cloudy days each week/month; and how tall their new plants have grown. Children experience geometry and improve their spatial relationships as they explore with blocks and puzzles, and arrange their school supplies in the limited space in their desks or classroom materials on shelves or in boxes. Children experience measurement (length, volume, and weight) when manipulating sand, water, and clay. They learn about money values when purchasing milk, lunch, and school supplies. Children also work with calculators to explore number sense and patterns. Although children's lives involve the use of numerous math concepts on a daily basis, they need support from others in order to formalize critical early childhood math concepts that act as the foundation for the more abstract math concepts that they will be introduced to in later school years (Charlesworth & Lind, 2003).

Our world continues to progress and change. In order to improve the futures of our children, all children should have the opportunity and support necessary to learn and understand mathematics. Doors open for those with mathematical competence (NCTM, 2000).

The Principles and Standards for School Mathematics (NCTM, 2000) addresses six overarching themes: (1) equity, (2) curriculum, (3) teaching, (4) learning, (5) assessment, and (6) technology. The Teaching Principle emphasizes that "effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to do it well" (p. 16). The Learning Principle emphasizes that "students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge" (p. 20). In addition to promoting principles and standards for mathematics, NCTM (2000) recommends the following standards that can assist educators in providing children with a solid cognitive and affective foundation in mathematics: Number and Operations, Algebra, Geometry, Measurement, Data Analysis and Probability, Problem Solving, Reasoning and Proof, Communication, Connections, and Representation. Standards specific to young learners can be found on pages 72-141 in *The Principles and Standards for School Mathematics*.

Research on cognition reveals that children have an innate ability to learn math. Children come to school with a natural curiosity about quantitative events as well as some informal problem-solving skills (Ginsburg & Baron, 1993). Educators must effectively guide children's informal mathematical skill development in order to provide them with opportunities to construct a meaningful understanding of mathematics.

Early Childhood Science and Mathematics Learning

Quantitative events found in a child's environment are common across widely diverse cultures. According to Ginsburg and Baron (1993), preschool-age children display a natural curiosity concerning quantitative events. Children are interested in science, mathematics, and numbers: "Children's natural curiosity about their world leads them to explore concepts of mathematics and the science of pattern and order" (Kellough et al., 1996, p. 189). Children spontaneously construct informal science and mathematics on a daily basis such as counting and numbers, comparisons, classification, and order. Statements such as, "He has more than me," "She took one of my cookies," "Dad can reach higher than me," "The round pieces are mine," and "He gets to go first because he's the biggest" demonstrate informal mathematics concepts. Informal science and mathematics is made up of perceptions and invented strategies that deal with everyday quantifications. It is important for early childhood teachers to help children form meaningful connections between informal and formal science and mathematics. Formal mathematics includes rules, methods, and procedures for solving math problems and is usually acquired through adult interaction (Kellough et al., 1996). This is also very evident with children's science knowledge. Children arrive at school with a wide variety of preconceptions and misconceptions about their environment. Early childhood educators need to determine children's understandings and design learning experiences that will provide them with numerous opportunities to discover, recreate, and reinvent concepts on their own, while clarifying preconceptions and misconceptions. It is important for adults to remember that while some children's misconceptions can be corrected, conducting science experiments does not necessarily cause students to alter their misconceptions (Pine, Messer, & St. John, 2001).

Inquiry

A prominent feature of the *NSES* (NRC, 1996) is inquiry: "The term inquiry refers to the abilities students should develop to be able to design and conduct scientific investigations and the understandings they should gain about the nature of scientific explanation" (Lind, 2005, p. 6). Students who engage in inquiry participate in similar activities and processes as scientists as they seek to expand knowledge. Students on the early childhood level should begin to develop the necessary abilities to do more advanced scientific inquiry in later years (NRC, 1996). Engaging students in inquiry serves the following functions:

> *Inquiry assists in the development of the understanding of scientific concepts, helps students "know how we know" in science, develops an understanding of the nature of science, develops the skills necessary to become independent inquirers about the natural world and develops the dispositions to use the skills, abilities, and habits of mind associated with science.* (Lind, 2005, p. 62)

Inquiry instruction reflects the constructivist model of active learning whereby students create meaning from their experiences. Young students should have various opportunities to observe, investigate, collect, sort, catalog, take notes, sketch, interview, and poll (Lind, 2005; Martin, 2003). The *NSES* include the following strategies to engage young learners in the active construction of knowledge:

- Ask a question about objects, organisms, and events in the environment.
- Plan and conduct a simple investigation.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data to construct a reasonable explanation.
- Communicate investigations and explanations. (NRC, 1996)

These strategies provide children with the ability to develop process skills and make meaning of the material learned. In addition, such opportunities should reach children at all learning modalities—visual, auditory, and kinesthetic.

Problem Solving

Problem solving is the central focus of the mathematics curriculum and the hands-on/minds-on component of science explorations and investigations. Opportunities for solving problems are abundant in early childhood classrooms and provide students with excellent opportunities to develop creative and critical thinking as well as decisionmaking skills—skills that will benefit them throughout their lives.

Today's early childhood-age children will be the adults of the 21st century. Real-life situations should be incorporated into the curriculum whereby children sense problems to be solved. In order to prepare children to address the challenges that they will face throughout their lives, relevant problem-solving opportunities that stimulate creative and critical thinking must be threaded throughout the curriculum, beginning at the early childhood level. Children should be presented with teaching models that require students to demonstrate various characteristics of effective problem-solving skills, methods, and strategies such as persistence, tolerance of ambiguity, use of related knowledge, use of logical reasoning, finding a pattern, trial and error, dealing with data, planning a solution, solving a challenge, analyzing and evaluating solutions, and working cooperatively.

Problem solving is a way of life. Even the youngest of children face problems daily; therefore, teaching problem solving must begin when children first enter school, and then continue throughout the entire school experience. Since the emphasis is on the process and not merely the product, the discussion of problems, proposed solutions, and methods of attacking problems should be considered across the curriculum at all times.

A variety of emotions can be experienced during the process of problem solving. Initial feelings of enthusiasm can change to feelings of frustration if each planned attempt is met unsuccessfully. Therefore, teachers must establish an atmosphere of success by introducing relatively simple, relevant problems for children to solve. Early childhood educators should address the importance of developing children's confidence, willingness, and persistence throughout the problem-solving process. Children should be encouraged to take charge of their thinking and share responses courageously.

Early childhood educators must demonstrate interest, energy, and enthusiasm in order to develop good problem solvers. A positive attitude toward the problem-solving process is necessary in order to reach success. Teachers must demonstrate confidence in class and exhibit the same enthusiasm for the problem-solving process that they wish to instill in their children.

Early childhood educators must also prepare carefully for problem solving and be aware of the various opportunities that present themselves in everyday classroom situations. Relevant experiences involve many opportunities for team problem-solving and group brainstorming. Children should be encouraged to work in pairs or in small groups while contributing to discussions. In one approach, children in a pair could think aloud, voicing their thoughts as they attempt to solve problems. Early childhood educators should encourage children to share as many ideas for solving each problem as possible. Grouping students is a productive method for encouraging respect for one another's abilities and ideas while searching for a variety of ways to solve problems. Furthermore, reflection applied immediately after a problem has been solved is a valuable tool for children in remembering newly discovered knowledge that can later be applied to similar situations.

The early childhood curriculum should be comprised of learning opportunities that will better prepare students to encounter success in the real world. Although we cannot predict the role that technology and the challenges of the future will play in the lives of our students, as educators, we can believe that methods for problem solving will indeed improve their basic life skills and relationships with others.

Affective Domain Issues Relevant to Learning Science and Mathematics

Level of Science and Mathematics Efficacy

According to Harlan and Rivkin (2004), "[S]elf efficacy, the feeling of adequacy and effectiveness in dealing with life, is critical to learning success" (p. 8). An element involved in acquiring science and mathematics knowledge concerns teachers' and students' beliefs about their ability to learn and do science and mathematics. An individual's self-efficacy with science and mathematics is important because it determines how successful one will be with a particular task (Harlan & Rivkin, 2004; Howe & Jones, 1993). Early childhood educators need to feel confident in their ability to do and teach science and mathematics because their level of efficacy can directly influence children's abilities and desires to learn. If students perceive that their teacher is not comfortable teaching science and/or mathematics, it could directly affect their own level of confidence and success with the subject content.

Both early childhood educators and parents need to believe that all children can learn and do science and mathematics. Very few differences exist concerning gender and racial differences in learning science and mathematics on the early childhood level (Sperry Smith, 2001). Therefore, every child, regardless of race, gender, ethnicity, or language difference should have an opportunity to fully participate in science and mathematics learning experiences. If adults have low expectations of their children's abilities to learn science and mathematics, then low motivation and achievement on the part of the children may result.

Another factor that adults need to consider when working with children is that the amount of time needed to complete a task is not necessarily an indicator of a child who is less capable when learning and doing science and/or mathematics. The use of additional time may simply be another learning style that reflects caution, a desire to be thorough, or a great interest in the subject matter (Kellough et al., 1996).

Early childhood educators, unlike most educators of other grade levels, are expected to be capable of teaching all subject areas well. Yet, we know that many teachers have specific subject intelligences, preferences, and interests. Therefore, to improve student motivation and learning, teachers often team-teach or departmentalize certain subjects in order to provide children with the best available instruction and guidance. Teachers who did not have positive personal experiences with science and mathematics as children, yet are determined to provide their own students with productive learning experiences, could find help from peers or administrators. With appropriate guidance, even teachers who have had negative personal experiences with science and/or math can positively influence children's attitudes toward the subjects.

Adult and peer feedback can strongly affect a child's school experiences. It is important as parents and teachers to reinforce that everyone, including children, learns from what they do, whether the immediate outcome appears to be positive or negative. Mistake making can result in powerful learning and prove to be very beneficial. Science inventions are often the result of eager, persistent, determined individuals who have been willing to try new avenues in spite of what has or has not worked. Witnessing a variety of ways of knowing, doing, and learning in science and mathematics helps to reassure children of their capabilities as well as broaden their perspectives, even at a young age.

As educators, we need to reinforce that learning includes experiencing mistakes and learning from them. If we constantly focus on only "one correct way," we could foster science and/or mathematics anxiety and learned helplessness within our children (Renga & Dalla, 1993). If children are taught at a young age that it is okay to learn through trial and error and through their mistakes, perhaps more of them would look forward to participating in science and mathematics courses as they continue through middle school, high school, and college.

Feedback and Assessment

Teacher feedback of learning strongly influences how children view themselves as learners of science and mathematics. Ongoing assessment is vital to effective teaching. Early childhood educators must constantly know what children know in order to effectively prepare for the next lesson/activity. According to Renga and Dalla (1993),

> *Since teacher feedback is positively related to children's assessment of their abilities, teachers should provide feedback that focuses on what students do right, treats mistakes as a normal part of learning, shows them what both their skill and conceptual errors are, helps them understand why they made errors, provides them with the means for evaluating their own processes and solutions, gives suggestions for improvement, and makes them feel that they are competent.* (p. 26)

Assessment methods used by teachers can affect children's attitudes when learning science and math content. Today, teachers are encouraged to incorporate various forms of alternative assessment techniques when evaluating children (Charlesworth & Lind, 2003; Martin, 2003). Pencil and paper tests, which often create anxiety in children, are now supplemented with a variety of authentic, performance assessment methods such as oral questioning; whole class, small group, or individual discussions; progress portfolios; teacher-created rubrics; observation accompanied by anecdotal records, checklists, and/or rating scales; journal writing; and teacher/student interviews. When appropriate, it is recommended that teachers inform children in advance of the criteria for assessment—whether they involve academics, social skills, or a combination of both. Portfolios, which could include both student and teacher selected artifacts, should also have a shared set of criteria so everyone interested in reviewing a child's progress will have a firm understanding of student outcomes in relation to student expectations.

It appears that children's accomplishments in science and math can be assessed more thoroughly and fairly with the use of alternative assessment methods

(Charlesworth & Lind, 2003; Martin, 2003; NCTM, 2000). Additionally, when authentic/performance-based assessment techniques are utilized, children's various learning modalities and multiple intelligences are more likely to be evaluated.

Additional Science and Mathematics Learning Considerations

Student Interaction

Facilitating knowledge construction in a social context is in support of Vygotsky's social learning theory. Lev Vygotsky (1896-1934) theorized that children's mental, language, and social development are supported and strengthened by others through social interaction. He believed that children seek out adults for social interaction beginning at birth (Morrison, 2000).

Vygotsky studied and agreed with Jean Piaget on most topics, but he differed with him concerning the role of learning through social interaction. Vygotsky felt that learning is most effective when students work cooperatively with one another (Kellough et al., 1996). Through social interaction, children become more self-directed and gradually assume more responsibility. Additionally, children need to talk and communicate in a friendly, relaxed manner during class time. These types of interactions help children to construct concepts and enhance social competence (Shaw & Blake, 1998).

Vygotsky's noteworthy concept of the "zone of proximal development" is very significant for early childhood educators. This concept emphasizes the value of social interaction whereby an individual is capable of accomplishing more when placed with a more competent adult or peer, in comparison to working independently (Kellough et al., 1996). Vygotsky believed that children learn best when tasks are set just beyond what they can accomplish on their own, and by receiving guidance from a competent adult or peer (Morrison, 2000). Gradually, the learner masters the task and/or concept.

Cooperative Learning

According to Martin (2003), it has been established that cooperative learning fosters achievement. Cooperative learning also fosters a strong sense of community. Many discovery teaching models implemented in science and mathematics instruction can result in both content knowledge construction as well as provide opportunities for children to interact socially with their peers and adults.

Children can work cooperatively with their classmates by acting as a partner or by being a member of a group. Martin (2003) recommends that group size vary in accordance with the needs of instruction and that students should vary in ability levels. In cooperative learning groups, opportunities to brainstorm, discuss, clarify, and synthesize knowledge are abundant. Various cooperative learning group structures exist. With role taking (Materials Manager, Reporter, Recorder, etc.), each member has a specific responsibility and is held accountable for his or her contribution (Howe & Jones, 1993). Martin (2003) proposes that when working in cooperative groups, the emphasis should be on constructivist learning wherein all children do all the activities and formulate their own ideas rather than assume specific roles. Regardless of what method is used, it is very important that the seating arrangement of the classroom should support student interaction.

Another benefit of cooperative learning groups is the emphasis on positive group behavior. Children are held accountable to listen to each group member's contributions and respond in an open, positive manner; allow all group members to share their ideas; share materials; and assist each other when needed. With cooperative learning activities, children in each group help their group members rather than compete against them. Powerful social skills are experienced with cooperative learning models along with an awareness of the value of contributing to the benefit of the whole concerning shared knowledge acquisition. Group project work often motivates children to share ideas, discuss various strategies, and disagree when appropriate. Because of the many benefits of cooperative learning—both academic and social—teachers should provide opportunities for children to experience science and mathematics in cooperative learning groups.

Peer and cross-age tutors can also be used effectively when working with children in science and mathematics. Children who need clarification on specific science and mathematics concepts/content can benefit when working with a child who has a positive attitude toward science and/or mathematics; has mastered the necessary content; and who is patient, understanding, and tolerant when working with classmates. In addition, the tutors benefit as they strengthen their knowledge base and their level of efficacy with specific content through teaching others (Gallenstein & Johnson, 1998).

Activities/Games/Puzzles

Another method that teachers often utilize when promoting enthusiasm for learning science and mathematics concepts is through the use of playful activities, games, and puzzles. Constance Kamii (1986), a student of Piaget's, reinforces how children need to be presented with situations to be solved through games and activities that challenge their minds. Many challenging and thought-provoking, higher-level science and mathematics games/activities are available for children via the Internet and on CD-ROMs. Commercially made games and puzzles are also available.

One element that should be included in science and mathematics games is that of "chance." If children find that only those who have fully mastered science and mathematics concepts continually win at games/activities, those still attempting to master the concepts might very well be discouraged from playing. Including an element of chance not only serves as a motivator for participating in a game/activity, but also can serve as a catalyst for sticking with the game, which should result in additional learning.

Play

The element of play is also a key component in designing a developmentally appropriate science and mathematics curriculum. Time should be allotted for children to explore materials and discover science and mathematics concepts through play: "Free exploration and play are a need that must be fulfilled before children can see materials as learning resources" (Winnett et al., 1996, p. 8). Additionally, according to the National Association for the Education of Young Children (NAEYC), science explorations, mathematics skills, and problem-solving are fostered through play, projects, and daily living situations (Bredekamp & Copple, 1997).

A wide variety of materials should be available in early childhood classrooms for play that contributes to children's mental growth in the areas of science and mathematics. Active exploration with materials and with classmates takes time. Children should be provided with enough time to play with materials so that they are not rushed from one project or activity to another. Also, if possible, space should be made available so children who require more time to complete their intricate constructions can do so at a later time. Additionally, early childhood teachers will find that children will "let go" and be able to move onto the next project more easily if a photograph is taken of their children's creations (Walmsley & Wing, 2004). These creations can later be displayed as an acknowledgment of the children's worthwhile and quality efforts.

An assortment of blocks, sand and water tables, containers of manipulatives, prop boxes, and interest centers can aid in children's discoveries of science and mathematics concepts. Furthermore, teachers must be available to interact with children during play as they listen to their conceptions, preconceptions, and misconceptions. Teachers can encourage "talking aloud" about how a child arrived at his or her answer and encourage listening skills as children nearby explain their solutions (Sperry Smith, 2001). Questioning and guidance by teachers during play can lead children to the next level of learning.

Sense of Competence

Another factor to consider when influencing children's attitudes toward learning science and mathematics is to design activities that will allow them to succeed: "Educators must provide activities that allow success and reinforce independence for children. Open-ended activities allow children to develop confidence in their abilities to analyze" (Shaw & Blake, 1998, p. 50).

Early childhood educators need to be aware of their children's learning levels in order to design activities that are developmentally appropriate and meaningful. Teachers should challenge children but not overwhelm them. They should also design activities that range across ability levels, learning styles, and multiple intelligences (Isenberg & Jalongo, 2001). Activities should provide children with opportunities to extend their thinking and allow them to freely interact with their peers and adults as well as allow for the integration of other curriculum areas. These activities can be introduced to all children as a group during whole class instruction and then placed in learning centers. Additionally, "materials should be accessible and the curriculum developed in such a way that children can return to or repeat experiences that they have completed some time ago. Repetition reinforces children's awareness of their own competence and the confidence that awareness brings" (Winnett et al., 1996, p. 3). In order for children to fully benefit from activities, teachers should observe, ask questions, and make suggestions to them while they work.

Making Learning Meaningful

Another important factor that early childhood educators need to consider when teaching science and mathematics is that children need to understand and appreciate the relevancy of what they are learning. Children need and deserve to understand the reasons why they are learning science and mathematics content. Teachers need to connect science and mathematics knowledge to real-life situations and career opportunities for children to have a greater appreciation of the content. Relevant science and mathematics learning opportunities are abundant in classrooms, school buildings, home settings, and local communities. A local grocery store, pizza parlor, or some other community field trip holds great promise for science and mathematics learning experiences. Additionally, many children delight in having their parents/guardians/relatives share aspects of their careers that deal with relevant, meaningful science and mathematics content that are age appropriate. Children can invite adults into their classrooms as guest speakers or the teacher can arrange field trips to visit the adults' places of employment.

Subject Integration

When promoting positive attitudes toward science and mathematics learning, early childhood teachers should also take into consideration their children's interests. Most children are interested in learning about everything. They are interested in insects, furry animals—large and small, boats, cars, calculators, computers, the Solar System, simple machines, and so on. It is highly recommended that teachers encourage children to discuss their interests as well as allow them to contribute to the design of integrated thematic curriculum units. If children's interests are piqued, they will more likely be willing to participate in the designed learning experiences.

Teaching with integrated thematic units (subject integration) is a productive way to make learning relevant and meaningful for children (Charlesworth & Lind, 2003; Harlan & Rivkin, 2004; Martin, 2003). The human brain seeks meaningful connections when presented with new information; therefore, current knowledge of brain development strongly supports curriculum integration rather than always distinguishing subject areas. In-depth knowledge and understanding of a topic is promoted versus quick, shallow learning (Bredekamp & Copple, 1997). In fact, Kellough et al. (1996) state, "For higher levels of thinking and for learning that is most meaningful and longest lasting, research supports the use of an integrated curriculum and instructional techniques that involve the children in social, interactive learning" (p. v). Although curriculum integration is strongly emphasized today, John Dewey advocated the approach as early as the turn of the 20th century (Shaw & Blake, 1998).

Connecting science and mathematics content to other subject areas such as language arts can also promote positive attitudes in children. Children's literature contains numerous relevant science and mathematics concepts. Often, the story and pictures in a trade book trigger a child's science and mathematics conceptual understandings. It is so exciting to observe a child's enthusiasm when the light bulb finally shines.

According to Charlesworth and Lind (2003), children strengthen their language skills by expressing mathematics concepts and contrasting characteristics such as big, small, light, heavy, square, round, long, short, etc. Literacy skills can also be reinforced through hands-on science as children observe, explore, discover, and reinvent concepts. Children use science and mathematics thinking skills, such as comparison and classification, as they discriminate between shape, size, and amount. These skills assist children with reading and writing in that it helps them discriminate between letters in the alphabet, syllables, and words. Additionally, children strengthen their language communication skills when discussing, drawing, and acting out their science and mathematics discoveries through various forms such as recording data and using graphic aids, drama, and/or puppetry. Prop boxes and interest centers that include science and mathematics concepts are wonderful tools for allowing children to express their understandings, preconceptions, and misconceptions of science and mathematics concepts (Isenberg & Jalongo, 2001). Sequencing and cause-and-effect relationships discovered in science and mathematics can aid children when predicting story outcomes and applying information to other situations (Charlesworth & Lind, 2003). Furthermore, providing opportunities for children to record their thoughts in a journal and draw pictures about what they have learned and experienced with science and mathematics can provide a teacher with the necessary insights on how a child thinks and feels.

Summary

An understanding of children in relation to learning science and mathematics is critical for early childhood educators when designing engaging learning experiences. When designing learning experiences, attention must be given to both the cognitive and affective domains. It is vital that teachers provide a variety of teaching methods for our nation's diverse population of students to think and reason.

According to Bredekamp and Copple's (1997) position statement guidelines, good teachers will "incorporate a wide variety of experiences, materials and equipment, and teaching strategies in constructing curriculum to accommodate a broad range of children's individual differences in prior experiences, maturation rates, styles of learning, needs, and interests" (p. 18). Teachers must be flexible and willing to try a variety of teaching techniques that result in meaningful learning. Learning considerations of children such as the role of student interaction, cooperative learning, use of games and puzzles, inclusion of play, awareness of a sense of competence, value of making learning meaningful, and subject integration must be considered in order to create productive environments that facilitate science and mathematics learning in early childhood settings.

As we progress in this highly technical Information Age, children will continue to need strong foundations in science and mathematics. Technology, as the application of knowledge, is fueled by science and mathematics knowledge. Early childhood educators must provide methods for teaching science and mathematics that will generate positive attitudes in their children. Our nation is counting on educators to create open, eager minds for the future in the area of science and mathematics. If educators live up to this responsibility, children's lives will be enhanced and society as a whole will benefit.

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