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ABSTRACT

Given the social importance of math, science and technology knowledge, the importance of establishing competence in a subject area early, and the link between early experience and subsequent achievement, it is puzzling that math, science, and technology do not have greater prominence in the preschool curriculum. This paper reviews some of the forces and trends that help frame early childhood curricula in these subjects, noting that controversy over teaching mathematics and science in preschools often begins with the conflicting theories of development and learning. The differing theoretical perspectives examined include the constructivist theory; the Romantic view of children rooted in Rousseau's theories; the basic skills approach; the social context perspective; and the developmentally appropriate practices perspective. Each theory offers a different emphasis on science and math. The paper also suggests that some conflict about how and what to teach young children arises from differing beliefs about the future and educational needs of citizens of the twenty-first century. The effect of educational quality concerns on preschool science and math is also addressed; generally, questions about standards have led to back-to-basics practices which reject new standards and teaching methods that might include interactive learning and motivation for science and math activities. Finally, the paper explores issues posed by involving high-risk children in math and science curriculum. (JPB)

MATH, SCIENCE, AND TECHNOLOGY IN EARLY CHILDHOOD EDUCATION

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Barbara Bowman

Math, science, and technology are not generally thought of as curricula for young children. Aside from counting, number recognition, growing plants, and learning food groups, math, science, and technology are generally given short shrift during the preschool years. Nevertheless, the roots of later competence are established long before school age and recent findings from neuroscience confirm the importance of the link between early experience and subsequent achievement. Given the connection, why has so little attention been given to what and how young children acquire their knowledge of math and science or how teachers and parents can enhance it? The limited attention is not surprising because literacy commands so much time during the preschool/primary years that there is often little left for other subjects. Further, the knowledge base for math, science and technology is formal, orderly, abstract, and based in a stern reality, whereas young children's learning is informal, relational, concrete, and often heavily imbued with fantasy. Nevertheless, how best to structure early learning to help children make connections to the formal disciplines is important and should be of interest to parents, educators, and policymakers.

Math, science, and technology are ubiquitous in our society. Even without organized curricula and instruction, children form an informal or intuitive base of knowledge of concepts in these disciplines through their interactions with people and things. They have many opportunities to consider numbers of objects, to observe physical

phenomena, to use technologically driven equipment (telephones, televisions) and to make hypotheses regarding cause and effect. Although some of the concepts they form are incorrect (presumably due to their immaturity and limited experience), the process of "doing" science and math and using technology is well established by the time children are three years old.

Over 50 percent of children between three and five are enrolled in preschool programs that provide somewhat organized learning experiences. However, there are no state or nationally enforced preschool curricula, nor are there commonly accepted math, science, or technology standards in these programs. So, as with children who stay at home, the amount and quality of their experience is extremely dissimilar. Nevertheless, there are forces that exert pressure on preschools and parents and create some coherence in what young children are apt to learn. In this paper I shall briefly review some of the forces and trends that help frame early childhood curricula in math, science, and technology.

The most contentious issues in education surround what to teach children and how to teach it. These issues have been bitterly contested throughout the century, primarily in public education, but increasingly in preschool education. Early childhood is defined as the years between three and eight, and educators have become concerned about discontinuities in the curricula between preschool, kindergarten, and the primary grades. At the core of the disagreements are different beliefs about development and learning and the needs of society.

THEORIES OF DEVELOPMENT AND LEARNING

Differences of opinion about how children learn and the content and methods for teaching have drawn adherents into bitter controversies, occasionally described as wars, and programs have made pendulum swings as one theory or another gained prominence. The "theory" disagreements have filtered into the preschool field as more children are enrolled in formal programs.

Constructivist Theory

Currently, the most influential theoretical position is often called "constructivist," or "progressive," and emphasizes the importance of young children constructing knowledge (understanding concepts) through their own activity, as opposed to simply being told correct answers by others. Children are encouraged to handle objects, observe and predict results, hear and use language, and collaborate with adults and older children to develop ideas. Children's own motivations and concerns are critical in shaping the learning process since engagement of the learner and control of the pace and type of information to be processed are essential characteristics of this type of teaching and learning. Although children may temporarily make mistakes in understanding, it is important for adults to encourage them to learn through doing and to have confidence in their own ability to think. This perspective speaks to the importance of relationships with others that either confer on learning the mantle of adventure, discovery, meaningfulness,

and pleasure or that of drudgery and monotony.

The Romantic View

A second perspective stems from the "romantic" or "Rousseau" view of young children in which they are thought to learn best when following their own interests and inclinations. According to this view, children are naturally curious about their world and will learn best through exploration, play, and practicing what they observe around them. Maturation, determined by the individual growth pattern of each child, is critical to understanding and enjoying formal learning. Forcing children to prematurely master adult knowledge systems before they are ready is thought to compromise their potential. Concern is often expressed about hurrying children into academic learning, rather than waiting until the child is mature enough to have laid a solid foundation. According to this view, formal learning should be delayed until children demonstrate their cognitive, social, emotional, and physical readiness to learn in school, until at least five or six years of age.

Basic Skills

Another perspective, often called the "direct instruction" or "basic skills" approach, focuses on young children's ability to "learn by rote" without fully understanding the ideas being expressed. Children can learn to perform specific skills (counting, adding) without knowing the precise meaning of their activity. For instance, a young child may say the number words correctly, but not point to a different object with each word, indicating that he or she has not mastered the relationship between number

words and the number of objects. Frequent practice of correct responses, however, is considered key to acquiring knowledge, and drill and practice sets the stage, if it is not a precondition, for understanding. Therefore, learning to count by rote, for instance, lays the foundation for understanding numbers. Advocates of this position identify a limited set of basic skills—counting, alphabet naming, number facts, etc.—which they believe young children can and should learn and consider such learning the building blocks for solving problems.

The Social Context

A fourth perspective focuses on the social context in which math, science, and technology are embedded. The empirical nature of these disciplines has led many people to assume they are "culture free," and this is certainly not the case. The basic assumptions about the nature of these disciplines are a part of western culture and must be learned. Further, children understand the personal meaning of math, science, and technology in the context of their own families and communities. Whether these disciplines are viewed as useful concepts for everyday life or as esoteric subjects only relegated to school comes through children's early interactions with their family, friends, and community members. Thus, children from different social classes and ethnic groups often do not learn about the disciplines in the same way as mainstream children, nor do they have the same expectations regarding their own acquisition of knowledge. According to this view, many low-income and minority-group children have fewer opportunities to engage with knowledgeable adults about the disciplines, their parents and teachers do not set high

expectations for their school learning, and their achievement suffers. This argues for parent education and support so that families can, in turn, support children's school achievement.

Support for all of these teaching/learning theories is easily found. Children explore and play with a variety of toys and materials, discuss with others how and why things work or happen, learn the conventions of the alphabet and numbers by rote in songs and games, observe older members of their family's use of math, science, and technology concepts. What differs is the relative emphasis advocates of each perspective place on their own approach in structuring programs for children.

Developmentally Appropriate Practices

Professional organizations have been among the most outspoken advocates of moving programs for young children toward more "progressive" theory. The National Association for the Education of Young Children (NAEYC), under the rubric "developmentally appropriate practices" (DAP) has probably had the greatest influence on what and how preschool children are taught. DAP reflects "constructivist" theory and directs teachers' (and parents') attention to children's individual differences in temperament and the pace of growth, age related abilities and learning styles, and cultural differences. Although no explicit curriculum is suggested, math, science, and technology are included as appropriate subject matter, with preference given for activities that are meaningful to children rather than having them learn primarily through drill and practice.

The National Association for the Education of Young Children, with over 100,000

members, has actively disseminated this position to its members and to other professional organizations. The concept of "developmentally appropriate practices" has found broad acceptance in allied fields. It has been endorsed by the National Association of Early Childhood Specialists in State Departments of Education, the National Association of Elementary School Principals, and the Council for Exceptional Children's Early Childhood Division and is consistent with recommendation of state departments of education and a broad range of professional organizations, including the National Council of Teachers of Mathematics and the National Academy of Sciences.

The DAP perspective has been frequently misinterpreted. It is not a model but a set of principles on which to select curriculum based on a number of different factors, such as the age of the child, individual interests, and maturation rates. Unfortunately, and too often, the principles have been taken as laws to prohibit academic content in preschools. Therefore, math and science instruction has been left to the whims of children's interests rather than being cultivated by thoughtful and developmentally appropriate programming. NAEYC has protested this as polarizing "into either/or choices many questions that are more fruitfully seen as both/and," and has sponsored a number of initiatives designed to correct this impression among teachers, administrators and the general public.

CHANGES IN MATH, SCIENCE, AND TECHNOLOGY

At least some of the heat about how and what to teach young children is generated because advocates have different beliefs about the future and the educational needs of citizens of the 21st century. The last quarter of the 20th century has seen a dramatic shift in how people organize their thoughts about the world, its resources, and their relationships with one another. The transformation in thinking is comparable to earlier paradigm shifts that took place during the commercial and industrial revolution. Among the characteristics of this new revolution are:

- reorganization of knowledge systems through the use of high-powered computers;
- access to inexpensive audiovisual and computer hardware and software, worldwide computer networks, and interactive technologies;
- new symbol systems (computer programming) and the use of old systems in new ways (word processing, calculators, etc.); and
- new models for understanding the world (artificial intelligence and problem simulations).

Many professionals in math, science, and technology envision new demands on their disciplines in the postindustrial world. They now assume a world in which new knowledge is quickly generated and even more quickly disseminated, thereby requiring students to have a broader range of skills and knowledge, to be more facile in their use of what they know, and to be ready to solve new problems. For instance, the National Council of Teachers of Mathematics (NCTM) published high standards for teaching

math. NCTM criticized traditional curricula as being preoccupied with computation and rote activities and failing to foster mathematical insight, reasoning, and problem solving. More serious, they contend that young children learn in the early grades that mathematics does not make much sense and they question their own ability to understand and learn.

The American Association for the Advancement of Science and the National Research Council of the National Academy of Sciences are similarly ambitious for the achievement of young children and also focus on problem solving, direct experience, and understanding as the primary goals. As with the NCTM standards, content ranges over an extensive list, including physical, biological, and chemical sciences, and encourages observation and simple experimentation. A separate standard focuses on helping students connect science and technology by giving them first-hand experience with technological products such as zippers, coat hooks, and can openers. Technology advocates are concerned that children learn to use computers as tools to extend their ability to solve problems rather than simply learning to how to perform specific skills from pre-programmed problems and solutions. They endorse the idea that children should be engaged in meaningful activities in which they act as doers and thinkers rather than as recipients of information from teachers.

IMPLEMENTING PROGRAMS

Over the past quarter century, there has been increasing concern about the quality of education in the United States. Politicians and business leaders, in particular, have been concerned that American children are losing the competitive edge as compared to children from other industrialized countries who often test better in math and science than American children. The National Governors Association, Congress, state governments, and local school districts have taken up the challenge to improve schools by setting high standards, assessing children's performance, and holding schools accountable. The result is that each state has devised its own standards and assessment strategies, and accountability measures and local school districts are expected to demonstrate the steps they will take to achieve the state goals. While this has resulted in new and creative practices in some schools, in others it has led to a call to a return to traditional practices emphasizing basic skills, and whole-class, direct instruction, even in preschool.

Although state and local standards, assessment strategies, and accountability practices focus on kindergarten through 12th grade, they have influenced early childhood programs in a number of ways. The first National Education Goal defined by Congress and the nation's governors, "All children will come to school ready to learn," has energized public support for pre-kindergarten programs to serve at-risk children. As a consequence, national allocations for Head Start have risen and states have increased their own funding for pre-kindergarten programs. In addition, the Department of Health and

Human Services and various states and localities sponsor initiatives to influence the quality of day care programs

Pressure on public schools to improve programs has also resulted in more careful screening of children before enrollment in kindergarten, more strict age requirements, ability grouping, and a more stringent kindergarten curriculum. Parents are targeted for education programs (such as Parents As Teachers in Missouri) to encourage them to help prepare their children for school. Two-generation literacy programs as well as GED instruction and work training, have also been connected to early childhood centers. Unfortunately, these programs have proven only moderately effective. In some areas there has been pressure on parents and teachers to hold children back who are not socially mature and achieving at the normative level—despite the lack of evidence that retention in preschool results in better performance in kindergarten.

Despite the overwhelming support of professional organizations for promoting curricula and methods that foster active and interactive learning and that motivate children to enjoy science and math activities, a backlash has built up in public education against the new standards and teaching methods. While there are probably many reasons for this, at least one is the inadequacy of current assessment techniques. As the result of using standardized tests as the primary way of determining children's learning, many public schools (and parents and legislators) have advocated curricula and teaching methods more likely to raise children's scores. Whole group, direct instruction is most in tune with this goal given the financial constraints on many school districts. In addition, the decreased ability to perform traditional computational skills has shaken the public's

faith in new standards and methods.

Another deterrent to implementing math and science standards is the inadequate preparation of teachers. Preparing children to meet the new high standards is a major challenge for teachers who, themselves, are unsure of the nature and implications of the change. Even college-level general education courses are often focused on operations rather than problem solving. Preschool teachers, many of whom are paraprofessionals without a general education background, are even less able to implement the ambitious programs recommended by the professional associations.

The media have taken up the banner of early learning and also present opportunities for young children to learn math, science, and technology. The groundbreaking program, Sesame Street, is still the most widely viewed program by our young children. Although Sesame Street tries to make math and science knowledge meaningful to children in each program segment, the format still relies heavily on rote counting and alphabet naming. Other programs, such as Mr. Rogers, fit math and science concepts into everyday contexts, focusing on meaning rather than memorized facts. Book publishers are similarly engaged in disseminating math and science ideas to young children. Again, many of these stress rote counting and naming alphabets, but many also embed numbers and science concepts into stories and poems.

There is little evidence that any one television program, book, or computer program alone can account for what young children know and are able to do. However, it is clear that children who are exposed to multiple opportunities to learn through the media, books, and computers, as well as those who have knowledgeable family members

and preschool teachers, are more likely to be well prepared for school than children who do not have such reinforcement.

HIGH-RISK CHILDREN

The first National Education Goal "All children will start school ready to learn" implicitly recognizes the importance of good cognitive physical, social and emotional health if children are to achieve well in school. Some low income and some minority group children—primarily African American, Latino, and Native American—arrive at school already disadvantaged since they are less likely to have the same opportunities to learn "academics" as do mainstream children. Children from low-income families are less likely to attend preschool (by a gap of 24 to 52 percent). Head Start still does not serve all of the eligible low-income four-year-olds and also serves fewer than 20 percent of eligible three-year-olds.

However, the idea of high quality early childhood education for children at risk is gaining broad acceptance, though children judged to be "at risk" are more likely to participate in skill-centered programs than in ones which offer multiple, rich opportunities to "learn by doing." Driven by the wish to raise low scores on standardized tests, schools and centers frequently endorse drill-and-practice type activities. Many parents in low achieving schools prefer such programs since they have clearer learning outcomes which can be assessed by the parents as well as the school or center. Further,

programs that serve children who come from families and communities that do not use much math, science, and technology in their daily lives are less apt to focus on these disciplines. Nevertheless, most early childhood educators still support the notion of providing a greater variety of opportunities to learn through direct experience.

Young children share their community's perceptions of the place of math, science, and technology in the social world and the individual's relationship to them. There is probably nothing "inevitable" about the way these subjects are integrated into the social fabric of our society. Young children can learn which skills are "socially desirable" and expected of them or conversely, what knowledge is exclusive and more available to some people than to others. In contemplating the social context of teaching, policymakers must be mindful that institutions tend to duplicate current power relationships among people. They must consider the effect, for example, of offering middle class children opportunities to play with ideas while providing few such chances for poor children. What seems to be needed is a balance between skills and intellectual content and between teacher-directed curricula and their children's own interests and motivation to learn. Children may learn to view math and science concepts as "the single truth" available to a few or as one way of looking at the world open to all. The choice is ours to offer.

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