MATH AND SCIENCE FOR YOUNG CHILDREN

3RD EDITION

Rosalind Charlesworth
Karen K. Lind

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MATH AND SCIENCE FOR YOUNG CHILDREN

DEDICATION

This book is dedicated to:

the memory of a dear friend

ADA DAWSON STEPHENS

—R. Charlesworth

and

my loving husband

EUGENE F. LIND

—K. Lind

Preface

Math and Science for Young Children, Third Edition, is designed to be used by students in training and teachers in service in early childhood education. To the student, it introduces the excitement and extensiveness of math and science experiences in programs for young children. For teachers in the field, it presents an organized, sequential approach to creating a developmentally appropriate math and science curriculum for preschool and primary school children. Further, it is designed in line with the guidelines and standards of the major professional organizations: NAEYC, NCTM, NSTA, AAAS, and NRC.

Activities are presented in a developmental sequence designed to support young children's construction of the concepts and skills essential to a basic understanding of mathematics and science. A developmentally appropriate approach to assessment is stressed in order to have an individualized program in which each child is presented at each level with tasks that can be accomplished successfully before moving on to the next level.

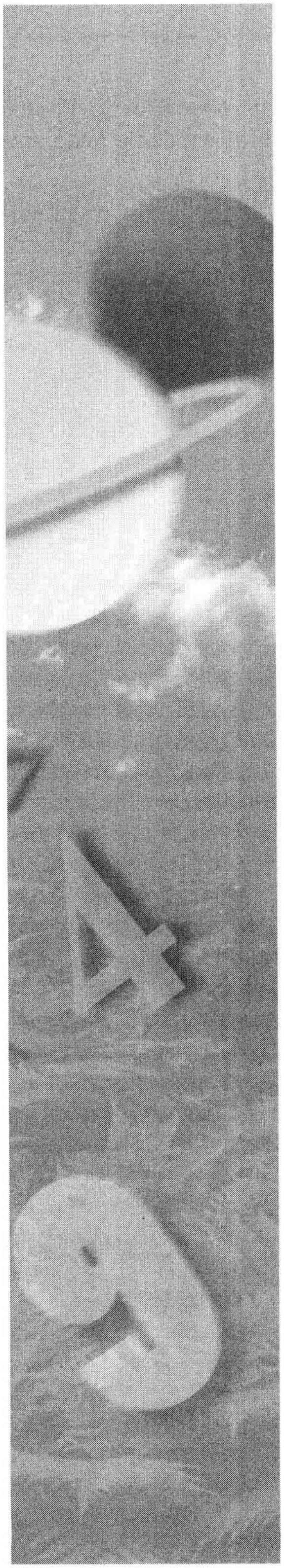
A further emphasis is placed on three types of learning: naturalistic, informal, and structured. Much learning can take place through the child's natural exploratory activities if the environment is designed to promote such activity. The adult can reinforce and enrich this naturalistic learning by careful introduction of information and structured experiences.

The back-to-basics and pressure-cooker instructional practices of the eighties and nineties produced a widespread use of inappropriate instructional practices with young children. Mathematics for preschoolers has been taught as "pre-math," apparently under the assumption that math learning begins only with addition and subtraction in the primary grades. It has also been taught in both preschool and primary school as rote memory material using abstract paper and pencil activities. Science, on the other hand, has been largely ignored with the excuse that teaching the basics precluded allowing time for science. This text is designed to counteract these developments and to bring to the attention of early childhood educators the interrelatedness of math and science and the necessity of providing young children with opportunities to explore concretely these domains of early concept learning. Further integration is stressed with language arts, social studies, art, and music with the goal of providing a totally integrated program.

Rosalind Charlesworth is a professor in the Department of Child and Family Studies at Weber State University in Ogden, Utah. She also works with the faculty of the Department of Teacher Education to develop continuity from preprimary to primary school in the program for students in the early childhood education licensure program.

Karen K. Lind is an associate professor in the Department of Early and Middle Childhood Education at the University of Louisville, Kentucky, where she is the recipient of the 1993 Distinguished Teaching Professor award from the university. Dr. Lind is the National Science Teachers Association (NSTA) Teacher Education Director and is Chair of the Science Teacher Education Committee. Dr. Lind's career in education has included teaching young children of differing socioeconomic backgrounds in a variety of settings. Dr. Lind has recently returned from the National Science Foundation where she was a program director in the Teacher Enhancement and Instructional Materials Development programs. Dr. Lind is a member of the Board of Examiners for the National Council for Accreditation of Teacher Education (NCATE) and is a member of the NCATE New Professional Teacher Standards drafting committee. Dr. Lind is past president of the Council for Elementary Science International (CESI). She is the early childhood column editor of Science and Children, a publication of the National Science Teachers Association (NSTA) and a member of the NSTA Preschool-Elementary Committee. Her research publications and inservice programs focus on integrating science into preschool and primary classroom settings.

Dr. Charlesworth's career in early childhood education has included experiences with both typical and atypical young children in laboratory schools, public schools, and day care and through research in social and cognitive development and behavior. Her current research focuses on early childhood teachers' beliefs and practices. She also taught courses in early education and child development at other universities before joining the faculty at Weber State University. In 1995 she was named the Outstanding Graduate of the University of Toldeo College of Education and Allied Professsions. She is the author of the popular Delmar text *Understanding Child Development,* has published many articles in professional journals, and gives presentations regularly at major professional meetings. Dr. Charlesworth has provided service to the field through active involvement in professional organizations. She has been a member of the NAEYC Early Childhood Teacher Education Panel, a consulting editor for *Early Childhood Research Quarterly,* and a member of the NAECTE (National Association of Early Childhood Teacher Educators) Public Policy and Long-Range Planning Committees. She served two terms on the NAECTE board as regional representative and one as vice-president for membership. She was twice elected treasurer of the Early Childhood/Child Development Special Interest Group of American Educational Research Association (AERA), is past president of the Louisiana Early Childhood Association, and was a member of the Editorial Board of the Southern Early Childhood Association journal *Dimensions.* She is currently on the editorial board of the *Early Childhood Educational Journal.*



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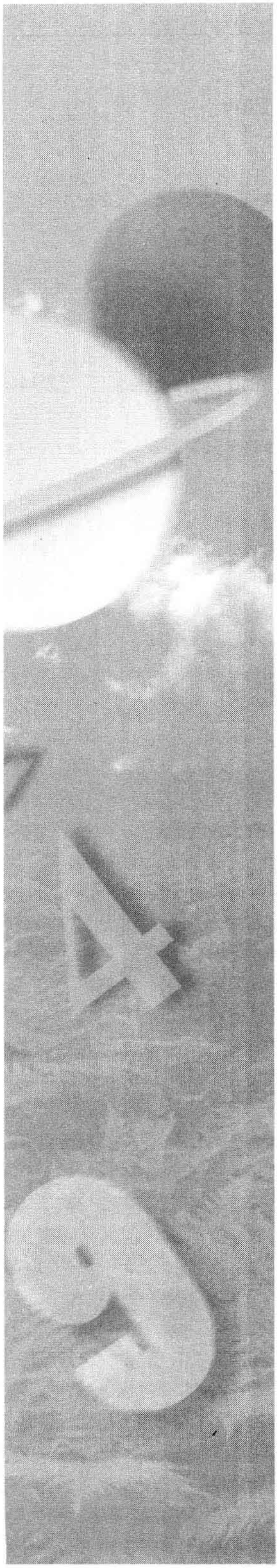


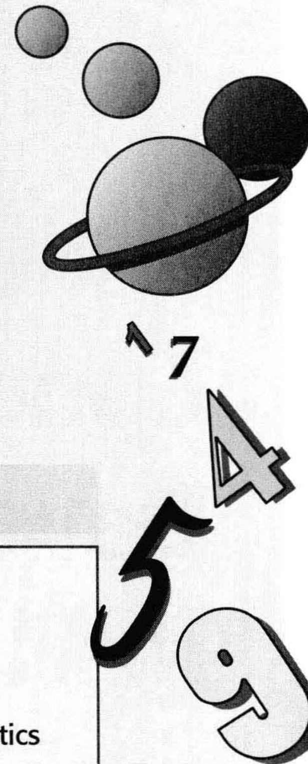
Contents

SECTION I

Concept Development in Mathematics and Science

UNIT 1

How Concepts Develop



OBJECTIVES

After studying this unit, the student should be able to

- Define concept development
- Identify the concepts children are developing
- Describe the commonalities between math and science
- Understand the importance of the professional standards for mathematics and science
- Label examples of Piaget's developmental stages of thought
- Compare Piaget's and Vygotsky's theories of mental development
- Identify conserving and nonconserving behavior, and state why conservation is an important developmental task
- Explain how young children acquire knowledge

Early childhood is a period when children actively engage in acquiring fundamental concepts and learning fundamental process skills. Concepts are the building blocks of knowledge; they allow people to organize and categorize information. As we watch children in their everyday activities, we can observe concepts being constructed and used. For example:

- One-to-one correspondence: Passing apples, one to each child at the table; putting pegs in pegboard holes; putting a car in each garage built from blocks
- Counting: Counting the pennies from the penny bank, the number of straws needed for the children at the table, the number of rocks in the rock collection
- Classifying: Placing square shapes in one pile and round shapes in another; putting cars in one garage and trucks in another
- Measuring: Pouring sand, water, rice, or other materials from one container to another

As you proceed through this text, you will see that young children begin to construct many concepts during the preprimary period. They also develop the processes that enable them to apply their newly acquired concepts and to enlarge current concepts and develop new ones.

During the preprimary period children learn and begin to apply concepts basic to both mathematics and science. As children enter the primary period (grades one through three), they apply these early basic concepts when exploring more abstract inquiries in science and to help them understand more complex concepts in mathematics such as addition, subtraction, multiplication, division, and the use of standard units of measurement.

As young children grow and develop physically, socially, and mentally, their concepts grow and develop as well. *Development* refers to changes that take place due to growth and experience. It follows an individual timetable for each child. Development is a series or sequence of steps that each child reaches one at a time. Different children of the same age may be weeks, months, or even a year or two apart in reaching certain stages and still be within the normal range of development. This text examines concept development in math and science from birth through the primary grades. For an overview of this development sequence, see Figure 1–4.

Concept growth and development begins in infancy. Babies explore the world with their senses. They look, touch, smell, hear, and taste. Children are born curious. They want to know all about their environment. Babies begin to learn ideas of size, weight, shape, time, and space. As they look about, they sense their relative smallness. They grasp things and find that some fit their tiny hands and others do not. Infants learn about weight when items of the same size cannot always be lifted. They learn about shape. Some things stay where they put them, while others roll away. They learn time sequence. When they wake up, they feel wet and hungry. They cry. The caretaker comes. They are changed and then fed. Next they play, get tired, and go to bed to sleep. As infants begin to move, they develop spatial sense. They are placed in a crib, in a playpen, or on the floor in the center of the living room. As babies first look and then move, they discover space. Some spaces are big. Some spaces are small.

As children learn to crawl, to stand, and to walk, they are free to discover more on their own and learn to think for themselves. They hold and examine more things. They go over, under, and in large objects and discover their size relative to them. Toddlers sort things. They put them in piles—of the same color, the same size, the same shape, or with the same use. Young children pour sand and water into containers of different sizes. They pile blocks into tall structures and see them fall and become small parts again. They buy food at a play store and pay with play money. As children cook imaginary food, they measure imaginary flour, salt, and milk. They set the table in their play kitchen, putting one of everything at each place just as is done at home. The free exploring and experimentation of the first two years are the opportunity for the development of muscle coordination and the senses of taste, smell, sight, and hearing. Children need these skills as a basis for future learning.

As young children leave toddlerhood and enter the preschool and kindergarten levels of the preprimary period, exploration continues to be the first step in dealing with new situations; at this time, however, they also begin to apply basic concepts to collecting and organizing data to answer a question. Collecting data requires skills in observation, counting, recording, and organizing. For example, for a science investigation, kindergartners might be interested in the process of plant growth. Supplied with lima bean seeds, wet paper towels, and glass jars, the children place the seeds in the jars where they are held against the sides with wet paper towels. Each day they add water as needed and observe what is happening to the seeds. They dictate their observations to their teacher, who records them on a chart. Each child also plants some beans in dirt in a small container such as a paper or plastic cup. The teacher supplies each child with a chart for his or her bean garden. The children check off each day on their charts until they see a sprout (Figure 1–1). Then they count how many days it took for a sprout to appear; they compare this number with those of the other class members, as well as with the time it takes for the seeds in the glass jars to sprout. The children have used the concepts of number and counting, one-to-one correspondence, time, and comparison of the number of items in two groups. Primary children might attack the same problem but can operate more independently and record more information, use standard measuring tools (i.e., rulers), and do background reading on their own.

Commonalities in Math and Science in Early Childhood

The same fundamental concepts, developed in early childhood, underlie a young child's understanding of math and science. Much of our understanding of how and when this development takes place comes from research based on Jean Piaget's and Lev Vygotsky's theories of concept development. These theories are briefly described in the next part of the unit. First, the commonalities that tie math and science together are examined.

Math and science are interrelated; fundamental mathematics concepts such as comparing, classifying, and measuring are simply called process skills when applied to science problems. (See Unit 5 for a more in-depth explanation.) That is, fundamental math concepts are needed to solve problems in science. The other science process skills (observing, communicating, inferring, hypothesizing, and defining and controlling variables) are equally important for solving problems in both science and mathematics. For example, consider the principle of the ramp, a basic concept in physics. Suppose a 2-foot-wide plywood board is leaned against a large block so that it becomes a ramp. The children are given a number of balls of different sizes and weights to roll down the ramp. Once they have the idea of the game through free exploration, the teacher might insert some questions such as, "What do you think would happen if two balls started to roll at exactly the same time from the top of the ramp?" or, "What would happen if you changed the height of the ramp or had two ramps of different heights? Of different lengths?" The students could guess, explore what happens, using ramps of varying steepness and length and balls of various types, observe what happens, communicate their observations, and describe commonalities and differences. They might observe differences in speed and distance traveled contingent on the size or weight of the ball, the height and length of the ramp, or other variables. In this example, children could use math concepts of speed, distance, height, length, and counting (how many blocks are propping each ramp?) while engaged in scientific observation. For another example, suppose the teacher brings several pieces of fruit to class: one red apple, one green apple, two oranges, two grapefruit, and two bananas. The children examine the fruit to discover as much about it as possible. They observe size, shape, color, texture, taste, and composition (juicy or dry, segmented or whole, seeds, and so on). Observations may be recorded using counting and classification skills (How many of each fruit type? Of each color? How many are spheres? How many are juicy? and so on). The fruit can be weighed and measured, prepared for eating, and divided equally among the students.

As with these two examples, it will be seen throughout the text that math and science concepts and skills can be acquired as children engage in traditional early childhood activities such as playing with blocks, water, sand, and manipulative materials, as well as during dramatic play, cooking, and outdoor activities.

In 1987, the National Association for the Education of Young Children (NAEYC) published *Developmentally Appropriate Practice in Early Childhood Programs Serving Children From Birth Through Age Eight* as a guide for early childhood instruction. In 1997 a revised set of guidelines was published (Bredekamp & Copple, 1997) by NAEYC. In 1989 the National Council of Teachers of Mathematics (NCTM) published standards for kindergarten through grade 12 mathematics curriculum, evaluation, and teaching. In 1996 the National Research Council (NRC) published the *National Science Education*

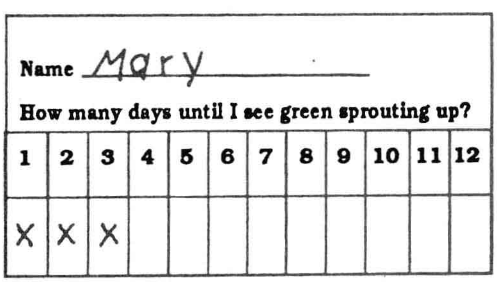


FIGURE 1–1 Mary records each day that passes until her bean seed sprouts.

Standards, which present a vision of a scientifically literate populace. They outline what a student should know and be able to do to be scientifically literate at different grade levels.

The three NCTM publications, *Curriculum and Evaluation Standards for School Mathematics* (1989), *Professional Standards for Teaching Mathematics* (1991), and *Assessment Standards for School Mathematics* (1995), set forth developmentally appropriate practices in mathematics. The NCTM curriculum standards emphasize five goals for students:

1. Learning to value mathematics
2. Becoming confident of one's own ability
3. Becoming a mathematical problem solver
4. Learning to communicate mathematically
5. Learning to reason mathematically

The major objective for mathematics instruction is *teaching for understanding*. Understanding occurs when a mathematical concept or procedure becomes a real part of the mental structure. Understanding is not present to any great degree when mathematics is learned as isolated skills and procedures. Understanding develops through interaction with materials, peers, and supportive adults in settings where students have opportunities to construct their own relationships when they first meet a new topic. Exactly how this takes place will be explained further throughout the text.

A national consensus is evolving around what constitutes effective science education. This consensus is reflected in two major national reform efforts in science education that affect teaching and learning for young children: the NRC's *National Science Education Standards* (1996) and the American Association for the Advancement of Science's (AAAS) Project 2061 (1989), which has produced *Science for All Americans* (1989) and *Benchmarks for Science Literacy* (1993). With regard to philosophy, intent, and expectations, these two efforts share a commitment to the essentials of good science teaching and have many commonalities, especially regarding how children learn and what science content students should know and be able to understand within grade ranges and levels of difficulty. Although they take different approaches, both the AAAS and NRC efforts align with the NAEYC (1987) guidelines for developmentally appropriate practice and the NCTM (1989, 1991, 1995) standards for the teaching of mathematics.

The national science reform documents are based on the idea that active, hands-on conceptual learning that leads to understanding, along with the acquisition of basic skills, provides meaningful and relevant learning experiences. The reform documents also emphasize and reinforce Oakes's (1990) observation that all students, especially underrepresented groups, need to learn scientific skills such as observation and analysis that have been embedded in a "less-is-more" curriculum that starts when children are very young.

The *National Science Education Standards* (1996) were coordinated by the National Academy of Science's National Research Council (NRC) and were developed with the major professional organizations in science and individuals with expertise germane to the process to produce the standards. The document presents and discusses the standards, which provide qualitative criteria to be used by educators and others making decisions and judgments in six major components: 1) Science Teaching Standards, 2) Standards for the Professional Development of Teachers, 3) Assessment in Science Education, 4) Science Content Standards, 5) Science Education Program Standards, and 6) Science Education System Standards.

The *National Science Education Standards* are directed to all who have interests, concerns, or investments in improving science education and ultimately achieving higher levels of scientific literacy for all students. The standards intend to provide support for the integrity of science in science programs by presenting and discussing criteria for the improvement of science education.

The AAAS initiative, Project 2061, constitutes a long-term plan to strengthen student literacy in science, mathematics, and technology. Using a "less-is-more" approach to teaching, the first Project 2061 report recommends that educators use six major themes that occur again and again in science to weave together the science curriculum: models, scale evolution, patterns of change, stability, and systems and interactions. Although aspects of all or many of these themes can be found in most teaching units, *models and scale, patterns of change, and systems and interactions* are the themes considered most appropriate for younger children.

The second AAAS Project 2061 report, *Benchmarks for Science Literacy*, categorizes the science knowledge students need to know at all grade levels. The report is not in itself a science curriculum, but it is a useful resource for people developing curriculum.

The NAEYC guidelines for mathematics and science (Bredekamp & Copple, 1997; Bredekamp, 1987) state that mathematics begins with exploration of materials such as building blocks, sand and water for 3-year-olds and extends on to cooking, observation of environmental changes, working with tools, classifying objects with a purpose, and exploring animals, plants, machines, and so on for 4- and 5-year-olds. For 5- through 8-year-old children, exploration, discovery, and problem solving are appropriate. Mathematics and science are integrated with other content areas such as social studies, the arts, music, language arts, and so on. The connections between the NAEYC guidelines and the standards for mathematics and science are described in *Reaching Potentials: Transforming Early Childhood Curriculum and Assessment, Volume 2* (Bredekamp and Rosegrant, 1995). These current standards for mathematics and science curriculum and instruction take a constructivist view based on the theories of Jean Piaget and Lev Vygotsky as described next.

Piagetian Periods of Concept Development and Thought

Jean Piaget contributed enormously to understanding the development of children's thought. Piaget identified four periods of cognitive, or mental, growth and development. Early childhood educators are concerned with the first two periods and the first half of the third.

The first period identified by Piaget, called the *sensorimotor period* (from birth to about age 2), is described in the first part of the unit. It is the time when children begin to learn about the world. They use all their sensory abilities—touch, taste, sight, hearing, smell, and muscular. They also use growing motor abilities—to grasp, to crawl, to stand, and, eventually, to walk. Children in this first period are explorers and need opportunities to use their sensory and motor abilities to learn basic skills and concepts. Through these activities the young child *assimilates* (takes into the mind and comprehends) a great deal of information. By the end of this period, children have developed the concept of *object permanence*. That is, they realize that objects exist even when they are out of sight. They also develop the ability of *object recognition*. They learn to identify objects using the information they have acquired about features such as color, shape, and size. As children near the end of the sensorimotor period, they reach a stage where they can engage in *representational thought*; that is, instead of acting impetuously, they can think through a solution before attacking a problem. They also enter into a time of rapid language development.

The second period, called the *preoperational period*, extends from about ages 2 to 7. During this period children begin to develop concepts that are more like those of adults, but these are still incomplete in relation to what they will be like at maturity. These concepts are often referred to as *preconcepts*. During the early part of the preoperational period, language continues to undergo rapid growth, and speech is used increasingly to express concept knowledge. Children begin to use concept terms such as big and small (size), light and heavy (weight), square and round (shape), late and early (time), long and short (length), and so on. This ability to use language is one of the *symbolic behaviors* that emerges during this period. Children also use symbolic behavior in their representational play, where they may use sand to represent food; a stick to represent a spoon; or another child to represent father, mother, or baby. Play is a major arena in which children develop an understanding of symbolic functions that underlie the later understanding of abstract symbols such as numerals, letters, and written words.

An important characteristic of preoperational children is *centration*. When materials are changed in form or arrangement in space, children may see them as changed in amount as well. This is because preoperational children tend to *center* on the most obvious aspects of what is seen. For instance, if the same amount of liquid is put in both a tall, thin glass and a short, fat glass, preoperational children say there is more in the tall glass "because it is taller." If clay is changed in shape from a ball to a snake, they say there is less clay "because it is thinner." If a pile of coins is