

Early Math: The Next Big Thing

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On February 6 of this year, U.S. Secretary of Education Rod Paige announced a five-year mathematics and science initiative, the first such effort since the country reacted to the Soviet Union's launching of Sputnik into space in 1957. "In this uncertain world, it is paramount that America graduate greater numbers of young people who are strong in mathematics and science," he asserted. Citing the emphasis on reading in the No Child Left Behind Act, the secretary said similar diligence must be brought to bear on encouraging students to enroll in math and science courses, training teachers, and conducting research on the most effective methods of instruction.

Unlike reading, research on math is only in the beginning stages.

Educators are anxiously waiting to see whether the "math wars" will follow the "reading wars," pitting back-to-basics advocates against those who support the more conceptual approach put forth in the standards of the National Council of Teachers of Mathematics (NCTM; 2000). There was reason for both sides to feel encouraged when the administration acknowledged that the research on math, unlike that on reading, was only in the beginning stages. An infusion of research dollars should allow the debate to be settled by empirical evidence, not politics and rhetoric.

In early childhood, the math debate centers on an even deeper issue—not only how but even whether mathematics should be taught to young children. One side says preschoolers are not ready for math, the other favors teaching counting and basic arithmetic before school entry. In reality, this polarization is pointless. National and state math standards already include math learning objectives for young children. Head Start will soon begin testing four-year-olds in numeracy as well as literacy, and state prekindergarten programs are likely to follow this lead. Early math education is here to stay.

Fortunately, not all the pressure comes from outside. The fact is, young children are themselves

interested in math. Their natural curiosity is evident in their everyday play and work. The role of teachers and parents is to provide children with the appropriate words, materials, and resources to explore their interests and scaffold new levels of understanding. To do this, we must recognize that early math is more than numbers and rote counting. It also includes preschoolers' investigations into size, quantity, categorization, patterns, space, speed, and sequence.

To support the beginning of mathematical knowledge, adults must further recognize that young children vary widely in their thinking about math. The following incident, which took place at the High/Scope Demonstration Preschool, is a good illustration (Graves, 2000b):

Nine children aged three to five were having snack with their teacher. They passed around a bowl filled with a mixture of Cheerios, raisins, and pretzel sticks, serving themselves with a large spoon. Five-year old Jessie placed two spoonfuls on her plate before giving the bowl to three-year-old Maya. "Take two spoons," Jessie advised, "so there's enough." Maya proceeded to fill her plate to overflowing and passed the still ample bowl to the next person. Jessie commented to the teacher, "Wow, you made a lot." "Yes," answered the teacher. "I used one big box of Cheerios, two big bags of pretzels, and lots of raisins!"

Before eating his snack, four-year-old Eli divided it into separate piles of the three ingredients. Then he announced, "I only like the pretzels and I didn't get too many." Five-year-old Ben was more interested in building with his snack than eating it. He inserted a pretzel stick into each Cheerio, laying them out in a row. When he ran out of pretzels but still had a few Cheerios left, he said, "I need more pretzels to finish my fence." Borrowing Ben's idea, three-year-old Natalie inserted a pretzel in a Cheerio and sang "Happy Birthday" to the teacher. When another child asked how old the teacher was, Natalie replied without hesitation, "Eleven."

In this example, five-year-old Jessie thinks about quantity and the number of people, while three-year-old Maya just wants a lot for herself. Natalie shows she has a concept of number and may even understand that 11 is bigger, and therefore “older,” than 3 or 4. Eli and Ben both compare snack components and conclude they are short of pretzels, but they reach this conclusion by different problem-solving routes. Eli sorts the ingredients and sees that pretzels, his favorite, make up the smallest pile. Ben does one-to-one matching to discover that his Cheerios outnumber his pretzels.

Three things are striking about these anecdotes. First, we see that early math is tied to concrete objects. Second, children’s actions and words present opportunities for adults to extend their thinking. Third, math thinking happens without rote lessons. However, this is not to suggest that learning happens on its own. Teachers need to systematically introduce mathematical experiences into the early childhood curriculum. Keeping the above three principles in mind, and guided by the appropriate High/Scope key experiences, teachers can promote learning in five areas of mathematics: classification, seriation, number, space, and time. (For more on the math key experiences, see Hohmann & Weikart, 2002, chapters 15–19.) To help them plan for and assess children, preschool teachers also use the related items on the new Preschool Child Observation Record (COR; High/Scope, in press).

Children’s early math thinking happens without rote lessons.

Next we offer instructional strategies for setting up the learning environment, planning the daily routine, and interacting with children around math-related concepts. We also address the challenges early childhood teachers face in seeing themselves as math educators. The article concludes with a brief discussion of how the High/Scope approach to curriculum and assessment fits within the early math framework that has been established by the NCTM and outlined in its joint position paper with the National Association for the Education of Young Children (NAEYC & NCTM, 2002).

Classification: Recognizing Similarities and Differences

Classification—grouping things according to common traits—is one way children organize their lives (for example, their toys and someone else’s, familiar

people and strangers, things that are easily carried and others that are too heavy for them). They construct relationships between similar things and develop rules for treating things the same or differently based on their attributes. High/Scope identifies seven key experiences in classification. The first four are easily observed in younger preschoolers; the other three involve a logic that is just beginning to emerge in older preschoolers.

High/Scope Preschool Key Experiences in Classification

- Exploring and describing similarities, differences, and the attributes of things
- Distinguishing and describing shapes
- Sorting and matching
- Using and describing something in several ways
- Holding more than one attribute in mind at a time
- Distinguishing between “some” and “all”
- Describing characteristics something does not possess or what class it does not belong to

Here are some ideas for making sure children have all these classification key experiences.

Learning environment. Provide and label materials that have distinct attributes like and unlike one another, such as household and natural materials with attractive characteristics (baby oil, sandpaper, shells); materials with moving parts (kitchen utensils, musical instruments, cameras); materials that change (clay, computer drawing programs, sand, water, real animals); and materials that encourage sorting according to two attributes. For example, when the teachers at one High/Scope preschool noticed the children were very interested in dinosaurs, they added a plastic set to the toy area. The dinosaurs came in two sizes (the children called them “mommies” and “babies”) and four colors (blue, green, yellow, and “Barney”). At first the teachers stored all the dinosaurs in one basket, but after hearing the children referring to them by size and color, they made a new storage box. It had four large storage cubicles on one side and four small ones on the other. The inside of each cubicle was lined in blue, green, yellow, or purple. Depending

on their developmental level, children sorted the dinosaurs by one attribute, both attributes, or not at all.

Daily routine. Encourage children to collect and sort things throughout the day, on the playground and on walks as well as in the classroom. Use cleanup as a natural time for matching and sorting (markers with their lids, dress-up clothes in one bin and doll clothes in another). Labeled storage areas not only encourage matching and sorting but also help children find and return materials independently.

Children's actions and words present opportunities for adults to extend their thinking.

Adult-child interaction. To encourage conventional and unconventional sorting, ask children to make things that are the same and to make things that are different. Encourage them to use the icon for the "no" concept (a line through the object or word). Also, challenge them with guessing games that require them to hold more than one mental image in mind. For example, "I'm thinking of something in the house area that's red and that you wear. What do you suppose it is?"

COR classification items. There are two items on the High/Scope Preschool COR that assess children's classification skills: *sorting attributes and identifying materials and properties*. The five developmental levels under *sorting attributes* progress from simply making collections to identifying at least two similarities between objects grouped together. The five levels in the other classification item start with identifying one feature of an object and move toward numbering multiple parts or features.

Preschool COR Items in Classification

Sorting Attributes

- Child creates collections of 5 or more objects.
- Child sorts a collection into smaller groups of objects that are the same.
- In sorting, child groups objects that are the same in some way but different in others.
- In sorting, child groups objects that are the same in some way and identifies the similarity.

- Child identifies 2 or more similarities between objects or groups.

Identifying Materials and Properties

- Child identifies a property of an object.
- Child identifies the material an object is made of.
- Child identifies a part of an object and the whole it belongs to.
- Child selects a material based on its properties.
- Child numbers the parts or features of an object.

Seriation: Creating Series and Patterns

In classification, objects are grouped by *similarities*; in seriation, they are ordered based on *differences* (e.g., smallest to largest) or a *repeating sequence or pattern* (e.g., alternating red and blue beads). With their growing ability to hold images in mind, preschoolers can identify and describe these variations among similar things, such as Joshua's comment that "I have lots more hair than my daddy. He's bald." They can also make decisions based on variations, such as insisting "I want the *biggest* piece of cake." Arranging things in series or patterns is satisfying for children, although their rules may change after one or two repetitions. Finally, preschoolers enjoy the challenge of matching one ordered series or set to another, for example, age and height. However, when they encounter someone like the author, who is old but very short, preschoolers find it disconcerting!

High/Scope has three key experiences in seriation. The first focuses on gross differences, and the other two involve the ability to explore finer distinctions and create patterns.

High/Scope Key Experiences in Seriation

- Comparing attributes (longer/shorter, bigger/smaller)
- Arranging several things one after another in a series or pattern and describing the relationships (big/bigger/biggest, red/blue/red/blue)

- Fitting one ordered set of objects to another through trial and error (small cup & small saucer/medium cup & medium saucer/big cup & big saucer)

Opportunities for seriation arise from manipulating materials and solving problems. Here are some strategies for giving young children these types of experiences.

Learning environment. Provide materials whose attributes can be easily compared: sets of materials in different sizes (nesting blocks, measuring spoons), materials children can use to make their own series and patterns (beads, collage materials), computer programs for recognizing and creating series and patterns, and ordered sets of materials that go together (nuts and bolts). These materials can also be stored and labeled in a way that encourages children to compare attributes; for example, keep large items of one type in a large container and smaller versions of the same item in a small container. Trace around three sizes of measuring spoons and attach these labels to a pegboard; children match the spoons to the outlines when they put them away.

Daily routine. To create opportunities for making comparisons, ask children to draw or make things that involve series and patterns, for example, a family sculpted from clay, a bead necklace, or pegboard patterns. Also, read and act out stories that feature graduated qualities, such as *The Three Bears*. Ask children to make beds for the three bears with play dough or to choose instruments varying in pitch or loudness to represent the papa, mama, and baby bears.

Adult-child interaction. High/Scope teachers validate children's attempts to compare things, and they also extend children's ideas and vocabulary. One way they validate is by *repeating* children's comments. At outside time, Abbey said, "The worms in this bush are smarter than the ones in that bush. They know to hang higher up so they don't get in my hair." Her teacher agreed, "Yes, I suppose that does show these worms are smarter." Adults also *extend* children's comments. Josh was washing his hands at one sink when his teacher Beth turned on the water in the next sink full blast. Josh said, "Mine is running slow." Beth turned down her water and said, "I made mine slower, like yours."

COR seriation items. Two High/Scope COR items address seriation: comparing properties and identifying patterns. The first progresses from using a simple statement with a comparison word to using measurement techniques and reporting results. The

second seriation item moves from simply lining up objects to extending a repeated or graduated series.

Preschool COR Items in Seriation

Comparing Properties

- Child makes or responds to a statement that includes a comparison word.
- Child describes contrasting objects using a word and its opposite.
- Child makes an object or structure smaller or bigger and comments on the change.
- Child uses a comparison word to describe the difference between two objects.
- Child uses a conventional or unconventional measuring tool and states the result.

Identifying Patterns

- Child lines up 3 or more objects one after the other.
- Child arranges 4 or more objects in a repeating series.
- Child arranges 3 or more objects in a graduated series.
- Child finds or points out a repeating or a graduated series.
- Child adds additional objects to extend a repeating or graduated series.

Number

The concept of number emerges as preschoolers sort materials into groups and collections. They see that counting involves equalities—for example, toy cars all have four wheels. In this way, number develops along with **classification**. At the same time, preschoolers see that there are ordered distinctions—for example, there is a first car, a second car, and so on. In this respect, their understanding of number develops in parallel with **seriation**. The idea of number also emerges with awareness of **one-to-one correspondence**, such as the matched series and patterns described above. Finally, number develops with **conservation**, the understanding that quantity remains fixed regardless of shape or spatial arrangement. This concept is still difficult for preschoolers. Does a line of four marbles really have

the same number as a line of four Frisbees? Generally, the larger the quantities, the more the appearance of a greater number wins out over the actual amount. With small quantities, however, counting and matching carry more weight with children.

To develop number concepts, children must exercise their current capacities, however flawed their conclusions might be.

To develop number concepts, children must exercise their current capacities, however flawed their conclusions might be. For example, Becky was the last child in her preschool to turn five. On her fifth birthday she said, “Now I’m finally the oldest in my class!” She knew that 5 was more than 4, even though she missed the idea that she would always be the youngest on the age continuum. Only by making her own observations and drawing her own conclusions can Becky build the base for the logical thinking she will need later.

High/Scope has three key experiences in number. In the first, children are often influenced by appearances as they compare two quantities. In the other two number key experiences, children apply more logical strategies to reach numerical conclusions.

High/Scope Preschool Key Experiences in Number

- Comparing the numbers of things in two sets to determine “more,” “fewer,” “same number”
- Arranging two sets of objects in one-to-one correspondence
- Counting objects

For preschoolers, number understanding comes from using manipulatives, exploring and pretending, and solving problems with materials and peers. Here are some strategies to help young children develop basic concepts about number.

Learning environment. Provide materials that encourage counting and comparing, such as beads, shells, and bottle caps. Art materials also work well; children enjoy comparing the number of colors in their paintings or the number of items in their collages. Stock materials that contain numbers, including calculators, playing cards, and simple board

games with dice or spinners. (Remember that rules are less important to young children than counting spaces as they move around the board!) Have wooden numbers to copy and trace. Finally, provide materials that fit together in one-to-one correspondence (pegs and pegboards, colored markers and tops). Children will use almost anything to create their own matched sets as they explore and play.

Daily routine. Howard Gardner has said that “preschoolers see the world as an arena for counting. Children want to count everything” (1991, p. 75). To support their love of counting, encourage children to gather and distribute materials at snack, cleanup, and small-group time. Plan group activities that involve multiple numbers of the same items, such as small toys and blocks, or pebbles and shells collected on a nature walk. Use numbers on sign-up sheets. Naomi, a teacher, helped children make a sign-up sheet for taking turns with a new camera. Several children made hatch marks after their names to indicate the number of turns they wanted.

Adults may learn more from questions children ask them than from the ones they ask children!

Adult-child interaction. When children spontaneously use numbers in their play, we advise adults to make comments but to keep questions to a minimum. Adults are more apt to learn from the questions children ask them than from the ones they ask children. Listen to the things children commonly compare, such as materials (“My tower has more blocks than yours”) and ages (“My cousin is older than us. She’s seven”). Listening to children will help you know how to respond at the level of each child’s understanding. Comment on the sets they generate (“Jason, I see you put one bear on each block. You have five bears on five blocks”). Finally, use written numbers during different parts of the daily routine, and support children who are interested in writing numbers themselves.

COR counting item. The Preschool COR counting item begins with using a number word and ends with counting and comparing the quantity in two groups of objects.

Preschool COR Item in Number

Counting

- Child uses a number word.
- Child counts objects, naming one number for each object.

- Child counts or responds to a request for 5 to 8 objects.
- Child counts 9 or more objects and uses the last number to say how many.
- Child counts two groups of objects and says which one has more.

Space

By the time they reach preschool, most children negotiate the physical world with confidence. They climb, run, and cycle. They find their way along familiar routes. They work on puzzles, build in three-dimensional space, and fill up two-dimensional space by drawing and writing. Preschoolers solve spatial problems with people and materials—who can sit nearest the teacher, how to add another block to the tower. As their command of language increases, they talk about their experience with space (“More of us can fit if we sit close together”). They form mental images of objects in space (“I need the scissors and tape from the art area—they’re on the top shelf”).

There are six key experiences describing how preschoolers construct an understanding of spatial relationships.

There are six preschool key experiences describing how preschoolers construct an understanding of spatial relationships. The first three involve actions on objects. The other three involve not only actions but also observations and interpretations about space.

High/Scope Preschool Key Experiences in Space

- Filling and emptying
- Fitting things together and taking them apart
- Changing the shape and arrangement of objects (wrapping, twisting, stretching, stacking, enclosing)
- Observing people, places, and things from different spatial viewpoints
- Experiencing and describing positions, directions, and distances in the play space, building, and neighborhood

- Interpreting spatial relations in drawings, pictures, and photographs

To provide these key experiences, enable children to move freely about the room, carrying out their plans with different combinations of people, objects, and activities. Better organization can create more space without significantly reducing the amount of materials.

Learning environment. Engage children in spatial exploration with materials they can fill and empty (continuous materials for pouring and scooping, materials that can be held and manipulated), fit together and take apart, (commercial items such as Legos and Tinkertoys and household items such as boxes and lids), and set in motion (things with wheels; things that roll, spin, and drip). Since children enjoy pictures of familiar situations, provide photographs, magazines and catalogs, art reproductions, and books; children may comment on the location depicted or spatial features they notice. Use a camera to document stages as children transform something (e.g., build a block structure). Photograph an object or event from different angles to encourage an awareness of perspective.

Daily routine. To help children focus on spatial awareness throughout the day, allow time for them to explore and work with materials on their own. Encourage them to talk about how they made things. Let them crawl, roll, bounce, and lie on their backs to view the world from various angles. Take walks so children get a sense of the school in relation to other neighborhood landmarks and see the same things from different viewpoints.

Adult-child interaction. To acknowledge and expand children’s spatial reasoning, imitate their actions and copy their positions. Allow them to solve spatial problems in their own way. For example, when the roof of Erica’s block structure kept falling down, she built an interior wall to hold it up instead of pushing the outer walls closer together. Her teacher, Linda, was tempted to tell Erica to just use a longer block, but Erica learned something about how things fit together by solving the problem with her own method. Finally, instead of always giving directions, take directions from children. Following their instructions encourages them to use words related to position, direction, and distance.

COR space item. The space item on the Preschool COR is *identifying position and direction* with five levels, from following a simple spatial direction to reading a map using an orientation word.

Preschool COR Item on Space

Identifying Position and Direction

- Child moves or places an object as requested.
 - Child uses a position word.
 - Child uses a direction word.
 - Child uses a distance word.
 - Reading a map, child uses a position, direction, or distance word.
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Time

Although time is an abstract concept, preschoolers deal with it in sensory and concrete ways. They miss a friend who is absent all week, grow bored when nothing of interest fills their time, or get angry when told to stop an activity before they are ready. Adults measure time objectively, using clocks and calendars. Preschoolers begin by measuring time subjectively, but as they begin to keep mental images in mind, they are increasingly able to see time in more symbolic ways using standard measuring devices. They can remember the past and anticipate the future, and they become aware of sequences and pacing.

Preschoolers deal with the abstract concept of time in sensory and concrete ways.

Four key experiences describe preschoolers' emerging understanding of time. The first three deal with duration, the last one with sequence.

High/Scope Preschool Key Experiences in Time

- Starting and stopping an action on signal
- Experiencing and describing rates of movement
- Experiencing and comparing time intervals
- Anticipating, remembering, and describing sequences of events

High/Scope teachers understand that children perceive time in very personal ways, relating time inter-

vals and the passage of time to familiar events, places, and feelings. Therefore, teachers create a consistent daily routine so children experience the regularity and predictability of time. They also allow children to control the use of time wherever possible, working at their own pace and for however long something interests them. The following strategies further help children develop time concepts.

Learning environment. Provide materials that children can use to signal stopping and starting (timers, stop signs, musical instruments) and things they can set in motion. Objects that foster spatial awareness (e.g., by spinning, dripping, rocking) can also be used to explore *fast*, *slow*, and other time concepts. Each movement becomes a concrete way to measure the units and passage of time. Finally, include living things indoors and outdoors to show natural cycles of plant and animal life. Take photos to help children describe and reflect on the changes in nature over time.

Daily routine. To help children anticipate each part of the daily routine, signal the beginning and end of time periods. Inform children about changes in the routine to call attention to the norm; knowing about the change in advance will also help them retain a sense of control. Encourage children to move at different rates throughout the day. For example, during a transition, ask them to move to a new area at different speeds. Encourage children to describe their intentions and activities in time-related language. Ask them to plan the sequence in which they will do something ("What will you add next?"). Ask about the timing of their actions ("Did it take longer to carry the blocks or to stack them?").

Early math education must embrace the characteristics of good early education in general.

Adult-child interaction. Comment on the speed with which things happen ("When you added another block at the top of the ramp, the cars rolled down faster"). Relate lengths of time to familiar actions or events ("It will be cleanup when the big hand on the clock points straight down"). Call attention to seasonal changes, and celebrate special occasions if and when they are meaningful to the children. Just because a date has passed on the calendar doesn't mean a child is ready to let it go. Expect children to still be playing "trick or treat" at Thanksgiving or reenacting Carla's fourth birthday party for several days afterward.

COR time item. The time item on the Preschool COR, *identifying sequence, change, and*

causality, progresses from anticipating the next event in a sequence to explaining cause-effect relationships.

Preschool COR Item on Time

- Child anticipates the next event in a sequence.
- Child describes a sequence of events.
- Child describes a change in an object or situation.
- Child compares the rates or durations of two events.
- Child explains that an event or change happens because of something else.

Staff Development

Teaching math does not come easily to many of us. Math phobia, poor preparation, and other factors all play a role. However, there are concrete things we can do to surmount these barriers.

Overcoming math phobia. When we accept that math for young children is more than numbers—that it involves logical operations like sorting and matching, arranging by size, and dealing with space and time—we realize we do these things every day in our own lives. Suddenly, math does not seem so difficult and abstract. Teachers don't have to be Einstein to teach math. In fact, when working with preschoolers, it probably helps to be grounded in the ordinary and concrete.

Providing resources. Although High/Scope does not advocate scripted lessons, there are many resources available to help teachers make math an everyday part of the classroom. The standards and guidelines of the National Council of Teachers of Mathematics (www.nctm.org) and publications of the National Association for the Education of Young Children (www.naeyc.org) are good starting points. High/Scope also offers many practical materials:

- *Educating Young Children—Active Learning Practices for Preschool and Child Care Programs* (Hohmann & Weikart, 2002) contains nearly 100 pages of adult support strategies specifically related to math and logical operations.
- The booklet and accompanying video titled *Classification, Seriation, and Number* (Preschool Key Experiences Series, High/Scope, 2003) outline and illustrate

adult support strategies for building math concepts. A forthcoming set will highlight space and time.

- The *Teacher's Idea Books* series (five volumes to date) contains several math-related experiences.
- The *Supporting Young Learners* series (three volumes to date) contains numerous math-related articles written by High/Scope consultants and teachers.
- *Literature-Based Workshops for Mathematics* contains six sets of math-related workshops for K–2 teachers.

These resources are not cookbooks—they leave a great deal of room for teacher innovation and especially for children's contributions—but they do help teachers get started. With more experience and growing confidence, teachers will generate their own ideas for math learning.

How High/Scope Fits With Standards in the Field

High/Scope and NCTM early math guidelines embrace common principles.

High/Scope curriculum and assessment materials in mathematics are compatible with the NCTM early childhood standards and NCTM's joint position paper with NAEYC. Both High/Scope and NCTM guidelines for early math education embrace the following principles:

- Informal learning does not mean education is unplanned or haphazard. Teachers can be helped to intentionally and systematically incorporate math into the daily program routine.
- True learning is neither short-term nor rote. Math—like literacy or any other content area—should be embedded in real and meaningful experiences.
- Children need to manipulate objects and explore math concepts in a materials-rich environment.
- Technology—if used age appropriately—can be one component of early math education.
- Children need time and freedom to construct, test, and reflect on their ideas about math.

- Natural conversations with adults help children extend their thinking about math.
- Staff development is critical to high-quality program implementation.
- The purpose of assessment is to gain information for teaching, not to sort children by skill level.

The joint NAEYC-NCTM position statement emphasizes that “providing good beginnings does not mean pushing down into the early years curriculum materials and teaching practices that are more effective for older children.” It is our job to make sure that early math education embraces the characteristics of good early education in general—*an understanding of child development, support for staff development, meaningful involvement of families, research-based curriculum and pedagogy, continuous assessment, and respect for everyone in the educational community.*

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To order any of the High/Scope publications mentioned in this article, go to www.highscope.org/welcome.asp. Pertinent ordering information: *The Teacher’s Idea Books* set (SM-P1161SET, \$110.00); *Classification, Seriation, and Number Booklet & Video* (SM-P1198SET, \$34.95); *Educating Young Children* (SM-P1178, \$42.95); *Supporting Young Learners* set (SM-P1170SET, \$74.95). *High/Scope Extensions—Newsletter of the High/Scope Curriculum* is available free of charge (six issues/year) to all *High/Scope Members*. To become a *High/Scope Member*, visit our Web site or call 1-800-40-PRESS. ■