Notes

I. Concepts
   a. Building blocks of knowledge
   b. Allow people to organize and categorize information
   c. Can be applied to the solution of new problems that are met in everyday experience
   d. Can be observed as we watch children in their everyday activities
      i. One-to-one correspondence
         1. Passing apples, one to each child at the table; putting pegs in pegboard holes
         2. Putting a car in each garage built from blocks
      ii. Counting
         1. 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
      iii. Classifying
         1. Placing square shapes in one pile and round shapes in another
         2. Putting cars in one garage and trucks in another
      iv. Measuring
         1. Pouring sand, water, rice, or other materials from one container to another
   e. Periods
      i. Preprimary period (years before children enter first grade)
         1. Young children begin to construct many concepts during the preprimary period
         2. Also develop the processes that enable them to apply their newly acquired concepts and to enlarge current concepts and develop new ones
      ii. Primary period (grades one through three)
         1. As children enter the primary period, they apply these early basic concept when exploring more abstract inquiries in science and to help them understand more complex concepts in mathematics, such as:
            a. Addition
            b. Subtraction
            c. Multiplication
            d. Division
            e. Use of standard units of measurement
   f. Children’s concepts grow and develop as they grow and develop physically, socially, and mentally
      i. Development refers to changes that take place due to growth and experience
         1. Follows an individual timetable for each child
         2. Development is a series or sequence of steps that each child reaches one at a time
g. Concept growth and development begins in infancy
   i. Babies explore the world with their senses
      1. Look, touch, smell, hear, and taste
   ii. Children are born curious and want to know all about their environment
      1. Develop their senses and concepts as they explore and experiment with their environment throughout childhood

II. Commonalities in Math and Science in Early Childhood
   a. The same fundamental concepts underlie a young child’s understanding of math and science
      i. Develop in early childhood
      ii. Much of our understanding of how and when this development takes place comes from research based on the theories of concept development developed by Jean Piaget and Lev Vygotsky
   b. Math and science are interrelated
      i. Fundamental mathematics concepts such as comparing, classifying, and measuring are simply called process skills when applied to science problems
      ii. Fundamental math concepts are needed to solve problems in science
         1. The other science process skills are equally important for solving problems in both science and mathematics, and include:
            a. Observing
            b. Communicating
            c. Inferring
            d. Hypothesizing
            e. Defining and controlling variables
      iii. Block building provides a setting for the integration of math and science
         1. Chalufour et al. identify the overlapping processes such as:
            a. Questioning
            b. Problem solving
            c. Analyzing
            d. Reasoning
            e. Communication
            f. Connecting
            g. Representing
            h. Investigating
            i. Common concepts of:
               i. Shape
               ii. Pattern
               iii. Measurement
               iv. Spatial relationships

III. Principles and Standards for School Mathematics and Science
   a. 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
      i. Guide for early childhood instruction
ii. Revised set of guidelines was published in 1997

b. In 1989, the National Council of Teachers of Mathematics (NCTM) published standards for kindergarten through grade 12 mathematics curriculum, evaluation, and teaching
   i. Was followed by two others
   ii. NCTM published Principles and Standards for School Mathematics in 2000, based on an evaluation and review of the previous standards’ publication
      1. Major change in the age and grade category levels is the inclusion of preschool
         a. First level is now prekindergarten through grade two
         b. Important that preschoolers are now recognized as having knowledge and capabilities in mathematics
            i. Also important to remember that not all preschoolers will enter school with equivalent knowledge and capabilities
         c. Important to recognize that preschoolers have an informal knowledge of mathematics that can be built on and reinforced
      2. Recommendations in the current publication are based on the belief that “students learn important mathematical skills and process with understanding”
         a. Children do not just memorize but have a true knowledge of concepts and processes
         b. Understanding is not present when children learn mathematics as isolated skills and procedures
         c. Understanding develops through interaction with materials, peers, and supportive adults in settings where student have opportunities to construct their own relationships when they first meet a new topic
   c. In 2002, the NAEYC and NCTM issued a joint position statement on early childhood mathematics
      i. Focuses on math for three- to six-year-olds, elaborating on the NCTM pre-K-2 standards
   d. Principles of School Mathematics
      i. Statements reflecting basic rules that guide high-quality mathematics education
      ii. There are six principles that describe the overarching themes of mathematics instruction:
         1. Equity: high expectations and strong support for all students
         2. Curriculum: more than a collection of activities; must be coherent, focused on important mathematics, and well articulated across the grades
         3. Teaching: effective mathematics teaching requires
understanding of what students know and need to learn and then challenging and supporting them to learn it well

4. Learning: students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge

5. Assessment: assessment should support the learning of important mathematics and furnish useful information to both teachers and students

6. Technology: technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student learning

e. Standards for school mathematics
   i. Standards provide guidance as to what children should know and be able to do at different ages and stages
      1. Ten standards are described for prekindergarten through grade two, with examples of the expectations outlined for each standard
         a. First five are content goals for:
            i. Operations
            ii. Algebra
            iii. Geometry
            iv. Measurement
            v. Data analysis and probability
         b. Next five include the processes of:
            i. Problem solving
            ii. Reasoning and proof
            iii. Communication
            iv. Connections
            v. Representation
         c. The two sets of standards are linked together as the process standards are applied to learning the content
   ii. In 2006, NCTM published Curriculum Focal Points
      1. Break the standards areas down by grade levels
      2. There are three Focal Points at each level with suggested connections to the other Standards curriculum areas

f. Standards for science education
   i. In 1996, the National Research Council (NRC) published the National Science Education Standards, which present a vision of a scientifically literate populace
      1. Outline what a student should know and be able to do to be scientifically literate at different grade levels
   ii. Prominent feature is a focus on inquiry
      1. 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 inquiry
2. Students who use inquiry to learn science engage in many of the same activities and thinking processes as scientists who are seeking to expand human knowledge
   a. In order to better understand the use of inquiry, the National Research Council has produced a research-based report, *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (2000), that outlines the case for inquiry with practical examples of engaging students in the process

iii. Additional addendums include:
   1. *Classroom Assessment and the National Science Education Standards* (2001)

iv. National consensus has evolved around what constitutes effective science education
   1. Reflected in two major national reform efforts in science education that affect teaching and learning for young children:
      a. NRC’s National Science Education Standards (1996)
      b. American Association for the Advancement of Science’s (AAAS) Project 2061 (1989)
         i. Has produced *Science for All Americans* (1989) and *Benchmarks for Science Literacy* (1993)
   2. 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
      a. Although they take different approaches, both the AAAS and NRC efforts align with the NAEYC (1997) guidelines for developmentally appropriate practice and the NCTM (2000) standards for the teaching of mathematics
   3. 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
      a. 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
      a. 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
\[ \text{b. Presents and discusses the standards, which provide qualitative criteria to be used by educators and others making decisions and judgments in six major components:} \]
  
  i. Science Teaching Standards
  ii. Standards for the Professional Development of Teachers
  iii. Assessment in Science Education
  iv. Science Content Standards
  v. Science Education Program Standards
  vi. Science Education System Standards

\[ \text{c. Are directed to all who have interests, concerns, or investments in improving science education and ultimately achieving higher levels of scientific literacy for all students} \]
  
  i. 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

5. The AAAS initiative, Project 2061

a. Constitutes a long-term plan to strengthen student literacy in science, mathematics, and technology

b. 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:
  
  i. Models
  ii. Scale evolution
  iii. Patterns of change
  iv. Stability
  v. Systems
  vi. Interactions

\[ \text{c. Although aspects of all or many of these themes can be found in most teaching units, models and scale, patterns of change, and systems and interactions are the themes considered most appropriate for younger children} \]

6. Second AAAS Project 2061 report, Benchmarks for Science Literacy

a. Categorizes the science knowledge students need to know at all grade levels

b. Not in itself a science curriculum, but it is a useful resource for people developing curriculum

7. One of the AAAS’s recent efforts to clarify linkages and understandings is the Atlas of Science Literacy (2001)
a. Graphically depicts connections among the learning goals established in Benchmarks for Science Literacy and Science for All Americans
b. Collection of 50 linked maps that show how students from kindergarten through grade 12 can expand their understanding and skills toward specific science-literacy goals
c. Show the connections across different areas of mathematics, technology, and science
d. Of particular interest, is the emphasis that the maps put on the prerequisites needed for learning a particular concept at each grade
   i. The maps show exactly how students from kindergarten through 12th grade can expand their understanding and skills toward specific science-literacy goals
   ii. The connections across different areas of mathematics, technology, and science are also outlined
v. NAEYC guidelines for mathematics and science
   1. State that mathematics begins with exploration of materials such as building blocks, sand, and water for three-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 four- and five-year-olds
   2. For five- through eight-year-old children, exploration, discovery, and problem solving are appropriate
   3. Mathematics and science are integrated with other content areas such as social studies, the arts, music, language arts, and so on
   4. These current standards for mathematics and science curriculum and instruction take a constructivist view based on the theories of Jean Piaget and Lev Vygotsky
   1. Recent consensus report published by the National Research Council of the National Academies of Sciences
   2. Brings together literature from cognitive and developmental psychology, science education, and the history and philosophy of science and synthesizes what is known about how children in the early grades learn the ideas and practice of science
   3. Findings from this research synthesis offer the insight that as educators, we are underestimating what young children are capable of as students of science
   4. Makes the following conclusions about what children know and
how they learn:

a. We know that children entering school already have substantial knowledge of the natural world, much of which is implicit

b. What children are capable of at a particular age is the result of a complex interplay among maturation, experience, and instruction
   i. What is developmentally appropriate is not a simple function of age or grade, but rather is largely contingent on their prior opportunities to learn

c. Students’ knowledge and experience play a critical role in their science learning, influencing all strands of science understanding

d. Race and ethnicity, language, culture, gender, and socioeconomic status are among the factors that influence the knowledge and experience children bring to the classroom

e. Students learn science by actively engaging in the practices of science

f. A range of instructional approaches is necessary as part of a full development of science proficiency

IV. Piagetian Periods of Concept Development and Thought

a. Piaget identified four periods of cognitive, or mental, growth and development
   i. Early childhood educators are concerned with the first two periods and the first half of the third

ii. First period – sensorimotor period
   1. From birth to about age two
   2. Time when children begin to learn about the world
      a. Use all their sensory abilities—touch, taste, sight, hearing, smell, and muscular
      b. Also use growing motor abilities—to grasp, to crawl, to stand, and, eventually, to walk

   3. Children in this first period are explorers and need opportunities to use their sensory and motor abilities to learn basic skills and concepts
      a. Through these activities the young child assimilates (takes into the mind and comprehends) a great deal of information
      b. By the end of this period, children have developed the concept of object permanence
         i. They realize that objects exist even when they are out of sight
      c. Also develop the ability of object recognition
         i. Learn to identify objects using the information they have acquired about features such as color,
shape, and size
d. As children near the end of the sensorimotor period, they reach a stage where they can engage in representational thought
   i. Instead of acting impetuously, they can think through a solution before attacking a problem
e. They also enter into a time of rapid language development

iii. Second period – preoperational period
   1. Extends from about ages two through seven
   2. 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
      a. These concepts are often referred to as preconcepts
      b. During the early part of the preoperational period, language continues to undergo rapid growth, and speech is used increasingly to express concept knowledge
         i. Children begin to use concept terms such as:
            1. Big and small (size)
            2. Light and heavy (weight)
            3. Square and round (shape)
            4. Late and early (time)
            5. Long and short (length)
         ii. This ability to use language is one of the symbolic behaviors that emerges during this period
            1. Children also use symbolic behavior in their representational play, where they may use:
               a. Sand to represent food
               b. A stick to represent a spoon
               c. Another child to represent father, mother, or baby
            2. Play is a major arena in which children develop an understanding of symbolic functions that underlie the later understanding of abstract symbols such as:
               a. Numerals
               b. Letters
               c. Written words
   3. Important characteristic of preoperational children is centration
      a. When materials are changed in form or arrangement in space, children may see them as changed in amount as well
         i. This is because preoperational children tend to center on the most obvious aspects of what is seen
            1. 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.”

ii. When the physical arrangement of material is
changed, preoperational children seem to be
unable to hold the original picture of its shape in
mind

1. They lack reversibility
   a. Cannot reverse the process of
      change mentally

2. Ability to hold or save the original picture in
   the mind and reverse physical change
   mentally is referred to as conservation
   a. Inability to conserve is a critical
      characteristic of preoperational
      children

4. During the preoperational period, children work with the
   precursors of conservation such as:
   a. Counting
   b. One-to-one correspondence
   c. Shape
   d. Space
   e. Comparing

5. Also work on seriation (putting items in a logical sequence, such
   as fat to thin or dark to light) and classification (putting things in
   logical groups according to some common criteria such as color,
   shape, size, use, and so on)

iv. Third period – concrete operations

1. Usually from ages seven to eleven
2. Children are becoming conservers
   a. Becoming more and more skilled at retaining the original
      picture in mind and making a mental reversal when
      appearances are changed
3. Time between ages five and seven is one of transition to
   concrete operations
   a. Each child’s thought processes are changing at their own
      rate
   b. During this time of transition, therefore, a normal
      expectation is that some children are already conservers
      and others are not

   i. Critical consideration for kindergarten and primary
      teachers because the ability to conserve number
      (the pennies problem) is a good indication that
      children are ready to deal with abstract symbolic
      activities

   1. They will be able to mentally manipulate
v. Final period – formal operations
   1. Ages eleven through adulthood
   2. During this period, children can learn to use the scientific method independently
      a. They learn to solve problems in a logical and systematic manner
      b. They begin to understand abstract concepts and to attack abstract problems
      c. They can imagine solutions before trying them out
   3. Note that this period may be reached as early as age 11, but it may not be reached at all by many adults

V. Piaget’s View of How Children Acquire Knowledge
   a. Piaget states that children acquire knowledge by constructing it through their interaction with the environment
      i. Children are continually trying to make sense out of everything they encounter
   b. Piaget divides knowledge into three areas:
      i. Physical knowledge
         1. Includes learning about objects in the environment and their characteristics (color, weight, size, texture, and other features that can be determined through observation and are physically within the object)
      ii. Logico-mathematical knowledge
         1. Includes relationships each individual constructs (such as same and different, more and less, number, classification, and so on) to make sense out of the world and to organize information
      iii. Social (or conventional) knowledge
         1. Created by people (such as rules for behavior in various social situations)
   c. Physical and logico-mathematical knowledge depend on each other and are learned simultaneously
      i. As the physical characteristics of objects are learned, logico-mathematical categories are constructed to organize information
   d. Constance Kamii, a student of Piaget’s, has actively translated Piaget’s theory into practical applications for the instruction of young children
      i. Emphasizes that according to Piaget, autonomy (independence) is the aim of education
         1. Intellectual autonomy develops in an atmosphere where children:
            a. Feel secure in their relationships with adults
            b. Have an opportunity to share their ideas with other children
            c. Are encouraged to:
i. Be alert and curious
ii. Come up with interesting ideas, problems and questions
iii. Use initiative in finding the answers to problems
iv. Have confidence in their abilities to figure out things for themselves
v. Speak their minds with confidence

2. Young children need to be presented with problems to be solved through games and other activities that challenge their minds
   a. Must work with concrete materials and real problems such as the examples provided earlier in the unit

   e. Duckworth (2006) explains how Piaget’s view of understanding focuses on the adult attending to the child’s point of view
      i. States that we should not view understanding just from the way we understand but should try to find out what the child is thinking
         1. When the child provides a response that seems illogical from an adult point of view the adult should try to find out about the child’s logic

VI. Vygotsky’s View of How Children Learn and Develop
   a. Lev Vygotsky was also a cognitive development theorist
      i. Contributed a view of cognitive development that recognized both developmental and environmental forces
      ii. Believed that just as people developed tools to aid them in the mastery of the environment, they also developed mental tools
         1. People developed ways of cooperating and communicating and new capacities to plan and to think ahead
            a. Helped people to master their own behavior
         2. Vygotsky referred to these mental tools as signs
            a. Believed that speech was the most important sign system because it freed us from distractions and allowed us to work on problems in our minds
            b. Speech both enables the child to interact socially and facilitates thinking
            c. Also believed that writing and numbering were also important sign systems
   b. While Piaget looked at development as if it came mainly from the child alone, from the child’s inner maturation, and spontaneous discoveries, Vygotsky believed this was true only until about the age of two
      i. At that point, culture and the cultural signs were necessary to expand thought
      ii. Believed that the internal and external forces interacted to produce new thoughts and an expanded menu of signs
      iii. Put more emphasis than Piaget on the role of the adult or more mature peer as an influence on children’s mental development
   c. While Piaget placed an emphasis on children as intellectual explorers making
their own discoveries and constructing knowledge independently, Vygotsky developed the concept of the zone of proximal development (ZPD).

i. ZPD is the area between where the child is now operating independently in mental development and where she might go with assistance from an adult or more mature child
   1. Cultural knowledge is arrived at with the assistance or scaffolding provided by more mature learners
   2. Vygotsky believed that good teaching involved presenting material that was a little ahead of development
   3. Children might not fully understand it at first, but they would understand in time, with appropriate scaffolding
      a. Instruction did not put pressure on development; instruction supported it as it moved ahead
      b. Concepts constructed independently and spontaneously by children laid the foundation for the more scientific concepts that were part of the culture
   c. Teachers must identify each student’s ZPD and provide developmentally appropriate instruction
      i. Will know when they have hit upon the right zone because children will respond with enthusiasm, curiosity, and active involvement

Piagetian constructivists tend to be concerned about the tradition of pressuring children and not allowing them freedom to construct knowledge independently

i. Vygotskian constructivists are concerned with children being challenged to reach their full potential
ii. Today many educators find that a combination of Piaget’s and Vygotsky’s views provides a foundation for instruction that follows the child’s interests and enthusiasms while at the same time providing an intellectual challenge
iii. The learning cycle view provides such a framework

VII. The Learning Cycle

a. The authors of the Science Curriculum Improvement Study (SCIS) materials designed a Piagetian-based learning cycle approach based on the assumption expressed by Albert Einstein and other scientists that “science is a quest for knowledge”
   i. The scientists believed that if science was to be taught, students must interact with materials, collect data, and make some order out of that data
   ii. The order that students make out of that data is either a conceptual invention or it leads to a conceptual invention
b. The learning cycle is viewed as a way to take students on a quest for knowledge that leads to the construction of knowledge
   i. Used both as a curriculum development procedure and a teaching strategy
   ii. Developers must organize student activities around phases, and
teachers must modify their role and strategies during the progressive phases

iii. The phases of the learning cycle are sometimes assigned different labels and are sometimes split into segments, but the essential thrust of each of the phases remains:

1. Exploration
   a. Teacher remains in the background, observing and occasionally inserting a comment or question
   b. Students actively manipulate materials and interact with each other
   c. Teacher’s knowledge of child development guides the selection of materials and how they are placed in the environment so that they provide a developmentally appropriate setting in which young children can explore and construct concepts

2. Concept development
   a. Teacher provides direct instruction
      i. Begins with a discussion of the information the students have discovered
      ii. Teacher helps the children record their information
   b. During this phase the teacher clarifies and adds to what the children have found out for themselves by using:
      i. Explanations
      ii. Print materials
      iii. Films
      iv. Guest speakers
      v. Other available resources

3. Concept application
   a. Provides children with the opportunity to integrate and organize new ideas with old ideas and relate them to yet other ideas
   b. Teacher or the children themselves suggest a new problem to which the information learned in the first two phases can be applied
      i. The children are actively involved in concrete activities and exploration

   i. The lessons vary according to the way data are collected by students and the type of reasoning the students engage in
   ii. Most young children will be involved in descriptive lessons, in which they mainly observe, interact, and describe their observations
   iii. Although young children may begin to generate guesses regarding the reasons for what they observed, serious hypothesis generation requires concrete operational thinking (empirical-inductive lesson)
iv. In the third type of lesson, students observe, generate hypotheses, and design experiments to test their hypotheses (hypothetical-deductive lesson)

1. This type of lesson requires formal operational thought, but this does not mean that preoperational and concrete operational children should be discouraged from generating ideas on how to find out if their guesses will prove to be true
   a. They need to be encouraged to take the risk
   b. Often they will come up with a variable solution, even though they may not yet have reached the level of mental maturation necessary to understand the underlying physical or logico-mathematical reasons

VIII. Adapting the Learning Cycle to Early Childhood

a. Bredekamp and Rosegrant (1992) have adapted the learning cycle to early childhood education

   i. Learning cycle for young children encompasses four repeating processes:
      1. Awareness: a broad recognition of objects, people, events, or concepts that develops from experience
      2. Exploration: the construction of personal meaning through sensory experiences with objects, people, events, or concepts
      3. Inquiry: learners compare their constructions with those of the culture, commonalities are recognized, generalizations are made that are more like those of adults
      4. Utilization: at this point in the cycle, learners can apply and use their understandings in new settings and situations

b. Each time a new situation is encountered, learning begins with awareness and moves on through the other levels

   i. Cycle also relates to development
      1. For example, infants and toddlers will be at the awareness level, gradually moving into exploration
         a. Three-, four-, and five-year-olds may move up to inquiry, whereas six-, seven-, and eight-year-olds can move through all four levels when meeting new situations or concepts

c. Bredekamp and Rosegrant caution that the cycle is not hierarchical

   i. Utilization is not necessarily more valued than awareness or exploration
   ii. Young children may be aware of concepts that they cannot fully utilize in the technical sense
   iii. Using the learning cycle as a framework for curriculum and instruction has an important aspect
      1. The cycle reminds us that children may not have had experiences that provide for awareness and exploration
      2. To be truly individually appropriate in planning, we need to provide for these experiences in school
d. Learning cycle fits nicely with the theories of Piaget and Vygotsky
   i. For both, learning begins with awareness and exploration
   ii. Both value inquiry and application
   iii. Format for each concept provided in the text is from naturalistic to informal to structured learning experiences
       1. These experiences are consistent with providing opportunities for children to move through the learning cycle as they meet new objects, people, events, or concepts

IX. Traditional vs. Reform Instruction
   a. A current thrust in mathematics and science instruction is the reform of classroom instruction, changing from the traditional drill and practice memorization approach to adoption of the constructivist approach
      i. A great deal of tension exists between the traditional and reform approaches
         1. Telling has been the traditional method of ensuring that student learning takes place
         2. When a teacher’s role changes to that of guide and facilitator, the teacher may feel a lack of control
      ii. Current research demonstrates that students in reform classrooms learn as well or better than those in traditional classrooms