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Process-Oriented Inquiry—A Constructivist Approach to Early Childhood Science Education: Teaching Teachers to Do Science

David Jerner Martin
Raynice Jean-Sigur
Emily Schmidt
Kennesaw State University

Process-oriented inquiry can help preservice and inservice early childhood teachers implement constructivist science education in their own classrooms. In this article, we discuss the basic elements of process-oriented inquiry applied to early childhood science education, show how we foster the development of process-oriented inquiry teaching skills with our preservice early childhood education students, and argue that the validity of children's conclusions is more important than right or wrong answers.

Introduction

Children are natural-born scientists. They are naturally inquisitive and begin doing science from the moment of birth by observing and sorting out their world—perhaps even earlier. They play with their hands and feet and with their fingers and toes, with blankets and toys, and with just about anything near them. They look; they manipulate; they move things this way and that; they throw; and they chase. Their eyes go wide with excitement when they encounter something new. They exhibit natural curiosity about almost everything—what things are, how things work, and how things are related to each other. The teacher of early childhood science has a wonderfully rich palate with which to work.

Science education capitalizes on this natural curiosity of children. It encourages children to construct information in ways that are meaningful to them. It focuses on experiences children do themselves—on doing rather than acquiring. The competent teacher of early childhood science encourages children to wonder, to ask questions, to explore possible answers to these questions, and to construct their own conclusions.

Teachers tend to teach the way they were taught. Many preservice teachers were taught science in a didactic manner and were required—unsuccessfully—to learn scientific facts, concepts, and theories through texts and worksheets. They perceive the job of the science teacher to be the skillful impartation of scientific facts and concepts to children, perhaps bolstered by an activity or two designed to demonstrate the truths of the material they are presenting. They believe the teacher's manual provides all the needed information. Children are discouraged from "actively making meaningful connections to their existing knowledge" (Ulerick, 1989, p. 2). As Penner (2001) writes, "Science education in school typically focuses on accumulating facts. . . . Scientific activity is often restricted to prepackaged experiments that are little more than demonstrations of the state of current scientific knowledge. The tacit goal in these experiments is to reproduce a known effect" (p. 1).

Many preservice teachers believe they do not know enough science to be able to teach it. Without a different model, they will tend to teach science to their students in the same didactic manner they were taught, if they teach it at all. It is critical for professors of early childhood science education to model a better way of teaching science—one that encourages students to inquire and form conclusions that are meaningful and understandable to them.

One of the primary goals of science education is to teach children how to do science through applying the processes of science in individual inquiries (Bruner, 1965; National Research Council [NRC], 1996; Rutherford & Ahlgren, 1990). In this paper, we describe a constructivist model we use to help early childhood teachers develop confidence and skill in teaching children how to do science. We call it process-oriented inquiry. We discuss the nature of this methodology, and we provide some examples appropriate for teachers of early childhood science. The best way for teachers to become comfortable in teaching science is to explore for themselves some activities intended for the children they teach. In our classes, students carry out activities and then construct ways they can implement them in actual classrooms. By doing the activities themselves, they gain familiarity with them and their use through first-hand experience. First, they conduct the activities in class in small groups. Next, they reflect on what they have learned and on their feelings about being encouraged to construct their own conceptualizations through their own explorations. Then, they develop lessons for young children which use the process-oriented inquiry activities from class as well as other activities that promote inquiry. The lesson plan format we suggest for use by preservice early childhood teachers is shown in Figure 1.

Figure 1. Preservice Teacher Lesson Plan Format for Early Childhood Science Activities

1. Targeted age or grade level
2. Scientific process(es) and topic addressed
3. Process objective
4. Student discovery objective
5. Description of introductory activity and initial discussion
6. Materials needed
7. Description of activities
8. Typical question
9. Encourage student investigation
10. Expected conclusions
11. Assessment
12. Applications to real-life situations

Scientific Processes

The processes of science are actions people take when they do science. Twelve processes make up the scientific endeavor and can be divided into the basic and the integrated processes. They are as follows:

Basic Processes

1. Observing
2. Classifying
3. Communicating
4. Measuring
5. Predicting
6. Inferring

Integrated Processes

7. Identifying and controlling variables
8. Formulating and testing hypotheses
9. Interpreting data
10. Defining operationally
11. Experimenting
12. Constructing models

Scientific inquiry is based on the application of these twelve processes. In our work, we help teachers become familiar with these scientific processes and explore ways in which they are utilized so they can help children learn to use them. Many activities our students do in class are described in the following paragraphs. Although many of these activities are explained in textbooks, we require students to do them so they will have the experiences that will enable them to facilitate the inquiries of the children they will be teaching.

Basic Processes

The basic processes form the foundation for scientific investigation. They embody the primary skills that underlie all scientific investigation and, therefore, comprise the chief focus of the early childhood science program.

Observation is the first and most important of the processes. We must observe if we are to have anything to investigate. Observing includes not only seeing, but also hearing, smelling, tasting, feeling (temperatures, textures, etc.), hefting weights, and a number of other observations using our senses. In our classes, we create environments designed to have students see, feel, smell, and so on, in order to foster the development of their powers and skills of observation. We ask them to look at shells, observe different kinds of leaves, or feel different kinds of cloth or weights of different blocks of wood. We ask them to recall what they saw on the way to school. They identify objects put in a "feely bag," observe the sizes and shapes of seeds, listen to the sounds of things dropped onto a table, look at rocks, and participate in other observational activities. Observation permeates the entire early childhood science curriculum.

The process of classifying also is known as sorting. Classification is a skill that pervades the scientific enterprise. It is a skill needed by children to help them understand seriation and spatial relationships. It is a skill children need to put facts together to form concepts, and it is essential to identifying variables as they form hypotheses and design experiments. Children should be given opportunities to classify in many different ways. It is important that teachers give children the opportunity to come up with their own classification systems. Our students sort buttons, candies, leaves, coins, shells, or just about anything else. Using their in-class activities, they learn that children can classify items in the room into those that are magnetic and those that are nonmagnetic; they can sort the materials that make up soil; or they can find similarities and differences in rocks and in seeds. Students group items that are similar and decide what these groups should be and what they should be named. Using this model, teachers ask children to do their own sorting and, from the names children give their groups, they identify the characteristics they used in their sorting.

In the process of communicating, teachers ask children to describe in clear terms what they saw, did, observed, predicted, and thought. Children first learn to identify objects and events with words. Then, they learn to describe these objects and events. Finally, they learn to express their thoughts in ways that other people can understand. Children should be given constant opportunities to communicate—not so much through answering the teacher's questions, but through offering their own comments. To foster the process of communicating, we ask students to describe what they did in their activities clearly enough that everyone can understand.

The process of measuring for young children includes five attributes: (1) length, (2) volume, (3) weight, (4) temperature, and (5) time. Mirroring the ways young children make measurements, our students use unconventional systems of measuring. Length is measured using plastic bears, counting squares, pennies, paper clips, etc. Volume is measured using paper cups, soda bottles, coffee cans, and other containers. Students investigate volume relationships in ways they will use with the children they teach. For example, they investigate how many children one bottle of soda will serve by pouring the soda into cups. Weight is measured using scales and plastic bears, counting squares, paper clips, Legos®, etc. Our students learn how to use the two-pan balance and then use it to find how many objects it takes to balance the item they are weighing. They investigate which of two cookies is heavier and which is lighter, and they explore other weight relationships.

Temperature is measured with thermometers and, of necessity, uses the Fahrenheit and Celsius temperature scales. Our students conduct several activities that deal with temperature; for example, they record the outdoor temperature every day at noon and construct a continuing graph using *Microsoft Excel* or the *Graph Club* software. Students also explore ways of determining relative temperatures using the sense of touch. Which is hotter in the summertime? Sand or asphalt? Which is colder? Soup or ice cream? What happens to the temperature of cold water if it is left in the room? What happens to hot water that is left in the room? Measuring time involves both time of day and time intervals. Children begin their understanding of the temporal relationships of minutes, hours, and days; weeks, months, and years; yesterday, today, and tomorrow; and morning, noon, and night by relating these concepts to birthdays, school activities, holiday activities, weekly home activities, etc. Our students measure time intervals using the "one-one-thousand, two-one-thousand" tool to count elapsed seconds, and use hour glasses, second hands on clocks, or stop watches to measure time intervals such as how long it takes a person to run across a field or how long it takes a ball rolling down the hall to stop.

Predicting is the process people use when they ask, "What would happen if . . .?" questions. A prediction is a way that a person describes what would happen next in a given situation or what would happen if they were to do something based on observation, experience, or scientific reason. Prediction is essential in doing science, and our students are required to predict before they try something out. Prediction opportunities abound in our classes and include such specific activities as sink-or-float and the behavior of earthworms or mealworms under various conditions.

Inferring is the process children use when they ask *why* something happened; it is an explanation of an observation. Inferential reasoning is basic to all scientific understanding. Young children should be encouraged to make inferences based on evidence whenever possible. Activities that foster the process skill of inferring can include identifying the seasons that are represented by given photographs, the kind of animal other children are pretending to be, or what direction the wind is blowing; playing games such as *Twenty Questions*; identifying unknown hidden objects; and so on. Our students actually do several of these activities. We require them to give the reasons for their inferences in addition to the inferences themselves. It is crucial that teachers ask for the reasons why children inferred what they did. An inference without a reason is useless.

Playing with water is an example of young children using several processes of science to investigate something of interest to them (although such an activity may be viewed as free play, messy, and nonfunctional by some teachers). Young explorers love to splash and pour water, and this is a wonderful opportunity to help children do science by asking such questions as "How does the water feel?" (observing), "What do you think makes it feel that way?" (inferring), "What sound would the water make if you hit it with the palm of your hand?" (predicting), and "What sound would it make if you clap your hands in the water?" (predicting).

The child observes what water looks like, what it does, how it moves, and how it feels. At some point the child begins to classify this knowledge: "This is water; this is not." "This is wet; this is not." Communicating newly discovered information about water occurs through body language such as splashing, squeals of delight, or choosing to explore the water table during playtime. Children may use new words in an effort to communicate and may repeat the same activity numerous times to sort out similarities and differences. Pouring water in and out of cups and various containers are ways of measuring. Children predict when they guess how many cups of water it takes to fill a bucket. They infer when they explain why ice cubes melt in a cup of water.

As language develops, it becomes easier to assess children's predictions and inferences; however, experienced observers of very young children can "see" these processes without verbal language. An example is the series of six photos of "Laura and the Watch" from the municipal schools of Reggio Emilia, Italy. In the first photo, 10-month-old Laura is looking at a magazine with the teacher. In the second photo, she has just turned the page to an advertisement of watches. The third photo shows Laura pointing to the page and looking inquiringly at the teacher. In the fourth photo, the teacher shows Laura her own, real watch. The teacher holds her watch to Laura's ear in the fifth photo, so she can experience the ticking sound. In the final photo, Laura places her head on the magazine page to "listen" to the watches on the page. These photos capture the elements of prediction, communication, and inference. The child uses previous data (the ticking of a real watch) to predict that other watches "tick." She communicates her prediction by putting her ear to the magazine. After discovering that the magazine watches do not tick, she infers that only real watches tick (Edwards, Gandini, & Forman, 1998, pp. 116-117).

Integrated Processes

After children have acquired facility in the basic processes, they are able to explore scientific concepts through applying the integrated processes in their inquiries. The integrated processes are complex activities that extend the basic processes into problem-based scientific explorations. The integrated process skills require deeper levels of thought than the basic skills. Popular beliefs about early childhood science education hold that children should focus on the basic processes rather than exploring and using the integrated processes; however, many young children are capable of moving beyond the basic processes to using the integrated skills in their inquiries. Metz (1995) and Tyler and Peterson (2002) argue that young children are, indeed, capable of manipulating variables, developing and executing experiments, and citing evidence to support their conclusions.

The process of identifying and controlling variables involves identifying all or most of the factors that might have an influence on a situation, selecting one to investigate, and figuring out ways of keeping all the other variables constant. For example, a child might identify variables that could influence whether a hard-boiled egg will float, how fast or how much sugar dissolves in water, or how large sugar crystals can grow from a sugar solution that is left to evaporate. These and many more activities are able to help students develop their own skills in identifying and controlling variables.

Formulating and testing hypotheses involves predicting what a person supposes will happen to one variable if another variable that interacts with it is changed, and then testing it to check the results. Examples we use with our students include formulating and testing hypotheses about how to make butter out of cream faster, the effect of exercise on heartbeat rate, or ways to speed up the drying out of a wet paper towel.

The process of defining operationally involves describing a variable that is hard to measure in terms that everyone understands. For example, plant health might be defined in terms of number of leaves, a clean penny might be defined in terms of how shiny it is, and the bounciness of a bouncing ball might be defined in terms of how high it bounces when it is dropped. When people define something operationally, they answer "What do you mean by . . .?" questions. Our students find they have had to formulate many operational definitions during the activities they did.

Interpreting data is the process used to decide what data to obtain in an investigation and how to analyze it to form conclusions. For example, in investigating the effect of temperature on the amount of sugar that will dissolve in water, the students keep track of the water's temperature and the number of spoons of sugar that dissolved at that temperature. They look at the data to form their conclusions. Graphing is a fundamental way of representing data so it can be interpreted. The computer program, the *Graph Club*, is an excellent tool for young children to use in constructing their own graphs, and our students explore applications of this program in our classes.

Experimenting involves finding how changing one variable affects the change of another interacting variable. Experiments appropriate for young children which our students do in class might include investigating how to make the best bubble-blowing solution, testing the ability of magnets to penetrate different materials and pick up paper clips, and investigating which food would make the best snack for astronauts in space ships.

Constructing models involves building or drawing representations of objects or concepts that cannot be seen or measured directly. Models commonly used include representations of the solar system, moon phases, dinosaurs, flowers, animals, etc. Models our students investigate, which they, in turn, can use with young children, include whale insulation (e.g., smear shortening on a gloved hand and then plunge the hand into ice water) and clouds (e.g., pour hot water into a transparent cup, sprinkle some chalk dust above it, and cover the cup with a small baggie of ice cubes).

Table 1 provides a list of young children's typical developmental stages, the scientific processes that most relate to that stage of development, and suggested teacher roles in fostering the development of the processes.

Table 1. Typical Developmental Stages, Relevant Scientific Processes, and the Role of the Teacher

Age Range	Naturally Occurring Behaviors	Scientific Process(es)	Role of the Teacher in Fostering the Development of Scientific Processes
0-1 month	• Sucks fingers and thumbs • Explores hands • Turns head to sounds • Searches according to smell	Observing	• Observe and share language during exploration. • Provide different sounds and smells for child to experience.
1-3 months	• Makes sounds with mouth (gurgle, coo, raspberries) • Begins to follow objects • Plays with hands	Observing	• Observe and share language during exploration. • Provide objects to track. • Encourage hand play.
3-6 months	• Plays with hands and feet. • Enjoys making sounds and making others smile • Begins to explore environment as mobility increases	Observing	• Encourage exploration (such as blanket on floor with toys that make sounds). • Interact with child to encourage different facial expressions. • Encourage child to explore with feet and hands (kicking and batting objects).
6-9 months	• Sits • Pulls self to stand and begins to crawl • Begins to look for objects that are out of sight (object permanence)	• Observing • Classifying	• Place objects to explore to encourage sitting and cruising. • Allow teacher and child to cover familiar objects and search for them (hide and seek).
9-12 months	• Stands and walks while exploring environment • May say first words • Uses pincer grasp (thumb and forefinger come together) • Develops hand coordination and may switch objects from hand to hand	• Observing • Classifying Communicating	• Encourage child to pick up objects using pincer grasp, palmer grasp (palm of hands), or open-handed. • Take child for a walk to explore environment. • Help child to form first words.
12-24 months	• Continues to develop facility in language	• Observing • Classifying • Communicating	Share language with child.
2- to 3-year-olds	• Increases vocabulary • Focuses on self and body • Dresses self • Shows interest in toilet • Shows interest in water play • Runs, jumps, and climbs	• Observing • Classifying Communicating • Measuring • Predicting • Inferring	• Observe and share language with child. • Convert child's dressing of self into a science exploration (How do a zipper, button, and Velcro® work?). • Allow child to run, jump, and climb during exploration. • Engage child in water play (How does the toilet flush? What makes that sound?).

Age Range	Naturally Occurring Behaviors	Scientific Process(es)	Role of the Teacher in Fostering the Development of Scientific Processes
3- to 4-year-olds	• Draws shapes and people • Asks "Why?" • Is very curious • Seeks to touch objects • Engages in imaginative play	• Observing • Classifying Communicating • Measuring • Predicting • Inferring • Identifying variables • Formulating hypotheses • Interpreting data • Defining operationally • Experimenting • Constructing models	• Observe and note "Why" questions that suggest inquiries related to science. • Develop these questions into activities for children's inquiries.
5- to 6-year-olds	• Begins to understand concepts of "dark" and "light" • Begins to explore clocks and daily routines and schedules • Begins to understand concepts such as "less" and "more" • Increases skills of conservation • Asks questions such as "Why?" "What?" "Where?" "When?" "How?" • Increases reading and writing skills	• Observing • Classifying Communicating • Measuring • Predicting • Inferring • Identifying and controlling variables • Formulating and testing hypotheses • Interpreting data • Defining operationally • Experimenting • Constructing models	• Observe and note questions and active explorations of materials that suggest inquiries related to science. • Develop these questions and explorations into activities for children's inquiries. • Provide materials of various shapes and sizes so child can explore concepts of shape and size.
7- to 8-year-olds	• Behaves similar to some 5- and 6-year-olds • Improves understanding of cause and effect • Begins to plan for future events • Shows fascination with events that appear "magical" • Increases and improves reading and writing skills	• Observing • Classifying Communicating • Measuring • Predicting • Inferring • Identifying and controlling variables • Formulating and testing hypotheses • Interpreting data • Defining operationally • Experimenting • Constructing models	• Observe and note questions and active explorations of materials that suggest inquiries related to science. • Develop these questions and explorations into activities for children's inquiries. • Provide materials of various shapes and sizes so child can explore concepts of shape, size, and conservation. • Provide opportunities for students to write and note their own findings.

Note: The behaviors of individual children vary widely.

Assessment

Assessment of the process skills in early childhood science education is best undertaken by watching children engage in hands-on activities that use the processes, and by using open-ended questions to discover the nature of their constructions and their reasons for their conclusions. Figure 2 shows some indicators that represent various levels of skill in each of the processes attainable by young children. We use these indicators, in part, to assess preservice teachers' facility with the processes.

Figure 2. Some Indicators of Proficiency in the Processes that May Be Exhibited by Young Children

Observing
- Identifies objects
- Uses more than one sense
- Uses all appropriate senses
- Describes properties accurately
- Describes changes in objects
- Provides qualitative observations
- Provides quantitative observations

Classifying
- Identifies major properties by which objects can be sorted
- Identifies properties similar to all objects in a collection
- Establishes own sorting criteria
- Provides sound rationale for classifications
- Sorts accurately into two groups
- Sorts accurately in multiple ways
- Forms subgroups

Communicating
- Identifies objects and events accurately
- Describes objects and events accurately
- Provides descriptions such that others can identify unknown objects
- Formulates reasonable and logical arguments to justify explanations and conclusions
- Transmits information to others accurately in oral and written formats
- Verbalizes thinking

Measuring
- Selects appropriate type of measurement (length, volume, weight, etc.)
- Applies measurement techniques appropriately
- Uses measurements as evidence
- Uses measurements to help explain conclusions
- Uses measurement instruments properly

Predicting
- Forms patterns
- Extends patterns
- Performs simple predictions
- Applies the process of prediction in appropriate situations
- Exhibits sound logic in verbalizing reasons for predictions
- Suggests tests to check for accuracy of predictions

Inferring
- Describes relationships among objects and events observed
- Utilizes all appropriate information in making inferences
- Separates appropriate from nonessential information
- Exhibits sound reasoning in verbalizing inferences
- Applies the process of inference in appropriate situations

Identifying and Controlling Variables
- Identifies factors that might affect the outcome of an experiment
- Identifies factors that will not affect the outcome of an experiment
- Identifies variables that can be manipulated and those that can be controlled
- Shows ways of keeping controlled variables constant
- Shows ways of changing manipulated variables such that useful data can be obtained.

Formulating Hypotheses
- Constructs a hypothesis when given a problem or question
- Formulates own hypothesis from own problem
- Suggests several plausible hypotheses to explain observed situations
- Develops ways of testing hypotheses
- Formulates tentative conclusions based on evidence from hypothesis testing

Interpreting Data
- Identifies data needed and how to measure it
- Plans for the collection of data
- Collects data that is useable as evidence
- Constructs data tables
- Constructs and interprets graphs
- Makes valid interpretations of data

Defining Operationally
- Tells whether a variable can be measured conveniently
- Recognizes the need for an operational definition in given situations
- Decides how to measure the variable in operational terms
- Verbalizes congruence between operational definition and the variable to be measured

Experimenting
- Follows directions for an experiment
- Develops alternative ways to investigate a question
- Manipulates materials
- Performs trial-and-error investigations
- Identifies testable questions
- Designs own investigative procedure
- Formulates valid conclusions based on evidence

Constructing Models
- Differentiates between model and real thing
- Identifies appropriate needs for models
- Interprets models in terms of the real thing
- Develops own accurate and appropriate models

Inquiry and Constructivism

Scientific inquiry refers to the ways in which scientists study the natural world (NRC, 1996). When preservice teachers or young children inquire, they investigate either a question or problem that was given to them by someone else or one that they, themselves, ask. They use the processes of science to conduct their investigations. The end result of an inquiry is some sort of conclusion. It is to be noted that inquiry involves seeking information, not seeking right information.

As stated earlier, however, the job of the science teacher is perceived by many as imparting the "truths" of science to their students.

Let us examine the "rightness" or "wrongness" of responses to inquiries through a few activities preservice teachers do in our classes. If we tie a string around the middle of a bar magnet, let it dangle, twist the string, and let the magnet come to rest, the same end of the magnet will point toward the earth's magnetic north pole each time we do this. In this respect, the magnet is like a compass. If the ends of the magnet are labeled, we can read the name of the end that points north. If we do the same thing with a lodestone (which is a natural magnet), however, and ask what we should name the end that points toward the North Pole, we obtain two opposite but equally correct responses. Some people call it "North" because it points to the North Pole, and some call it "South" because opposites attract. Although these responses are opposites, both are "correct" based on the reasons given.

Do crayons sink or float? Fill a fish bowl about half full with water, and then drop ordinary Crayola™ crayons into the bowl. Some will sink, and some will float, showing that both responses to the question posed are correct. Our students are challenged to find the reasons why this happens.

We provide magnets for students to use to explore what is magnetic and what is not magnetic. While trying paper clips, coins, and other items in the classroom, they may discover that coins are not attracted to the magnets. Is it true that coins are nonmagnetic? When they bring the magnet near American coins, the coins are not attracted, and therefore they are nonmagnetic. This makes a lot of sense because we can foresee all sorts of problems if our coins were magnetic. If they try the same thing with coins from Mexico, Germany, or any of a number of other countries, however, they will find—much to their surprise—that many of them are magnetic.

These activities point to the idea that there are no right and no wrong answers. In each, we thought we knew what would happen, but, after exploring it, we were not sure because we experienced something unexpected, or, in more formal terms, discrepant events, cognitive dissonance, or cognitive disequilibration.

Teachers who believe they have to know the "right" answers so they can transmit this information to their students can take comfort from these activities. There are *no right answers.* Neither are there *wrong* answers. Note, however, that we do not want to promote the idea that teachers don't need to understand *any* science concepts. For example, in the above activities, they need to know the principles of magnetism, the properties of American and foreign coins, and the nature of magnetite.

The process-oriented inquiry method of early childhood science education encourages teaching that fosters children's construction of their own conceptualizations in ways that make sense *to them*. We have said there are no right answers and there are no wrong answers; however, there are *valid* answers. We suggest that, rather than looking for *correct* answers, we should look for *valid* answers. Valid conclusions have three characteristics:

1. *They have explanatory power* – The conclusion is able to explain the situation satisfactorily. For example, we can explain the conclusion that American pennies, nickels, dimes, and quarters are nonmagnetic because they are made of nonmagnetic materials.

2. *They have predictive power* – The conclusion is able to predict similar occurrences in the future. If my conclusion about coins is valid, I should be able to predict that American half-dollars and silver dollar coins are also nonmagnetic. When I try this out, I find it to be true.

3. *They have utilized the input of others* – The student has asked the teacher; has weighed the conclusions made by other groups; has asked parents and friends; has explored books, media, and the Internet; and has used all this input to develop his or her conclusion. In the coin example, the person testing the coins has checked with many other people, and has interacted with other groups of students in the classroom, and all have said the same thing—the coins are nonmagnetic.

When these three criteria are met, the conclusion is valid. It is not necessarily right, and it is not necessarily wrong, but, it *is* valid. It is valid until the person encounters a new experience that fails to fit in with the current conceptualization (such as finding coins that *are* magnetic). The former conceptualization does not explain the new experience; the former predictions no longer happen; or another source of information raises questions not thought of before. At this point, the person inquires again into the concept to account for the new information. A new conceptualization is formed that is valid, has explanatory power, has predictive power, and utilizes the input of others. The conceptualization is reconstructed, and it stays this way until the person again experiences something new that causes him or her to question his or her thoughts.

Discrepant events seem to require an answer. When people witness a discrepant event, something inside of them wants to reconcile what happened with what they thought would happen—to turn this cognitive disequilibration into cognitive equilibration or self-regulation (Piaget, 1964). The only way this can be done is to attach these new experiences to experiences we have previously had. This is known as constructivism.

Constructivism is the notion that the only way people learn is by attaching new experiences to experiences (or knowledge) they already have. Learning does not occur by transmitting information from the teacher to the child's brain. Instead, each child constructs his or her own meaning by combining prior information with new information such that the new knowledge provides personal meaning to the child (Cobern, 1993). The way this desired cognitive equilibration is achieved is by "fooling around" with the situation, trying different ideas, doing different things, and checking out findings that seem to be promising. The teacher presents new experiences to the children to get them thinking, and encourages them to investigate their ideas to their natural end.

Inquiry is the agent of constructivism. In inquiry, children try many variations of the same situation to try to make sense of what they observe. Isn't it wonderful *not* to know all the answers? When we don't know certain answers, we aren't able to lead the children to "correct" answers because we don't know for sure what they are! Children have to *inquire* to find out what they can. Teachers acquire basic understandings of the concepts and principles of science appropriate for young children, but they remain open to children's own unique ideas.

To Summarize

- Every person has different prior experiences.

- Every person has different existing knowledge.
- Every person attaches the new knowledge to their existing knowledge in different ways.
- Every person ends up with different constructions.
- Therefore, every person constructs different understandings or conceptualizations.

Finally, since constructivism involves children constructing their own conceptualizations, we need to ask how we can tell how students are constructing information. We have several suggestions:

- Watch them do their activities and assess their proficiency in terms of certain indicators.
- Ask them.
- Talk with them.
- Have them make representations through drawing, sculpting, and painting (as seen in the schools of Reggio Emilia).
- Observe them at play (as suggested by Piaget).
- Ask them to prepare concept maps.
- Ask them to prepare videos, websites, or presentations.

Conclusion

The goal of early childhood science education is to enable children to investigate phenomena so they can construct their own valid conceptualizations to learn how to *do* science. The process-oriented inquiry method of teaching science is a constructivist way of making this possible. Preservice teachers must construct their own understandings of constructivist science teaching, and the only way they can do it is to try it for themselves. Faculty of early childhood science education courses can ensure this by making the process-oriented inquiry integral to their teaching.

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Correspondence regarding this article should be directed to

Dr. David J. Martin
Department of Elementary and Early Childhood Education
Kennesaw State University
1000 Chastain Road
Kennesaw, GA 30144
(770) 423-6445
dmartin1@kennesaw.edu

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