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ASSESSING "IMPERFECT" CONCEPTIONS

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A VIEW OF ELEMENTARY SCHOOL SCIENCE

Assessment of children's progress in elementary science is embedded in an educational approach and serves clear purposes. In this article I shall describe my preferred approach to elementary science learning and outline what I think are appropriate data for assessment.

Children achieve a better understanding of the world by continually building and reinterpreting their direct knowledge. Their conceptions of the world undergo change as they grow and gain more direct experience with the physical world and with the world of symbols and ideas. Conceptual imperfection and continual refinement are, therefore, part and parcel of elementary school science learning. At the City College Workshop Center in New York, we view children's learning of elementary school science as encompassing content and approach. The content is found in common materials and phenomena that we encounter, and the approach is inquiry built around making meaning from observations and experience.

Direct experience with phenomena of the world connects the content of elementary science with children's experiences and observations outside the classroom. This connection reconfirms that science is a continuing search for underlying commonalities in apparently disparate phenomena, and an intense engagement with things that arouse our curiosity.

In an illustration of this approach, Jos Elsgeest (1969), a Dutch science educator who worked for many years in African science education, engaged African children studying the larval stage of the ant lion, an insect that resembles a dragonfly. The children's curiosity had led them to wonder about

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Figure 8.1. Children's Scheme for Classifying Insects

CATEGORY	CHARACTERISTIC	EXAMPLES
Live communally	Very small, build houses	Wasp, white ant
Attack intruders	Eat other insects or powdery things	Bee, safari ant
Do not bite	Humble	Mantids, butterfly, ant lion, earthworm
Make honey	Lay eggs, obtain food from flowers, suck food, hairy legs	Bee, butterfly
Have three parts	Short wings, eat tender leaves, big eyes, winged	Wasp, house fly, termite, bee
Live underground	No eyes	Ant lion, white ant, small black ant, safari ant
Live in trees	Eat fruits, bite	White ant

questions the educators asked or in what direction they tried to lead the children, the children persisted in looking at the events as races. Within the frame of "races," children observed some events and failed to notice others which would be important in a different frame of reference. The important observation to children was spotting the winners; ties were irrelevant. Hein concluded logically and reasonably: "These children do not have a statistical view of data and scientific observation. Instead they have a particulate view of events. Each observation has its independent existence, each observation could decide the contest" (p. 87). Looking for winners in this activity is not what a scientist would do. Scientists would attend to "ties" in their frame of reference because they are interested in probabilities of independent events.

Children's science tends to draw understandings directly from the nonidealized conditions we all know, whereas scientists' views relate to established canons of knowledge drawn from idealized or controlled laboratory conditions. For example, children know that in free fall, heavy objects fall faster than lighter ones. Scientists make the same observations; but children's explanations of this phenomenon will differ from the scientists' because children's frame of reference is centered only on the weight of the objects and does not encompass observations of free fall in a vacuum. The different frames of reference or presuppositions with which children and scientists approach this observation result in different "facts," different trials of one factor or another, and different degrees of elaborateness of investigations.

If children's frame of reference of winners and losers is flawed as a basis for scientific understanding of rolling objects down inclined planes, it has to be improved by creating an interest in examining ties which still need to be

Figure 8.2. A Child's Classification of Caterpillars

COLOR	FATNESS	HAIRY	FOUND ON	SAMENESS
Green	Thin	Not hairy	Hawthorn	Not the same
Yellow and grey	Fat	Bit hairy	Hawthorn	
Brown	Fat	Hairy	Dock leaf	Not the same
Brown	Medium	Bit hairy	Hawthorn	Same

explained. Such an examination might lead children to consider frames of reference that allow for a more comprehensive and reliable description of observed events. They might go beyond "naive" notions or theories to careful operational statements that lay ground for predictions and for broader understandings. A close look suggests that children's work is important in assessing their progress in science inquiry.

Children's Work

A fifth grade class which had been looking at insects for several lessons developed its own classification scheme (see Figure 8.1) and a "key" for identifying insects found locally. A person looking at the children's classification scheme might be struck by its unusual basis and by errors it contains. For example, a person might think that the first column is not necessary—that the categories are actually also characteristics in some sense. One notices also that some of the organisms belong to more than one "class." From the Linnean frame of classification (the genus and species frame of reference) earthworms should not be included because they are not insects. These are legitimate sources of concern but the concern must not overshadow the power of the children's creation of a scheme (Science Education Program for Africa, 1978).

Independently of these fifth grade children, other children in an elementary school class in England engaged in a similar science learning activity. One of them developed the classification scheme shown in Figure 8.2 (Rowland, 1984, p. 27).

In this classification activity the teacher reported that the child *first thought* about the attributes he wanted to use and then examined the specimens over and over again and selected those that share the attribute. This thinking about an embracing attribute from discrete observations is a very bold and constructive intellectual activity whether it is done at the frontiers of a discipline or, as in this case, at earlier stages of learning. The action signifies the interpretations of nature on the basis of observations, representations, and understanding of the selected organisms in the environment.

The creation of an interpretive scheme shows that the children have gone beyond particular examples to think of generalizations that can be supported by demonstrable observations. What remains to be done to further their science development is no small task; it is to encourage them to be willing to refine and modify their scheme, and to make finer distinctions. Before children can evaluate the usefulness of any scheme, however, they would have to use it extensively. From that use, perhaps they would recognize problems with a scheme that does not, for example, discriminate well among things that are very different from one another in some important respects. In time, they might see the value of seeking guidance from schemes developed by others. Perhaps as they observe other living things closely, they will look at the structural characteristics of the organisms in order to make fine classification distinctions. They will recognize their earlier schemes as first approximations that were useful for gaining a general idea and for laying a foundation for a coherent picture.

Observations need not be represented only in prose, drawings, and tables; they can be represented in verse, as the 10-year-old Leo's poem show. (Leo—not his real name—did this work at the Prospect School, Bennington, Vermont [The Prospect Archive, 1984]):

It's a Spider

Moving through the night
As if always in flight
From some unseen enemy.
In the summer webs on trees
In the fall webs in the leaves
In the winter you die on out
In the spring your children
Search for a new home.

There is a sense here that Leo has focused on the spider not momentarily, but over an expanse of time and space. He has arrived at the notion of the physical home (the web) located in a broader habitat—the tree at one time and the leaf at another. The life cycle is captured by the child: life of the spider in the summer, fall, and winter and then the young ones appear in the spring. Unstated, but understood is that in the summer they become adults, that will presumably die in the winter. The young ones have the task of building a home or searching for one. The great explosion of life in the spring and the end of a lifetime in the winter have been duly noticed and recorded by the child. *That* is the essence of observation to make meaning (Carini, 1979).

Documenting Children's Inquiry Work

Children have a natural inclination to make connections and to create schemes that account for perceived relationships. Previous examples of children's work

indicate that children can generate knowledge directly from objects of nature; such knowledge goes beyond mere speculation and guessing. Children can obtain information from direct experience with concrete natural phenomena through systematic manipulation and observation. They can utilize symbolic material to represent the observations faithfully, and make relevant abstractions from the representations. The challenge for assessment is to find strategies and mechanisms that portray this development in elementary science learning.

Documentation of children's work over *significantly long periods of time* is one of the best sources for assessing children's progress in elementary school science inquiry. The documentation can be obtained through the research technique of observing and recording a single child's experiences and responses. Although this method yields invaluable information for assessment purposes, it cannot be used consistently by classroom teachers who have responsibility for *all* children in their class for *only* nine months. But this technique can be modified to meet these constraints. The records of children's work at The Prospect Archive and Center for Education and Research are an excellent example of such a modification.

The Prospect Archive is a unique collection of individual children's drawings, writings, constructions, and other artifacts spanning an average of six to eight years of a child's school experience. The material on each child also includes a teacher's weekly statements about the child's educational activities, as well as a general summary covering each term. Below is an excerpt from a teacher's general summary about Leo, the child whose work has been cited above:

> He (Leo) builds intricate structures all of which have long explanations to go with them. One building of (Leo's) was...a building on another planet complete with laboratory, energy sources, water systems, solar collectors, secret passageways with trap doors. (Leo) has a natural sense of balance and symmetry....He is very inventive with wood and thinks up very original projects for himself to do. He built a base for a star ship. For this he invented a pivotal cannon that could move up and down and around. It was very impressive because he had come up with the whole thing completely independently. (The Prospect Archive, 1984, p. 54)

These evaluative statements are part of the data attached to the child's work. Interested persons can have access to the entire portfolio to make their own judgments. The teacher's statements do not make reference to the inquiry process associated with these activities, but there could have been such reference had the teacher included science inquiry as a major focus of the child's activities. However, the teacher did view making representations of objects as a very important activity for the child, hence the following comments:

> (Leo's) drawings often express his mechanical interests. They are often cross sections of buildings revealing all the inner networks of stairways, water systems, energy systems, and structural supports. His drawings are striking for the detail and depth. (p. 54)

The teacher's comments indicate quite vividly what a close observer Leo is; the comments lead us to look at the child's work directly to satisfy our curiosity about it.

Another mechanism for assessing development in elementary science learning is the documentation of group activities within a class over extended periods in the form of a "teacher's journal." In this case, work of groups of children is accumulated over time, thus creating a "bank" of detailed material encompassing their science learning activities. Included with the children's work are their teachers' perceptions and reflections about the work. The children's work cited above can be used to make inferences about the children's progress in science learning. *Juba Beach* (1971), a teacher's journal prepared for and published by the African Primary Science Program, is an example of such a journal. The journal includes children's descriptions of their science inquiry activities complete with written accounts, diagrams, and questions related to the organisms the children studied along a beach. The teacher's comments, interspersed in the children's own accounts, are informative. For example, in *Juba Beach* the teacher wrote:

> The general topic of beaches and sea integrated many experiences of learning. The children found and observed a wide variety of animals. They examined rocks and shells and sand. They tasted and tested water for salt content. They counted waves and the flow of rivers and talked to fishermen. The challenges were without limit...The events of this unit encouraged them to find answers to new questions. They wanted to learn and because of this they used and developed their skills—they measured, weighed, compared and counted, they kept notes and discussed their findings. For me, their own evaluations and this record book tell more about the progress of the children than any written examination I might have given them.

Computer technology can be used to build a data bank based on children's work which can provide evidence of the quality of their participation in science inquiry activities. In such cases the computer is a tool that children use to record the observations, experiments, and abstractions derived from their science investigations. The records can be retrieved by the children, the teacher, or by someone else interested in them. The Bank Street College of Education's Center for Children and Technology in New York City has done interesting work in this respect. In the *Earth Lab* project, children work in groups to do earth science inquiries; they collect data and later share their findings. The Center's project *INQUIRE* is a software design that makes it possible for children to keep notes, and record their ideas, plans, guesses of expected findings, and findings while engaged in inquiry activities on sports physics. As a result, it is possible for children to create their portfolios as they progress in their elementary school science learning activities during science investigations (McCarthy, 1989).

Another interesting use of computer technology in elementary school science learning which has a great potential as a documenting mechanism for assessment purposes is *The National Geographic Kids Network*. This project for grades four through six is carried out by Technical Education Research Centers and combines the use of computers with telecommunications. Children in the network conduct experiments in their local areas, such as collecting data on acid rain. The telecommunications network links them with children in other localities by sending the results of their local experiments to a central computer. Through the network, children in various parts of the world can discuss their findings with their peers and work collaboratively in a manner similar to how a research team works together. Although many classrooms might not have easy access to a telephone line, the computer component of the activities can be good for recordkeeping.

The question is: Who assesses this work? The answer is teachers. Most documentation described here can be done by suitably educated teachers enjoying unfettered professional judgments. They would use prepared assessment guidelines indicating how the children's work is to be judged. The guidelines would be faithful to the advocated science approach, both sufficiently flexible and unambiguous. Carefully selected panels including teachers, science educators, child development specialists, leading scientists, and school children would prepare these crucially important guidelines. Since community schools are local institutions, groups of teachers at the local level, assessment specialists, science educators, and if possible, outstanding scientists would come together to examine children's work. Based on that examination they would prepare detailed reports describing the work and indicating how it was assessed. It would be left to the local school districts' or the state's discretion to make assessments by child, grade, school, district, or a combination of all those elements. For purposes of comparison across school districts, samples of assessed children's work could be examined by panels of teachers and assessment specialists drawn from the districts, with additional members drawn from other states. These panels would also prepare detailed reports on the documents they examined. These informative reports would be used widely to improve elementary school science instruction. Tests would not be eliminated; instead they would be restructured to focus on children's demonstrated capability to make sense of observations derived from physical materials presented to them.

I have portrayed elementary science education as focusing on children's engagement in organized inquiry with natural phenomena in their surroundings. I have also implied that science inquiry requires a considerable density of often repeated experience over long periods of time. I view one major purpose of assessment as support for quality instruction in science inquiry. The examples of children's work indicate that children are capable of conducting inquiries into nature, but are still developing "imperfect" conceptions by adult scientific standards. Through children's work, one gains insight into their developing art, skill, and knowledge of doing science. I am calling, therefore, for assessment that portrays children's continuing development in science inquiry through appropriate, practical, concrete investigative activities; and children's capacity to communicate their understanding by the questions they raise about nature, by the observations they choose to make, and through the symbols they devise. The willingness to document such data will not come about until it is accepted that elementary school children's inquiries are valuable starting and continuing points for science inquiry instruction, and that teachers can play a large role in assessment activities.

REFERENCES

Arons, A. B. (1983). "Achieving Wider Scientific Literacy." *Daedalus*, 112(2).

Carini, P. F. (1979). *The Art of Seeing and the Visibility of the Person.* Grand Forks, ND: University of North Dakota Press.

Elsgeest, J. (1969). "Ask the Ant Lion." From *African Primary Science Program.* Newton, MA: Education Development Center.

Science Education Program for Africa. (1978). *Handbook for Science Teachers.* Accra, Ghana: Author.

Hawkins, D. (1983). "Nature Closely Observed." *Daedalus*, 112(2).

Hein, G. E. (1970). "Children's Science Is Another Culture." From *ESS Reader.* Newton, MA: Education Development Center.

Juba Beach, A Unit of the African Primary Science Program (1971). Newton, MA: Education Development Center.

McCarthy, R. (1989). "Behind the Scenes at Bank Street College." *Electronic Learning*, October, pp. 30–34.

Morrison, P., and Morrison, P. (1984). *Primary Science: Symbol or Substance?* New York: Workshop Center.

The Prospect Archive. (1984). *(LEO).* Unpublished manuscript, North Bennington, VT: The Prospect Archive and Center for Education and Research, Inc.

Rowland, S. (1984). *The Enquiring Classroom.* London: The Falmer Press.