4H-591
1997

Nurturing Scientific Literacy Among Youth Through Experientially Based Curriculum Materials

Developed for the National Network for Science and Technology (NNST)

Cooperative Extension System—Children, Youth and Family Network CSREES-USDA

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photo: Jodi Miller

Cooperative Extension System Children, Youth, and Family Network. To support collaboration among universities and community-based programs, the Cooperative State Research, Education, and Extension Service (CSREES), USDA, created five National Networks to marshal faculty and program resources to directly respond to the economic, social, and human stresses faced by children, youth, and families.

These networks, which constitute the Cooperative Extension System Children, Youth and Family Network (CYF), are linked and accessed through CYFERNet, an Internet-based children, youth, and family information system operated by CSREES.

The CSREES currently funds the five networks, for Child Care, Collaboration, Family Resiliency, Science and Technology, and Health.

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Contents

Abstract

This publication formalizes the process for developing experientially based non-formal science teaching materials. Based on D.A. Kolb's (1984) definition of experiential education, the publication demonstrates how all planned learning episodes can be accommodated within an experiential framework. This includes organizing content along an experiential path, identifying instructional methodology and science life skills necessary to teach the content, using an experiential facilitation process to guide the learner through the content, and delineating post-unit assessment techniques.

Introduction

Although the concept of scientific literacy was developed in the 1950s, it remains a universal, timeless goal for science education. In an ideal world, an individual's progress toward scientific literacy continues throughout life, beginning with a firm foundation in elementary school. The American Association for the Advancement of Science document *Science for All Americans* describes a scientifically literate person as one who is aware that science and technology are human enterprises with strengths and limitations, understands key concepts and principles of science, is familiar with the natural world and recognizes both its diversity and unity, and applies scientific knowledge and skills for individual and social purposes (AAAS, 1990).

Science for All Americans offers the premise that less is more, indicating a shift away from the emphasis on rote memory to higher levels of cognition such as critical thinking. Bybee and DeBore (1994) sum up the basic dimensions for scientific literacy as follows.

Scientific literacy continuously develops when the science curriculum incorporates a wide variety of learning episodes that clearly emphasize:

- learning from the concrete to abstract and from the familiar to the unfamiliar;
- learning from the local setting to the global setting;
- real-world doing (hands-on);
- cooperative and individual performance;
- learner self-evaluation and curriculum embedded assessment;
- developmental appropriateness of process and content;
- cooperative planning by learners and leaders;
- interdisciplinary connections;
- assessment of the risks and benefits while making choices;
- movement toward independence; and
- responsible decision-making in real-world situations.

However, these goals can only be achieved when youth educators have enabling resources, adequate materials, applied training, and time to implement the teaching of science in an engaging and meaningful fashion. For science curriculum developers, this means that a science education program enriching enough to facilitate the continuous development of scientific literacy requires powerful learning episodes that are relevant and engaging to all learners.

Although there is substantial debate regarding the desired approach for the reform of science curriculum materials, there is consensus that the materials should

- include more emphasis on attitudes, problem solving, critical thinking, decision making, applications, technology, and societal issues;
- reflect current understanding of the nature of the learner and of learning;
- increase the amount of time needed for science instruction;
- provide appropriate experiences for targeted youth audiences;
- increase the use of appropriate technology;
- use alternative assessment techniques that match the learning events more closely.

In 1978 the National Science Foundation (NSF) awarded a major research contract for the synthesis and interpretation of more than 2,000 pages of information from three NSF studies and National Assessment of Educational Progress (NAEP) reports. A team of 23 science educators, led by Norris Harms of the University of Colorado, participated in the research effort. Project Synthesis, one of the most significant documents on the development of curriculum materials to promote scientific literacy, documented the fact that science education has traditionally stressed content and neglected the basic thinking and process skills areas that contribute to an individual's overall comprehension and application of science knowledge.

To remedy these deficiencies, Project Synthesis called for major reform in our traditional approach to science curriculum development. The project outlined a broader developmental focus for designing effective curriculum materials. Its prescription for effectiveness included more than helping learners master facts and organize independent data for success. Emphasis was placed on organizing activities along an experiential path that engages students in the process of learning through discovery and the application of scientific skills.

Since then, science curriculum developers have looked at the recommendations of Project Synthesis as a set of general assumptions about the development of effective youth-centered science curriculum materials. The assumptions put forth by the project include

- organizing content along an experiential path;
- establishing a relationship between content and experience;
- facilitating experience from an experiential perspective;
- providing opportunities for post-unit assessment.

By conforming to these assumptions, we can do more than merely develop materials that prepare youth academically for advanced studies in science. We can also prepare youth to use the skills they learn in their daily lives, engage them in intelligent decision-making relative to science and societal issues, and orient them toward rewarding life opportunities in science and technology (Harms and Kahle, 1973).

It is the intent of this document to encourage the development of new and effective science curriculum materials that present youth with a continuum of activities that emphasize the general assumptions put forth by Project Synthesis. The remainder of this publication will concern itself with a discussion of each assumption and include specific recommendations for curriculum developers.

Organizing Content Along an Experiential Path

Inevitably, all curriculum developers are confronted with the question of *what* to include for the purposes of learning. Then they address *how* to arrange the material selected. In other words, they begin by looking at the knowledge and skills to be addressed, followed by the sequencing of this information for teaching and learning to take place. Regardless of their philosophical orientation, curriculum developers should not ignore these two elements.

Identifying Content. Curriculum designers cannot use all possible content choices. Regardless of the curriculum design or experiential model they follow, they must somehow make sense of what is available and select content that will enable youth to learn the most. This task can perhaps be made a bit easier depending on how they define curriculum content. Parker and Rubin (1966) have noted that when educators speak of content, they refer "to the compendium of knowledge and skills which comprise a particular course of study."

Some educators argue that it is more important to learn life skills than content and related skills. Such a philosophy dichotomizes content and life skills, however, when in reality they should receive equal emphasis. Life skills are a type of specialized content, related to methodology and procedures. Parker and Rubin (1986) indicate that the term *life skills* suggests "random or ordered operations which can be associated with knowledge and human activities." A variety of life skills, creatively embedded in the curriculum, can help "create" knowledge as well as "communicate" and "utilize" knowledge.

Content is more than just information to be learned and skills to be mastered for educational purposes. Dewey (1916) argued long ago that if content is to be more than information for educational purposes, it must bear some relationship to "the questions with which the child is concerned" and it must "fit into the child's more direct acquaintance so as to increase its efficiency and deepen its meaning." When selecting content and content skills, the curriculum planner must take into account the potential of the content to address all the cognitive, social, and psychological dimensions of the individual learner.

Taba (1962) recommends that content for a particular unit of study be selected by a team of individuals with proficiency in the subject and individuals with an understanding of the interests, needs, and abilities of the target audience. These individuals should be concerned with weighing their decisions against a predetermined set of criteria:

- *Validity*. Worthiness of the content when held against a recognized set of standards. For science-related content, the American Association for the Advancement of Science's (AAAS) Benchmarks for Science Literacy and the National Network for Science and Technology's (NNST)Science Guidelines for Non-formal Education provide valid answers to the dilemma of what to teach and to whom. We must be aware, however, that the standards we rely on today to substantiate the validity of our content may be different 10 years from now. As new knowledge is discovered, content currently assumed valid may be judged misleading or even false.

- *Significance*. Relevance of the content to a greater body of knowledge; contribution of the content to the development of learners' abilities, skills, and attitudes.

- *Interest*. Capacity of the content to attract and hold learners' attention.

- *Utility.* Level of content's usefulness for learners.

- *Learnability.* Applicability of the content to learners at their particular stage of understanding and development.

- *Accuracy*. Precision and timeliness of the content presented.

- *Feasibility.* Limitations to the effective teaching/learning of the content, including setting, time, availability of resources, and qualified learning facilitators.

Organizing Content. Most curriculum developers agree that content should be organized by going from the learners' immediate environment to a more distant environment, that is, content should be organized so that the concrete is experienced before the abstract. This psychological factor is a key principal when basing content sequencing on Experiential Learning Theory, which combines content with experience, perception, cognition, and behavior. In *Experiential Learning: Experience as the Source of Learning and Development* (1984), Kolb describes experiential learning as a holistic, integrative approach. Building on the writings of Dewey, Lewin, and Piaget, Kolb postulates that content is best organized along an experiential path, where learning takes place as a series of transactions among four adaptive modes (see Figure 1): concrete experience, reflective observation, abstract conceptualization, and active experimentation.

Figure 1. Experiential Models of Kolb and Williamson

Kolb	Concrete Experience	Reflective Observation	Abstract Conceptualization	Active Experimentation
Williamson	Experience	Reflect	Generalize	Apply

In concrete experience, the learner is openly introduced to the content as a new experience. In reflective observation, the learner reflects and observes the content from many different perspectives. Learners create concepts, in which observations are formed into generalizations, in the abstract conceptualization mode. These concepts are then used to solve problems, create applications, and make decisions in the active experimentation mode.

Kolb (1984) reminds us that higher forms of cognition, creativity, and personal development often require a more dynamic interaction among the four modes. According to Williamson (1979), the framework for experiential learning (experience, reflection, generalization, application) is the same for a 40-minute lesson, a four-week unit, or an entire year's work. For example, a 40-minute lesson might be organized in such a way that the content flows sequentially from one experiential mode to the next until all four modes have been equally addressed. A four-week unit might be arranged by topical areas, with content flowing back and forth between the first two experiential modes (experience and reflection) until all new information within a topical area has been addressed. The content could then be collectively generalized and applied (the two remaining experiential modes) by topical area. A third scenario might be to flow content along an experiential path that crosses an entire unit. In this way, each of the unit's topical areas would be connected along a single experiential path. (See Figure 2.)

Figure 2. Organizing Blocks of Content Along Williamson's Experiential Path

40 Minute Lesson	E	R	G	A

4 Week Unit (Independent Topics)

Topic	E	E	R	G	A		
Topic	E	E	E	R	G	G	A
Topic	E	E	R	G	A		
Topic	E	E	R	G	A	A	

4 Week Unit (Dependent Topics)

Topic	E	R							
Topic		E	R						
Topic			E	R	G				
Topic					E	E	R	G	A

E = Experience—Present the content to the learner(s).
R = Reflect—Explore the meaning of the content.
G = Generalize—Seek comprehension and appreciation of the content.
A = Apply—Apply content to real world situations.
■ = Content Block

Establishing a Relationship Between Content and Experience

If content is the "meat" of the curriculum plan, experiences are the "heart." Experiences are the key factors that shape learners' orientation to the content and, ultimately, their understanding of it. Taba (1962) noted that learning experiences, not content, are the means for achieving a wide range of objectives; knowledge and understanding are the exceptions.

Curriculum experience is shaped by the instructional component of the curriculum, that is, the human interaction between the facilitator (leader, teacher, coach, or parent) and the learner. It is specialized behavior, planned in light of particular objectives, and consists of teaching activities designed to attain the goals of the unit. Educational activities include viewing videos, conducting experiments, interacting with computer programs, taking field trips, and listening to speakers.

According to Hirst (1974), no curriculum, regardless of its design, can ignore content and experience. Learners cannot engage in learning without experiencing some activity and some content. Likewise, they cannot deal with content without being engaged in an activity. Content and experience do not exist apart: Even merely thinking involves content. If learners are actively engaged in an activity, such as reading a book, they are combining experience with content. Curriculum planners sometimes try to separate content from experience. They soon realize, however, that in the actual delivery of educational programs, the two elements co-exist. As Taba (1985) notes, "One can speak of effective learning only if both content and experience are fruitful and significant."

Criteria for Selecting Level of Experience. When designing educational experiences, it is important to consider not only the level of involvement for each experience, but also the standards of quality for the experience and the learners' ability to respond. For example, observing a live presentation by "Bill Nye the Science Guy" might rank low on a scale of experientiality but high on a scale of quality. However, if learners are not prepared for or capable of responding to Nye's presentation, the experience will be low on a scale of readiness to learn. The same can be said for the environment in which the experience is facilitated. Watching the presentation on television will have a much different effect on the learner than watching it live on stage.

When matching experiences with content, one must begin by establishing a range of experientiality for the unit. To facilitate the process, Gibbons (1980) has adapted this aspect of decision-making to the following hierarchy of experiences:

Receptive mode. Experiences, or representations of them, are presented to learners, who remain a passive audience throughout.

1. *Simulated experience*. Learners passively experience slides, pictures, videos, and other simulations of reality.
2. *Spectator experience*. Learners experience the object of study with all senses, but as observers.

Analytical mode. Learners conduct field studies in which they apply theoretical knowledge and skill in order to study some event, analyze some aspect of the environment, or solve some practical problem.

1. *Exploratory experience*. Learners are exposed to interesting sites and encouraged to explore the possibilities of the materials at hand.
2. *Analytical experience*. Learners study field sites systematically, often applying theory to solve problems in practical situations.

Productive mode. Learners generate products, activities, and services, either assigned or of their own devising.

1. *Generative experience*. Learners build, create, compose, organize, or otherwise generate products in appropriate settings.
2. *Challenge experience*. Learners are challenged to pursue goals of productivity and accomplishment.

Developmental mode. Learners pursue excellence in a particular field by designing and implementing long-term programs of study, activity, and practice.

1. *Competence experience*. Learners focus on a particular field, practice the skills involved, become absorbed in the activity, and achieve recognized competence.
2. *Mastery experience*. Learners go beyond competence, developing commitment to a set of high personal standards of excellence.

Psychological Mode. Learners learn to understand themselves and their relationships with others. They accomplish the tasks presented by their stage of development toward maturity and make contributions to the lives of others.

1. *Personal growth experience*. Learners gain understanding of themselves as unique individuals and learn to direct their own activities effectively and responsibly.
2. *Social growth experience*. Learners become more socially competent with people of all ages and act in more socially responsible ways, using their accomplishments in service to the community.

According to Gibbons' (1990) hierarchy of experiences, as the degree of experience increases, the learner takes on more responsibility for learning. At an introductory level, an experience at the lower end of the scale may be quite appropriate. On the other hand, if a unit builds on previous knowledge gains and is designed for highly motivated and competent learners, experiences should be at the higher end of the scale. (See Figure 3.)

Figure 3. Gibbons' Scale to Measure the Level of Experience in an Experience-Based Program

Level of Experience	Defining Elements (Activities & Skills)										The Students' Activities
10 Social	A/S	A/S	A/S	A/S	A/S	A/S	A/S	A/S	A/S	A/S	Becomes exemplary as a community member
9 Personal Growth	A/S	A/S	A/S	A/S	A/S	A/S	A/S	A/S	A/S		Pursues excellence and maturity as a person
8 Mastery	A/S	A/S	A/S	A/S	A/S	A/S	A/S	A/S			Develops a high standard of quality in performance
7 Competence	A/S	A/S	A/S	A/S	A/S	A/S	A/S				Strives to become skillful in important activities
6 Challenge	A/S	A/S	A/S	A/S	A/S	A/S					Sets difficult, but desirable, tasks to accomplish
5 Conservative	A/S	A/S	A/S	A/S	A/S						Creates, builds, organizes, theorizes, or otherwise produces
4 Analytical	A/S	A/S	A/S	A/S							Studies the setting and experience systematically
3 Exploratory	A/S	A/S	A/S								Plays, experiments, explores: probes the setting
2 Spectator	A/S	A/S									Sees the real thing in its normal setting
1 Simulated	A/S										Sees movies, TV, slides

The higher the level of experience. . .the more defining elements ⟶ necessary to fulfill the experience.

Gibbons (1990) cautions curriculum designers to view his hierarchy in relative terms rather than absolutes. In the real world, learning does not take place at just one level of experience. Rather, it functions as a range of experiences that reflect the interests and expertise of the learners. The same is true for an instructional unit. If it is to be truly experiential, it should present a range of activities that reflect the level at which the content is addressed, the interests and abilities of the learners, and the environment in which the learning will take place.

Elements of Experience. Gibbons (1990) defines the elements of experience as "the things that make the experience happen," including the *nature of the activities* selected, the *skills to be applied* through the activities, and the *way in which the activities are facilitated*. As shown in Figure 4, Gibbons illustrates how higher levels of experience require a more sustained number of *defining elements* (activities and skills).

Figure 4. Topics at Moderate and Low Levels of Experience

Williamson's Experiential Components	**Experience** Present content to learner	**Reflect** Explore the meaning of the content	**Generalize** Seek comprehension and appreciation of the content	**Apply** Apply content to real world situations
Topic At Low Experience Level	A/S	A/S	A/S	A/S
Topic At Moderate Experience Level	A/S	A/S A/S	A/S A/S	A/S A/S A/S

A/S—activities and skills

= content block

The stages of Mastery and Competence mark degrees of expertise in the application of a selected set of skills through a sustained and facilitated pattern of experience. Learning to function as an expert has traditionally been accomplished through apprenticeship. In such a system, the beginner, faced with clearly defined content that comprises a craft or trade, is guided through a clearly defined set of skill-building activities leading from apprenticeship to journeyman to mastery. The lower level Exploratory stage may call for nothing more than, for example, a career exploration day for ninth grade students.

Activities for Learning. The activity element of a structured experience is often referred to as the instructional methodology by which learning takes place. It reflects a multitude of both formal and non-formal *teaching methods* including demonstrations, role playing, case studies, brainstorming, journaling, simulations, and labs. With such a wide variety of instructional methods to choose from, are particular teaching methods more appropriate at certain levels of the experience than others?

Challenged by this question, experiential researchers Marilla Svinicki and Nancy Dixon set off in 1987 to devise a theoretical framework for identifying and organizing teaching methods that affect learning. The researchers looked to Kolb's (1984) model as the framework for characterizing the types of activities that best fit within each component along the experiential path. They believed that by constructing learning activities congruent with the mission of each component, they could achieve a more effective learning experience for the entire unit.

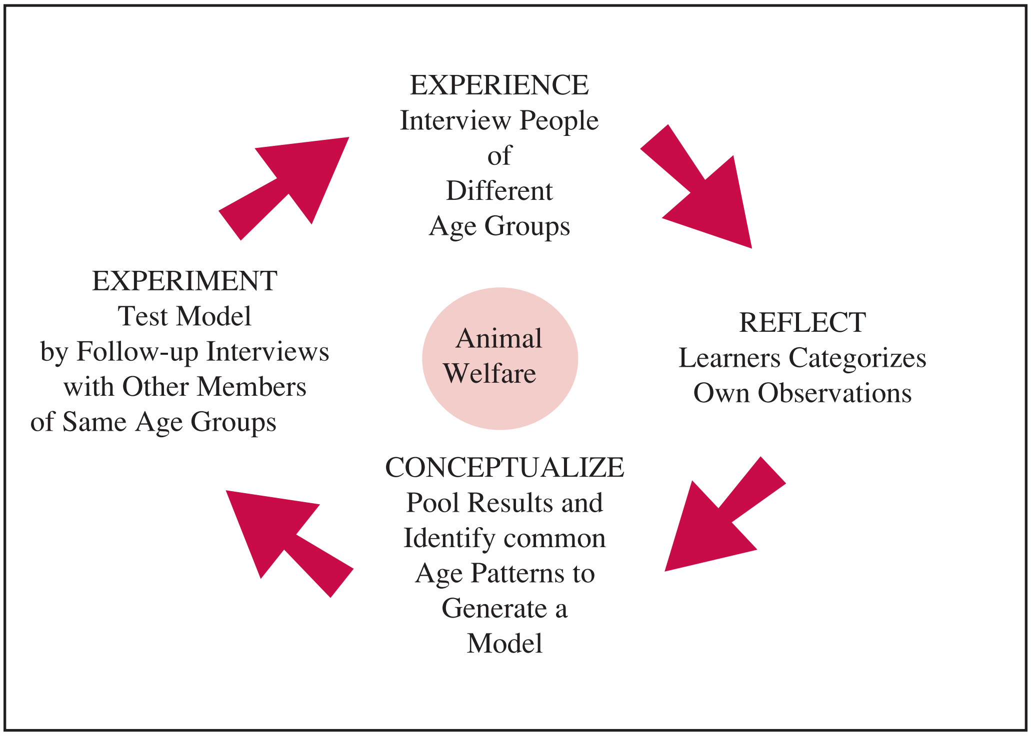
Figure 5 illustrates the learning activities representative of each component of Kolb's (1984) model. Activities such as field experiences, inquiry laboratories, direct data collection, and the reading of primary sources, for example, poetry, are all designed to give the learner firsthand, personal experience with the content. Discussion and journal-keeping force students to reflect on their experiences and the experiences of others. Model-building exercises, research papers, and lectures that present a model all are activities that foster abstract conceptualization. Simulations and projects force students to apply the models to problem situations.

Figure 5. Kolb's Model with Activity Components

Kolb	Experiential Education	Concrete Experience	Reflective Observation Logs	Abstract Conceptualization	Active Experimentation
Svinicki and Dixon	Instructional Methodology/ Learning Activities Laboratories	Observations Primary Text Reading Simulations/ Games Field Work Trigger Films Readings Problem Sets Examples	Journals Discussion Brainstorming Thought Questions Rhetorical Questions Lectures	Papers Model Building Projects Analogies Simulations	Case Studies Laboratory Field Work Projects Homework

For instance, an animal science topic, focusing on animal welfare issues, might begin with field work. Learners could interview people of different age groups (concrete experience). Each learner could then categorize his or her own observations (reflective observation) and make initial speculations on differences among the ages represented. Next, the learners could pool their results and identify common age patterns to generate a model (abstract conceptualization) that describes how different age groups are likely to react to animal welfare questions. Finally, the group could test its hypotheses by follow-up interviews with other members of the same age groups (active experimentation). (See Figure 6.)

Figure 6



Science Skill Development. Ways of thinking and doing in science are collectively known as *science skills*. Science skills, as compared to content skills like planting a seed, wiring an outlet, or trimming an animal's hoofs, form the basis of human learning and understanding. As scientists, we use these skills whenever we define scientific concepts or develop taxonomies. We use them whenever we speak, hear, read, write, or think, as we mentally structure sensory input from our environment. In an attempt to understand the world, we have become proficient in using scientific skills, making them the most powerful tools we have for producing and arranging information about the world.

Ideally, learners engaged in science activities use such skills as inferring, hypothesizing, measuring, estimating, and experimenting to bring meaning to their world. These types of science skills, together with the knowledge, scientific values, and intellectual habits they produce, define the nature of science education outlined in *Benchmarks for*

Science Literacy, 1992. Unfortunately, learners are too often burdened with activities that fail to properly facilitate the application of science skills in a meaningful and significant way. Science curriculum designers tend to focus their attention on the content of their units, equating "teaching" with "covering the content" and giving much less thought to the skills students develop and apply.

Fortunately, there is an increasing body of research supporting the notion that learners learn best when actively engaged, physically, mentally, and emotionally, in hands-on and minds-on activities (*Science for All Americans*, 1990). In fact, there is a greater likelihood that the skills learners apply during a properly conducted learning experience will far outlive the usefulness of the knowledge they were intended to promote in the first place.

The challenge appears to be in knowing which set of science skills to emphasize within a particular activity, experiential component, or unit of study. Our review of the literature found no definitive listing of science skills from which to cite. There are as many different lists of process and thinking skills as there are individuals writing on the subject. Perhaps the best way to approach the problem is from an experiential perspective.

In December 1978, Kolb presented a paper at the National Science Foundation Conference on Contributions in Information Science in which he theorized that all science activities fall under eight *categories* of science process skills**:** exploration, focusing, grounding, structuring, investigation, verification, recording, and communication (Figure 7). The knowledge-base skills of *Bloom's Taxonomy of the Cognitive Domain* are found under Kolb's headings of exploration and focusing. The remaining cognitive skills, often called the "higher-order skills," are found under the headings of grounding, structuring, investigation, verification, recording, and communication.

Diagram 7. Kolb's Model with Inquiry Process Components and Science Skill Categories

Experiential Education	Concrete Experience		Reflective Observation		Abstract Conceptualization		Active Experimentation	
Scientific Inquiry Process Domains	Problem Finding		Question Asking		Answer Seeking		Portrayal of Knowledge	
Science Skill Categories	Exploration	Focusing	Grounding	Structuring	Investigation	Verification	Recording	Communication

Science educators have attempted to expand upon Kolb's thinking by examining the most basic skills necessary for the learning of science and the application of those skills beyond the classroom. For example, the publication *Science Guidelines for Non-formal Education*, lists the processes of science as observing, communicating, comparing and measuring, ordering, categorizing, relating, inferring, and applying. Likewise the National Science Teachers Associations publication *The Content Core* (1993) identifies science processes as observing, classifying, measuring, interpreting data, inferring, communicating, controlling variables, developing models and theories, hypothesizing, and predicting. Still others, such as the *Handbook of Research on Science Teaching and Learning* (1994), list them as observing, classifying, predicting, inferring, hypothesizing, measuring, controlling variables, questioning, using space and time, and experimenting. (See Appendix C.)

To aid curriculum developers, we have identified 25 of the most commonly reoccurring science thinking and process skills found in today's literature (Figure 8). Furthermore, we have applied Kolb's research to align these various skills with the science skill categories linked to his experiential model. From Figure 8, curriculum designers can quickly identify the types of specific skills to emphasize during selected experiences along an experiential path. It is important to note that the skills within a particular category are not mutually exclusive to that category. On the contrary, the ability to target skills based solely on their particular location within the model becomes less important as learners acquire the ability to function at multiple skill levels. These groupings are simply a starting place for designing activities.

Figure 8. Kolb's Model with Inquiry Process Domains, Skill Categories, and Compilation of Science Skills

Kolb	Experiential Education	Concrete Experience		Reflective Observation		Abstract Conceptualization		Active Experimentation	
	Scientific Inquiry Process Domains	Problem Finding		Question Asking		Answer Seeking		Portrayal of Knowledge	
	Science Skill Categories	Exploration	Focusing	Grounding	Structuring	Investigation	Verification	Recording	Communication
Horton and Hutchinson	Science Skills (skills to be learned as well as facilitate learning)	Observing	Categorizing	Inferring Questioning	Predicting Hypothesizing Evaluating Defining Operationally Making Assumptions Using Scientific Tools	Ordering Controlling Variables Using Space or Time	Relationships Recording Data Reducing Error Analyzing Experimenting	Interpreting Data Relating Comparing & Measuring	Using Numbers Graphing Making Models Applying Communicating to Others

Facilitating Experience from an Experiential Perspective

Up until now, we have concerned ourselves with the constructs of identifying and organizing science-based content, experiences, activities, and skills along an experiential path. If we were simply concerned with the development of curricular training manuals, that would be all that is necessary. Certainly, one can argue the importance of training manuals in their sequential approach to education; for example, where would the commercial pilots industry be without its plethora of flight training manuals? From a youth development perspective, however, one can argue that the mission of science education should go beyond merely training a child to do something. As expressed by Bybee (1994), “there appears to be little difference in a lesson that trains a monkey, versus a small child, to plant a seed, if the only goal is getting the seed into the ground.” There is quite a difference, on the other hand, if planting the seed is just part of several carefully mediated events about plants, their role in nature, and our cultivation of them for food.

> *“Now, what I want is Facts. Teach these boys and girls nothing but Facts. Facts alone are wanted in life. Plant nothing else, and root out everything else. You can only form the minds of reasoning animals upon facts: nothing else will ever be of any service to them. This is the principle on which I bring up my own children, and this is the principle on which I bring up these children. Stick to Facts, sir!”*
>
> *—Thomas Gradgrind, in Charles Dickens’* Hard Times

For generations—and even in modern textbooks—curriculum developers have designed materials in the tradition of Dickens’ schoolmaster. By taking a prescriptive approach to education, curriculum developers have sought to achieve education’s primary goal: the mastery of facts. Often publishers who claim to offer progressive science textbooks retain a “training-like” approach to science. They argue that, as this may be the students’ last chance to learn the material, it makes no sense to risk the moment with anything less than structure (*The Content Core,* 1993).

Even 4-H is not exempt from criticism. As noted by Mocker and Spear (1982), the Cooperative Extension Service has a history of preparing learn-at-home 4-H project manuals on a myriad of topics relating to the farm, garden, lawn, home, and family. Many of those manuals present information that is organized along an experiential path and include activities that allow members to practice and apply skills. For all practical purposes, however, the manuals focus on training a child to do something. Even the use of the term “4-H Project Manual” fosters the perception of instructions to be followed rather than activities to be experienced. As Spear puts it, receiving an *A* ribbon on a 4-H project probably has more to do with how well a child follows directions than it does his or her appreciation and understanding of the project area.

Proudman (1995) further explains this distinction between training and education:

> The mere fact that a curriculum is said to be “hands-on” or “learn-by-doing” does not guarantee that the intended learning outcomes are taking place nor that other learning isn’t. For that matter, just “living” could be described as learning by doing.

For example, just because a child is actively engaged in building a model rocket does not guarantee the child is learning about rocketry. More likely, the child is merely engaged in a routinized pattern of instructions that teaches one to stay within the boundaries of the instructions or risk failure. The same could be said for people on an assembly line soldering components onto a circuit board. Although they may know little about what the circuit does, they probably have even less understanding of or appreciation for the circuit itself, who designed it, or the purposes of its various components.

In the simplest of terms, the experiential facilitation process is a series of steps that, when observed, will assure that a learner has an experience that is richly and truly experiential (Chapman, McPhee & Proudman, 1992). In this *non-formal* process, teachers are cast as *facilitators of learning* rather than as directors. According to Proudman (1995), their job is to maintain critical relationships among the learners themselves, between the learners and the facilitator, and between the learners and the learning environment. In this way, each learner is engaged emotionally and is responsible for his or her own learning.

To truly define a curriculum as "experiential," there must be some evidence that "experiential processing" takes place. According to Joplin (1995), experience alone is not experiential education. Rather, true experiential education is characterized by systematic interventions of the learning facilitator with the learner along an experiential path. Joplin identifies these overt interventions as follows.

- *Focus*. Includes presenting the task and isolating the attention of the learner for concentration. It defines the subject of study and prepares the student for encountering the challenging action that is to follow. A good focusing stage is specific enough to orient the learner, but not so specific as to rule out unplanned learning.

- *Support and feedback*. Exists throughout the learning experience and includes maintaining close proximity to the learner during the activity to facilitate questioning and clarify instructions. Adequate support enables the learner to continue to try. It includes demonstrating interest in the learner's situation and letting the learner know that help is available if needed. Adequate feedback will ensure that the learner has the necessary information to move ahead. It includes comments about how the learner works, the learner's manner of interactions, and the substance of the learner's work.

- *Debriefing*. Here, the learning is recognized, articulated, and assessed. It should complement the natural breaking points for subthemes and subactivities within the learning experience. It can also serve as a bridge between natural transition points in the curriculum, as in moving from one component to the next along the experiential path. This is also the learning facilitator's opportunity to assure that the learner's previous actions do not go unquestioned, unrealized, unintegrated, or unorganized. This is the opportunity to ensure that the learner's conclusions are verified and mirrored against a greater body of perception. This intervention includes facilitating decisions about what needs to be done next or how things could have been done differently.

Figure 9. Joplin's Experiential Facilitation Process

Williamson's Experiential Components	Experience—present the content to the learner	Reflect—explore the meaning of the content	Generalize—seek comprehension and appreciation of the content	Apply—apply content to real world situations
Topic at moderate level of experience	A/S	A/S A/S	A/S A/S A/S	A/S A/S A/S

— Focus, Support, Feedback, Debrief

— Content Block

A/S — Activity and skill

Figure 9 organizes Joplin's experiential processing components around a central, hurricane-like theme. It is designed as a template to be overlaid onto the activities and skills (defining elements) that collectively make up a learning experience. It does not require that each defining element be facilitated using Joplin's model to legitimize it as "experiential." Rather, this model is intended to communicate an experiential action strategy for the overall collection of defining elements that comprise a learning experience. As Joplin explains, the approach to which the defining elements (activities and skills) of a learning experience are facilitated using this model is up to the discretion of the curriculum designer. Most importantly, *the process should complement the sequence of learning events rather than intrude as some repetitious prescription for learning*. For example, a learning experience comprising three defining elements (activities and skills) may be processed on an element-by-element basis. However, the facilitation process may also begin by collectively focusing on the defining elements at hand, followed by the support and feedback of each defining activity, and conclude with a debriefing of the total learning experience. This decision rests entirely with the curriculum designer and his or her *vision* for the learning experience.

A second important point made by Joplin is that materials developed for use by learning facilitators should "overtly" communicate the components of her model, like beacons strategically placed along the experiential path that describe the type of intervention necessary. If anything, the "training" for such materials should focus on modeling the experiential behavior of the learning facilitators rather than simply on how to conduct a series of activities. The same could be said for learn-by-doing booklets prepared by curriculum designers for use by 4-H members at home with a parent or adult facilitator. Here, too, there must be clearly defined roles along the experiential path for the intervention of facilitators in the learning process.

Providing Opportunities for Post-Unit Assessment

Whether we are talking about elementary science assessment or other applied social science activity, there are only three major ways to find out something about humans: We can observe them, ask them, or note the results of their activity.
—*George Hein,* The Assessment of Hands-On Elementary Science Programs

Behaviorist psychologists, who dominated American academic life for decades, refused to discuss such issues as intention, feelings, and mental models. Why children learned, how they felt about learning, or what might be going on inside their heads was considered beyond the reach of empirical study. Evaluators and researchers were urged to concentrate on the relationship between teachers' actions (stimulus) and students' responses. Today most educators no longer hold that limited view of the human experience; the fact remains, however, that what is directly accessible to us in developing any assessment system is "behavior." We don't know what children learn, how they feel, or why they act as they do, but, as Hein (1990) says, we can make valid inferences based on our assessment of what we see children do, what they tell us, and what the products of their activity reveal to us.

Developing a meaningful post-unit assessment begins with a clear understanding of the contrast between this type of assessment and the type that goes on during the debriefing phase of the experiential facilitation process. During debriefing, assessment focuses more on process than product. It is the opportunity to assure that the actions previously taken do not drift along unquestioned, unrealized, unintegrated, or unorganized. It is also the opportunity to ensure that the learner's conclusions are verified and mirrored against a greater body of perception. On the other hand, post-unit assessment concerns itself with the product of the total experience as it relates to the thought and work processes behind it. It is the opportunity to help learners reflect on what they learned, determine strategies for what could be done differently next time, establish goals to extend the learning, and celebrate what they accomplished. Post-unit assessment also can be used to help learning facilitators assess their impact on the learners and consider how to improve the quality of their intervention next time.

The term *assessment* comes from the Latin *sedere,* meaning to sit beside. The etiology suggests that a much closer relationship should exist between the learner and the learning facilitator throughout the assessment phase of the unit and, hence, that a variety of innovative post-unit assessment methods is needed to satisfy differences in teaching and learning styles among learners and learning facilitators. This requires a clear understanding of what the particular science unit is about, which activities are central to it, and what the are learners are expected to accomplish. The following diagram, adapted from *Learning and Assessing Science Process Skills,* summarizes the most commonly recognized forms of post-unit assessment found in the literature today. Figure 10 is a compilation of research on the subject conducted by Rezba, Sprague, Fiel, and Fuk (1995). An in-depth definition of these post-unit assessment types can be found in Appendix E.

Figure 10. Multiple Forms of Post-Unit Assessment

Assessment	Characteristics
Open-Ended Questions	Responses are constructed rather than selected from a set of “forced” choices.
Performance Task	Knowledge and skills are demonstrated.
Portfolio/Record Book	Documentation of significant tasks worthy of time and commitment.
Checklists	Learners compare what they accomplished to a predetermined set of goals for the unit.
Rating Sheets	Performance is evaluated against a predetermined set of standards.
Interview	One-on-one interaction between the learner and the learning facilitator or an independent assessor.

According to Hein, these sources of post-unit assessment can easily be contrived to strengthen the learner’s total experience with the unit. The role of the learning facilitator is to view the post-assessment phase of the unit as an opportunity to create a sense of closure, as well as to guide learners toward a consideration of next steps. Curriculum designers should *overtly* communicate the role of learning facilitators in this final phase of the teaching/learning process. The curriculum should include specific recommendations for the type of post-unit assessment and the role of the learning facilitator.

Evaluating Curriculum Materials: Content and Product Considerations

Curriculum developers perform curriculum materials evaluation to gather data that will enable them to accept, change, or revise a particular curriculum product. The first step is to validate the authenticity of the curriculum product with a panel of experts, typically, a mix of subject matter and youth development specialists, which compares the curriculum against a predetermined set of criteria to answer the question, Is this a valid teaching/learning tool? The validation process does not require that the panel be exclusively judgmental, meaning it is not directly charged with determining *how well* the curriculum product matches up to the criteria, only if it does or does not. However, panels are often encouraged to point out any specific weaknesses in the materials before pilot testing.

The panel of experts addresses the accuracy and relevancy of the content, its appropriateness in relation to the learner, the organization of the content, and the appropriateness of the activities selected in relation to the content and the skills and abilities of the learner. Figure 11 shows the most commonly addressed criteria used to determine the validity of experientially based science curriculum materials. These criteria are common to most curricular orientations; however, some curriculum developers place greater emphasis on a certain few.

The second phase of the evaluation process involves determining the worth of the curriculum product (do the users like it?) and whether it produced the desired results (reliability). This phase provides evaluators with information that will enable them to decide whether to continue, terminate, or modify the curriculum product. For example, the evaluation might furnish data that show a rocketry product is especially effective as a curriculum directed toward students with learning disabilities.

This phase of the evaluation process usually involves a pilot program with some combination of learners and learning facilitators. According to Talmadge (1985), the evaluation should include the following components: level of satisfaction, readability, efficiency of design, graphic blandishments, clarity of instructions, level of completion, and attainment of desired learning outcomes. (See Figure 12.)

Figure 11. Criteria Used to Authenticate Face Validity of Experientially Based Science Curriculum Materials

Content

Is it

—valid?
—learnable?
—interesting for the learner?
—accurate?
—addressed in a significant way?
—feasible to teach in a meaningful way?
—addressed by topical areas?

Experientiality

- Within each topical area is the content logically arranged along an experiential path?
- Is there a reasonable range of experience at which content will be addressed?
- Is the range of experience supported by an appropriate number of defining elements, activities, and skills?
- Are the activities facilitated using a non-formal experiential process?

Skill Development

- Can the science skills be learned?
- Is the learning of science skills properly facilitated?
- Is there equal emphasis placed on the learning of content skills and the learning of science skills?
- Do the science skills facilitate the learning of content and content skills?
- Are the science skills
  —congruent with the activity being conducted?
  —appropriate for the learner?
  —applied to the content in a meaningful and significant way?

Activities

Are they

— appropriate for the content knowledge and skills being taught?
— engaging enough for the learner?
— appropriate for the age and skill level of the learner?
— interesting for the learner?
— feasible to conduct in a meaningful way?
— facilitated with experiential methods appropriate for the activities selected?
— congruent with the science skills being developed?

Assessment

- Does the product have any type of post-unit assessment component?
- Is it appropriate for the type of learning that has taken place?
- Does it add meaning to the child's learning experience?
- Does it enhance the overall self-esteem of the learner?
- Does it bring a sense of closure to the unit?
- Does it allow the learning facilitator to reflect on his/her role in the teaching/learning process?

Figure 12. Criteria Used to Determine Reliability of Experientially Based Curricula Materials

- Level of user satisfaction
- Readability of curriculum material
- Efficiency of design
- Use of graphic blandishments
- Clarity of instructions
- Level of completion
- Attainment of desired learning outcomes

Conclusions and Recommendations

4-H has been actively engaged since the early 1920s in the development of science education materials for youth. It is not the goal of this publication to indict the quality nor the effectiveness of the science education materials developed to date; in fact, many of the existing pieces are, to varying degrees, congruent with our observations. This publication is, however, both a recommendation for the development of valid, experientially based science curriculum materials and a call to devise a strategic plan of action for change.

If as an organization we truly believe our actions are research based, we are compelled to commit to a specific plan of reform that includes a concerted effort on the part of 4-H curriculum developers nationwide to utilize the recommendations of this publication in devising products for others to model. Those products will, of course, reflect each curriculum developer's unique interpretation of this publication's recommendations. The more creative examples there are, the greater the chance for system-wide adoption. Without such a strategy, this publication is no more than an exercise in individual enlightenment.

We further recommend additional research on evaluating experientially based 4-H science curriculum materials, from both content and product perspectives. There is a plethora of 4-H science curriculum materials currently in development; however, there is a conspicuous absence of research based processes or instruments to determine the validity of those products. If the recommendations set forth in this publication are accepted as a sound set of curriculum development standards, it is logical to use these same standards to affirm a product's effectiveness as an experientially based teaching/learning tool. To do so, we must establish both the process for conducting a critical review of our materials before pilot testing and the review instruments to be used. These same instruments could be used by 4-H curriculum juries when reviewing the merit of a particular science curriculum product for inclusion in the National 4-H Curriculum Collection.

Likewise, we must establish a process and instrumentation for determining product reliability during the pilot/demonstration phase of the curriculum development process. Without this step, we might never know the perceived worth of our curriculum products nor if they consistently produce the desired results for their intended audiences. The evidence collected during this phase, too, could be used in assessing products for inclusion in the National 4-H Curriculum Collection.

Appendix A.

Developing Experientially Based Science Curriculum Materials: A Summary of Steps

Experientially based science curriculum materials are a series of non-formal activities, arranged along an experiential path, that engage youth in the process of learning through the application of personal life skills.

1. Select content for a particular unit of study using a team comprising both individuals with proficiency in the subject and individuals with an understanding of the interests, needs, and abilities of the target audience.

2. Organize the content you wish to address by topical area, with the content knowledge and skills arranged along an experiential path (experience, reflection, generalization, application).

3. Determine the range of experience at which the content will be addressed.

4. Utilize the appropriate number and type of defining elements (activities and science skills) that best support the range of experience you've identified along the experiential path.

5. Maintain the experiential integrity of each experience by incorporating the facilitation process (Joplin's experiential processing components: focus, support, feedback, debriefing).

   The process should complement the sequence of learning events rather than intrude as some repetitious prescription for learning. For example, a learning experience comprising three defining elements (activities and skills) may be processed on an element-by-element basis. However, the facilitation process also may begin with collective focusing on the defining elements at hand, followed by the support and feedback of each defining activity, and conclude with a debriefing of the total learning experience. This decision rests entirely with the curriculum designer and his or her vision for the learning experience.

   Materials developed for use by learning facilitators should "overtly" communicate these components, like beacons strategically placed along the experiential path that describe the type of intervention necessary.

   In preparing learn-by-doing booklets for use by 4-H members at home with a parent or adult facilitator, provide clearly defined roles along the experiential path for the intervention of facilitators in the learning process.

6. Whenever possible, utilize post-unit assessment techniques as a logical way of bringing closure to the unit.

   Communicate the role of the learning facilitators in this final phase of the teaching/learning process, which should include specific recommendations for the type of post-unit assessment to take place and the role the learning facilitator should play. An in-depth description of these post-unit assessment types can be found in Appendix E.

7. Before publication, evaluate curriculum materials for content and product considerations.

   a. Establish a panel of youth development and subject matter experts to authenticate the face validity of the content, experientiality, skill development, activities, and assessment components of the curriculum product.
   b. Pilot test to determine the reliability of the curriculum product. Did the users like it. Did it produce the desired results? Include the use of survey instruments that are sensitive to determining the level of satisfaction, readability, efficiency of design, appropriate use of graphics, clarity of instructions, level of completion, and attainment of desired learning outcomes.

Appendix B.

Kolb's Model with Inquiry Process Domains, Skill Categories, and Compilation of Science Skills

Kolb	Experiential Education	Concrete Experience		Reflective Observation		Abstract Conceptualization		Active Experimentation	
Kolb	Scientific Inquiry Process Domains	Problem Finding		Question Asking		Answer Seeking		Portrayal of Knowledge	
Kolb	Science Skill Categories	Exploration	Focusing	Grounding	Structuring	Investigation	Verification	Recording	Communication
Horton and Hutchinson	Science Skills (skills to be learned as well as facilitate learning)	Observing	Categorizing Inferring	Questioning Predicting	Hypothesizing Evaluating Defining Operationally Making Assumptions Using Scientific Tools Ordering	Controlling Variables Using Space or Time Relationships Recording Data Reducing Error	Analyzing Experimenting Interpreting Data Relating	Comparing and Measuring Using Numbers Graphing Making Models	Applying Communicating to Others
Svinicki and Dixon	Instructional Methodology/Learning Activities	Laboratories Observations Primary Text Reading Simulations/Games Field Work Trigger Films Readings Problem Sets Examples		Logs Journals Discussion Brainstorming Thought Questions Rhetorical Questions		Lectures Papers Model Building Projects Analogies		Simulations Case Studies Laboratory Field Work Projects Homework	

Appendix C.

A Summary of Commonly Identified Science Process Skills

Source	observing	categorizing	predicting	inferring	hypothesizing	interpreting	evaluating	comparing and measuring	communicating to others	making models	graphing	controlling variables	defining operationally	reducing error	questioning	using space or time relationships	using numbers	recording data	making assumptions	experimenting	analyzing	relating	using scientific tools	ordering	applying
Science: Ohio's model competency-based program	✓	✓	✓	✓	✓	✓				✓		✓												✓	
Science Process Skills: Assessing hands on student performance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	
New dimensions in science education	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Science in the national curriculum					✓		✓	✓			✓		✓			✓	✓			✓		✓			✓
Integrating environmental education and science	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓			✓	✓			✓				✓	
Learning and assessing science process skills	✓	✓	✓	✓	✓			✓	✓		✓		✓	✓						✓	✓	✓		✓	✓
Thinking in context: Teaching process across the elementary curriculum	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓			✓	✓					✓		✓	✓
Dimensions of thinking A framework for curriculum and instruction	✓	✓	✓	✓	✓					✓	✓			✓						✓				✓	
Guide to assessment in education: science	✓	✓			✓			✓							✓			✓				✓		✓	✓
Science for elementary schools	✓		✓	✓		✓		✓		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓		✓
Science literacy	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		✓	✓		✓	✓		✓	✓	
Handbook of research on science teaching and learning	✓	✓	✓	✓	✓	✓		✓				✓	✓		✓	✓				✓			✓	✓	
Science guidelines for nonformal education	✓	✓		✓				✓	✓													✓		✓	✓

Appendix D.

Definitions of Scientific Thinking and Process Skills

Analyzing
Determining the nature and relationship of the parts of the whole. In an experiment, it is the process by which one establishes the relationship between controlled factors and the outcome.

Applying
Using sources of information to help solve problems.

Categorizing
Putting objects or events in groups or classes

Comparing and Measuring
A procedure by which one uses an instrument to estimate a quantitative value associated with some characteristic of an object or an event.

Controlling Variables
Identifying and managing all the factors that may influence a situation or event so the effect of one factor may be learned.

Communicating to Others
Anyone of several procedures involving various media which transfer information from one person to another

Defining Operationally
Producing definitions of a thing or event in terms that give it a physical description.

Evaluating
The technique of examining and judging data presented.

Experimenting
Performing a series of data-gathering operations that will test a hypothesis or answer a question.

Graphing
The technique of representing the variables for comparison in a visual diagram.

Hypothesizing
Stating a tentative generalization, which is subject to immediate or eventual testing by one or more experiments, to explain a relatively large number of events.

Inferring
Explaining an observation in terms of one's previous experience.

Interpreting Data
Finding a pattern inherent in a collection of data. This process leads to stating a generalization or drawing conclusions.

Making Assumptions
The process of accepting previously known information as true as a basis for testing hypotheses.

Making Models
Devising a scheme or structure that will describe specific real objects or events.

Observing
The most basic process of science, in which learners use their senses to obtain information about themselves or the world around them.

Ordering
Putting objects or events in a sequence or series.

Predicting
Projecting future observations on the basis of previously known information.

Questioning
Raising an uncertainty, doubt, or unsettled issue that may be based on the perception of a discrepancy between what is observed and what is known by the questioner.

Relating
Devloping solutions to unfamiliar problems through reasoning, observation, and experimentation

Recording Data
Collecting information in an organized fashion about objects and events that illustrate a specific situation.

Reducing Error
The technique of determining the most valid procedures and processes for effective experimentation.

Using Numbers
The technique of expressing ideas, observations, or relationships with numbers, often to complement the use of words.

Using Scientific Tools
Manipulating objects, instruments, and materials as a means of furthering a learner's understanding, appreciation, and application of scientific knowledge.

Using Space or Time Relationships
Describing spatial relationships and their change with time.

Appendix E.

Definitions of Post-Unit Assessment Types

Checklists

Checklists allow parents and learners to take more active roles in assessing progress. Such lists provide learners with a predetermined set of goals to achieve for the unit. Checklists seek to facilitate discussion about the goals that were met rather than about how well the goals were accomplished.

Interviews

When learner interviews can be managed, there is great potential for gaining insight into learners' conceptions, as well as their misconceptions, because of their interactions with a learning facilitator. This type of assessment can be conducted by an independent facilitator at a prescribed time and location, or at a time and place that is convenient to the learner and the learning facilitator.

Typically this type of assessment is facilitated by a set of guiding questions that the learner is privy to beforehand.

Open-Response Questions

Open-response (also called open-ended) questions provide learners with the opportunity to make observations, analyze investigations, and draw conclusions by constructing their own responses in writing or by drawing. A range of possible responses is typical because learners are asked to construct a response rather than choose from a presented set. Questions typically contain two parts, the *directions to the learner* and the *prompt*. The directions tell learners what is expected of them, while the prompt provides the scenario and necessary information for the problems. Scoring guidelines, often called *rubrics*, are developed for the range of responses. Although rubrics can take many forms, they often consist of a scale with four, five, or six levels of proficiency. At the highest level, a learner demonstrates an in-depth understanding of the unit and an ability to communicate it effectively. The reverse is true at the lowest level where little or no evidence of concept mastery or ability to communicate ideas is evidenced.

Performance Tasks (skillathons, demonstrations, illustrated talks)

Performance tasks in science are activities in which learners can demonstrate their knowledge and higher order thinking skills by manipulating equipment and materials and recording their observations and conclusions. They provide learners with the opportunity to demonstrate their understanding of important scientific processes and concepts by actually demonstrating their knowledge and abilities to others. Manipulating materials is characteristically part of the assessment. Performance tasks can be completed individually or by groups.

Portfolios and Record Books

Portfolios and record books may be broadly defined as a collection of representative work including some evidence that the learner has documented his or her level of involvement in the unit. These devices have long been used by 4-H members taking livestock projects and include production, logistical, and financial information about the member's project. A growing trend has been to use portfolios and record books to create a cumulative record of learners' growth in other 4-H project endeavors. These devices should evidence significant tasks, worthy of time and commitment.

Portfolio and record book assessment allows learning facilitators to track learners' progress toward high standards by collecting evidence of learners' ability to identify variables, construct hypotheses, tabulate and graph data, write conclusions, and so on.

Rating Sheets

Rating sheets facilitate the assessment of a learner's performance against a predetermined set of standards for the unit. Typically, an independent facilitator conducts the assessment in the presence of the learner. Often, the learner is asked to perform certain tasks or respond to certain questions as part of the assessment process. The goal of this type of assessment is to determine how well the goals for the unit were accomplished.

References

American Association for the Advancement of Science (1990). *Science for all Americans*. New York: Oxford University Press.

American Association for the Advancement of Science (1992). *Benchmarks for science literacy*. New York: Oxford University Press.

Bybee, R. W., & DeBoer, G. E. (1994). Research on goals for the science curriculum. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 357-387). New York: Macmillan Publishing.

Cantrell, D. C., & Barron, P. A. (Eds.). (1994). *Integrating environmental education and science: Using and developing learning episodes*. Newark OH: Environmental Education Council of Ohio.

Carlson, S., & Maxa, S. (1997). *Science guidelines for non-formal education*. St. Paul, MN: Center for 4-H Youth Development, University of Minnesota.

Champagne, A. B., Lovitts, B. E., & Calinger, B. J. (1989). *Scientific literacy: The year in school science. Papers from the 1989 American Association for the Advancement of Science Forum for School Science*, Washington, DC.

Chapman, S., McPhee, P., & Proudman, B. (1992). *What is experiential education?*

The Journal of Experiential Education, *15*(2).

Dewey, J. (1916). *Democracy and Education*. New York: Macmillan.

Dickens, C. (1961). *Hard Times* (Based on the first book form printing of 1854; p. 11). New York: Penguin Books.

Duschl, R. A. (1994). Research on the history and philosophy of science. In D. L. Gabel (Ed.) *Handbook of research on science teaching and learning* (pp. 443-465). New York: Macmillan Publishing.

Gibbons, M., & Hopkins, D. (1980). How experiential is your experience-based program? *The Journal of Experiential Education*, *3*(1).

Harlan, W. *Guide to assessment in education: Science*. (1983). London: Macmillan Education.

Harmes, N. C., & Kahle, J. (1978). *The status and needs of pre-college science education: Report of project synthesis* (Final Report to NSF for Grant, SED 77-19001). Washington, DC: National Science Foundation.

Hein, G. (Ed.). (1990). *Assessment of hands-on elementary science programs*. Grand Forks, ND: Center for Teaching and Learning, University of North Dakota.

Hirst, P. (1974). *Knowledge and the curriculum*. London: Routledge & Kegan.

Hutchings, P., & Wutzdorff, A. (1988). *Knowing and doing: Learning through experience.* San Francisco: Jossey-Bass.

Hyde A. A., & Bizar, M. (1989). *Thinking in context: Teaching cognitive process across the elementary curriculum.* White Plains, NY: Logman, Inc.

Joplin, L. (1995). On defining experiential education. In K. Warren, M. Sakofs, & J. S. Hunt, Jr. (Eds). *The theory of experiential education* (pp. 22-29). Dubuque, IA: Kendall/Hunt Publishing Co.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kolb, D. A. (1978, December). *Applications of experiential learning theory to the information sciences.* Paper presented at the meeting of the National Science Foundation Conference on contributions of the behavioral sciences to research in information science, Washington, DC.

Luckman, C. (1996). Defining experiential education. *The Journal of Experiential Education*,19(1), pp. 6-7.

Marzano, R. J., Brandt, R. S., & Hughes, C. S. (1988). *Dimensions of thinking: A framework for curriculum and instruction.* Alexandria, VA: Association for Supervision and Curriculum Development.

Mocker, D. W., & Spear, G. E. (1982). *Lifelong learning: Formal, non-formal, informal, and self-directed.* (Report No. 723). Columbus, OH: ERIC (CE). (ERIC Document Reproduction Service No. 220723).

Ohio Department of Education, Document Management Services. (1988). *New dimensions in science education* (Publication No. 188). Columbus, OH: K. Wagoner.

Ohio Department of Education, Document Management Services. (1994). *Science, Ohio's model competency-based program* (Publication No. 194). Columbus, OH: E. Sheppard & K. Wilson.

Ostlund, K. L. (1992). *Science process skills . . . assessing hands-on student performance.* New York: Addison Wesley Publishing.

Parker, J. C., & Rubin L. J. (1966). *Process as content: Curriculum design and the application of knowledge*. Chicago: Rand McNally.

Pearsall, M. K. (Ed.). (1993). *Content core* (Vol. I). Washington, DC: National Science Teachers Association.

Proudman, B. (1995). Experiential education as emotionally engaged learning. In K. Warren, M. Sakofs, & J. S. Hunt, Jr. (Eds.) *The theory of experiential education* (pp. 232-239). Dubuque, IA: Kendall/Hunt Publishing Co.

Quinsland, L. K., & Van Ginkel, A. (1984). How to process experience. *The Journal of Experiential Education*, *7*(2), 8-13.

Reynolds, S. (1981). A marriage proposal: Competency based education and experiential learning. *The Journal of Experiential Education*, *4*(2), 34-39.

Rezba, R. J., Sprague, C., Fiel, R. & Fuk, J. (1995). *Learning and assessing science process skills*. Dubuque, IA: Kendall/Hunt Publishing.

Svinicki M. D., & Dixon. N. M. (1987). The Kolb Model modified for classroom activities. *Journal of College Teaching*, *35*(4), 141-146.

Taba, H. (1962). *Curriculum development: Theory and practice*. New York: Harcourt, Brace.

Talmage, H. (1985, May). *Evaluating the curriculum: What, why and how*. National Association for Secondary School Principals, pp. 1-8.

Victor, E. (1989). *Science for elementary schools* (6th ed.). New York: Macmillan Publishing.

Watts, M. (1991). Science across the curriculum. In M. Watts (Ed.), *Science in the national curriculum* (pp. 3-6). New York: Cassell Educational Limited.

Williamson, J. (1979, Fall). Designing experiential curricula. *The Journal of Experiential Education, 2*(2), 15-18.

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The authors would like to thank the following individuals for reviewing and supporting this document.

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Produced by the Communications and Technology Section
Ohio State University Extension

Technical Editor—Jan Leibovitz Alloy, JLA Communications
Production Editor—David E. Scardena
Graphic Design—John K. Victor

Printed on recycled paper with minimum of 10% post-consumer waste, using agribased inks.