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ABSTRACT

A concept/process-based science education program is any science education program in which curriculum instruction, learning, activities, and evaluation are organized by an identified set of fundamental concepts and processes to be developed by students. This differs from science education programs that are topically based. Although topical organization is not necessarily excluded in concept/process-based science programs, such instruction should nonetheless clearly focus on the development of fundamental concepts and processes. This paper includes the following sections: (1) "What Is Concept/Process-Based Science Education?"; (2) "Why Change to Concept/Process-Based Science Programs?"; (3) "How to Understand the Science Process Skills"; (4) "How to Understand Science Concepts"; (5) "How to Facilitate Concept/Process Skill Development"; and (6) "What to Change in a Program." (KR)

Oregon Department of Education
SCIENCE EDUCATION

A SCIENCE RESOURCE PAPER

A Discussion of

Concept/Process-Based Science

I. What is Concept/Process Based Science Education?

The Oregon Science Education Common Curriculum Goals (Oregon Department of Education, 1988) directs Oregon educators to design and implement a science curriculum that addresses seven designated science education goals. Collectively, these goals are intended to focus the science learning experiences in such a manner as *"to develop environmentally, scientifically, and technologically literate members of society"* (Oregon Department of Education, 1988, p. 2).

The first two goals of the Oregon Science Education Common Curriculum Goals (Oregon Department of Education, 1988) are:

(1) students' application of an understanding of fundamental concepts on which science is based and

(2) students' application of problem solving and inquiry skills.

These two goals of the Science Education Common Curriculum Goals are intended to be the primary organizers for the K-12 curriculum and instructional activity. The first goal regarding science concepts lists 25 concepts as fundamental, and the second goal regarding science processes and inquiry lists 15 process skills as fundamental (Oregon Department of Education, 1988, p. 3).

Because of the curricular and instructional emphasis on key concepts and processes, the Oregon Science Education Common Curriculum Goals represents an attempt to shift Oregon science education to a "concept/process-based approach". A concept/process based science education program is any science education program in which curriculum, instruction, learning activities, and evaluation are organized by an identified set of fundamental concepts and processes to be developed in students. This differs from science education programs which are topically based. Although topical organization is not necessarily excluded in concept/process- based science programs, such instruction should nonetheless clearly focus on the development of fundamental concepts and processes.

II. Why Change to Concept/Process Based Science Programs?

Three sources are pushing science educators toward concept/process-based science programs. First, national educational studies and reports (e.g., Boyer, 1983; National Commission on Excellence in Education, 1983; the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, 1983) have criticized the poor quality and quantity of science education. Second, recommendations and suggestions for needed improvements in science education also come from professional organizations (e.g., NSTA, 1989). And third, research from the cognitive sciences is providing a clearer understanding of the role of students thus allowing programs to be designed which take into account students' development of concepts and processes in their scientific understanding and perspectives.

Program research in science education verifies that concept/process-based science education programs respond to the current problems in science education. Concept/process-based science programs are clearly more effective than traditional textbook-based science programs in improving students' science attitudes, interests, achievement, creativity, and higher level cognitive skills, and these findings extend across all grade levels (Holdzkom and Lutz, 1984; Bredderman, 1983; Shymansky et al., 1983; Blosser, 1985; Thomson and Voelker, 1970; Weber and Renner, 1972; Bowyer and Linn, 1978; Renner and Marek, 1988).

Concept/process-based science education programs enhance learning and skill development in other subject areas, particularly language arts and mathematics especially if the skills are developed through first-hand experiences with objects and events (Holdzkom and Lutz, 1984; Renner et al., n.d.; Wellman, 1978; Bredderman, 1983; Shymansky, 1983; Mechling and Oliver, 1983). Concept/process-based science education programs increase the long term retention (in terms of years) of science concepts and process skills. This retention is especially significant compared to the short "life expectancy" (eight weeks) of the majority of rote learned material that is not used regularly (e.g., Montgomery, 1969; Bowyer and Linn, 1978; Cox, 1982).

And science programs which are locally developed have also been shown to be as effective or better in students' cognitive and affective performances when compared to national curricula (Aikenhead, 1980; Harknesss and Norton, 1981; Cox, 1982; Rawers and Cox, 1983).

The general conclusion is that science education should and is moving away from a singular focus on isolated traditional science content and textbook bound instruction toward an emphasis on concepts and process skills. Current efforts are now directed to balancing several aspects--process skill development, concept development, practical application, and science in the context of society (STS).

III. How to Understand the Science Process Skills

The processes emphasized in the Science Education Common Curriculum Goals are those "intellectual skills which students use in the classroom as they collect and interpret data" to successfully engage in science (Tobin and Capie, 1980, p. 590; see also Commission on Science Education, 1970). The process skills consist of two categories. The first nine--observing, using space-time relationships, classifying, using numbers, measuring, communicating, predicting, inferring, and questioning--are those which are basic and foundational for later, more complex skills, and their development progresses during the primary grades. A second category of six process skills--controlling variables, interpreting data, formulating hypotheses, defining operationally, experimenting, and formulating models--are "integrated" skills which are more complex and should be emphasized in the intermediate grades (Commission on Science Education, 1970; Showalter et al., 1974; Nay, 1981; Harlen, 1985).

The science process skills are of foundational value to learners in order to successfully engage in science. They also contribute to achievement in other academic areas and outside the formal school setting. The process skills continue to develop in learners even without the benefit of formal science instruction, and are long-lived in that they do not show the same rate of loss as with rote learned material.

IV. How to Understand Science Concepts

Concepts are mental constructs that serve as organizers for groups of objects, phenomena, events, conditions, etc. and are usually designated by one or two word descriptors (Cox. 1987). They are "the meanings attached to scientific terms" (Duxbury, 1985, p. 85) or are "a person's organized information about one or more entities--objects, events, ideas, or processes--that enable the individual to discriminate the particular entity or class of entities and also to relate it to other entities and classes of entities" (Klausmier, 1985, p. 276). Examples of concepts are 'bird', 'tree', 'planet', 'volcano', 'cycle', 'gradient', 'energy-matter', and 'symmetry'.

Science concepts serve as perceptual organizers, facilitate communication, and are the building blocks of conceptual frameworks. Concepts are transferable and enhance the meaning of principles, generalizations, and laws. Therefore, concepts are important because they provide a framework for meaningful learning by connecting new information to the cognitive structure. And they represent the basic operational units of the cognitive domain.

Novak (1979) suggests that, *"In the past decade or two, philosophers of science...have moved increasingly toward a consensus that concepts are the most important aspect of knowledge..."* Renner and Marek (1988) state that, *"Our belief is that knowledge is constructed by the abstracting concepts from some type of experience."* Marzano and others (1988) believe that concept formation is a foundation for the other thinking processes such as comprehension, problem solving, and decision making.

V. How to Facilitate Concept/Process Skill Development

Several nationally distributed science instruction programs are process/concept based programs such as Science--A Process Approach (S-APA), Science Curriculum Improvement Study (SCIS), and Elementary Science Study (ESS). Some common characteristics of concept/process-based science programs are:

1. They emphasize the use of con ~~te, hands-on experiences.
2. They coordinate closely-spaced multiple learning experiences involving the concept.
3. They draw upon multiple learning contexts from a variety of disciplines and settings.
4. They make available both positive and negative examples of concepts.
5. They emphasize the use of operational definitions of concepts.
6. They maximize the students' use of the concept in language, both written and oral, and consistently demonstrate proper vocabulary with the concept.
7. They focus learning experiences specifically on the concepts or processes.
8. They provide many opportunities to apply concepts and processes to familiar settings.
9. They relate concepts to other similar ideas.
10. They are aware of the long-term development needed to produce learners' confident, independent use of concepts.
11. Their teaching practices provide wait time both before and after students' responses to instructional questions.
12. Their teaching practices provide ongoing feedback to learners regarding their progress.
13. Their teaching practices establish organization, structure, objectives, sequence, and break down the desired objective into specific knowledge and skill components by task analysis

For example, if the process skill to be taught is observing, four components of the skill can be identified:

(1) using all appropriate senses when observing,
(2) differentiating observations and inferences,
(3) making quantitative observations and measurements when possible, and
(4) extending the senses such as by use of a magnifying glass or stethoscope.

In a collection of hands-on activities over a week or two, learners are assisted in the development of the skill by the teacher constantly interacting and providing feedback and guidance to students. Students complete self-administered progress checks which are an integral part of the sequence of learning activities.

The formation of useful concepts depends on cognitive development. Concrete experiences with the real things which will be conceptualized (e.g., mother, father, house, dog, tree) are also necessary as are activities involving the abstraction of common, shared attributes of the elements. Other important aspects of this model include conceptualizing non-examples and social interaction such as with teachers and students regarding the logic and use of the concept. The labeling or 'languaging' of the concept, which is part of the social aspect, is also necessary and serves both as a communication function and as an element for thought regarding the concept. Science concepts therefore depend on both developmental factors internal to students and external factors of social interaction, language, and physical experiences of activity with concrete objects.

Concepts are mental constructions which represent something in its absence and make possible the description of a large number of phenomena; concepts allow predi tions to be made and they make representation and communication possible. To facilitate concept development, concept/process-based science education programs use some form of instructional cycling such as the 'learning cycle' (Renner and Marek, 1988), the 'Klausmeier Model' (Marzano et al., 1988), and the 'Generative Learning Model (GLM)' (Osborne and Freyberg, 1988). Since the conceptualization process involves a cognitive construction by learners out of the factors mentioned above, instructional cycling is a necessary means for replacing learners' misconceptions with more valid ones.

VII. What To Change in a Program

To change a content oriented science education program to a concept/process-based science education program, several changes must be made:

1. Goals, philosophy, and objectives must be specifically related to the science process skills and concepts.
2. The science curriculum must be re-organized and re-structured to facilitate the development of process skills and concepts.
3. Instructional materials and learning experiences must be changed to facilitate the development of concepts and processes.
4. Teaching strategies and the instructional model must be changed to facilitate the development of the process skills and concepts.
5. Evaluation must shift its focus to the development of science process skills and concepts.

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