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Systems Theory and the Earth Systems Approach in Science Education. ERIC Digest.

During the past three decades, scientists, philosophers, and mathematicians have been working to construct a theoretical framework for unifying the many branches of the scientific enterprise for science education. The outcome of this effort, system theory, provides a framework for understanding both natural and human-constructed environments (Chen & Stroup, 1993). One example, the Earth system developed by the Earth System Sciences Committee (1988) provides Earth science educators with a conceptual approach to curriculum integration (Mayer, 1993). In this approach the Earth is regarded as a unified system of interacting components, including lithosphere, atmosphere, cryosphere, hydrosphere, and biosphere (Earth System Sciences Committee, 1988). The general idea of "Earth systems" is used as a unifying theme of integrated science in over 30 states (Biological Science Curriculum Study, 2000) and has considerably influenced the restructuring of science curriculum and curriculum development. The Earth system concept is also being used by scientists to investigate the role that human activities play in global environmental change (Steffen & Tyson, 2001).

SYSTEM THEORY

As Blauberg, Sadovsky and Yudin (1977) observed, a German-Canadian biologist, Ludwig von Bertalanffy (1901-1972) was a creator of General System Theory (GST). His conceptual approach has had a wide impact on such diverse disciplines as biology, psychology, and economics, and his system theory is an attempt to formulate common laws that apply to every scientific field. Heylighen and Joslyn (2001) stated, Bertalanffy was both reacting against reductionism and attempting to revive the unity of science. He emphasized that real systems are open to, and interact with, their environments, and that they can acquire qualitatively new properties through emergence, resulting in continual evolution. Rather than reducing an entity (e.g., the human body) to the properties of its parts or elements (e.g., organs or cells), systems theory focuses on the arrangement of and relations between the parts which connect them into a whole (cf. holism). This particular organization determines a system, which is independent of the concrete substance of the elements (e.g., particles, cells, transistors, people, etc). Thus, the same concepts and principles of organization underlie the different disciplines (physics, biology, technology, sociology, etc.), providing a basis for their unification. (p. 1)

In Bertalanffy's outline of the major aims of general system theory, we can find the implications for education (Chen & Stroup, 1993). His system theory provides a basis and unifying focus for integrated science education. His list of the major aims includes:

* There is a general tendency towards integration in the various sciences, natural and social.

* Such integration seems to be centered in a general theory of systems.

Such theory may be an important means for aiming at exact theory in the nonphysical fields of science.

* Developing unifying principles running "vertically" through the universe of the individual sciences, this theory brings us nearer to the goal of the unity of science.

* This can lead to a much-needed integration in scientific education. (Bertalanffy, 1969, p. 38)

Heylighen and Joslyn (2001) describe the system theory as "the transdisciplinary study of the abstract organization of phenomena, independent of their substance, type, or spatial or temporal scale of existence. It investigates both the principles common to all complex entities, and the (usually mathematical) models which can be used to describe them." (p. 1) In addition, at the core of system theory are the notions that:

* A "system" is an ensemble of interaction parts, the sum of which exhibits behavior not localized in its constituent parts. (That is, "the whole is more than the sum of the parts.")

* A system can be physical, biological, social, or symbolic; or it can be comprised of one or more these.

* Change is seen as a transformation of the system in time, which, nevertheless, conserves its identity. Growth, steady state, and decay are major types of change.

* Goal-directed behavior characterizes the changes observed in the state of the system. A system is seen to be actively organized in terms of the goal and, hence, can be

understood to exhibit "reverse causality."

* "Feedback" is the mechanism that mediates between the goal and system behavior.

* Time is a central variable in system theory. It provides a referent for the very idea of dynamics.

* The "boundary" serves to delineate the system from the environment and any subsystems from the system as a whole.

* System-environment interactions can be defined as the input and output of matter, information, and energy. The system can be open, closed, or semipermeable to the environment. (Chen & Stroup, 1993, pp. 448-449)

INFLUENCE OF SYSTEM THEORY ON SCIENCE EDUCATION

In building on the traditional science disciplines to study the Earth, the system approach has become widely accepted as a framework by science communities. Several documents also support the 'system' idea as a unifying theme to understand science, and science education. The Earth System Sciences Committee (1988) suggested that "maturation of traditional disciplines, a global view of the Earth from space, and the recognition of the human role in global change have combined to stimulate a new approach to Earth studies-Earth systems science. In this approach, the Earth system is studied as a related set of interacting processes, rather than as a collection of individual components" (p. 13). Furthermore, Mayer (1995) mentioned that the Earth system can provide science educators with a conceptual approach to curriculum integration. Support for teaching and learning about "systems" in science has growing over time (Chen & Stroup, 1993; Karplus & Thier, 1969; Mayer, 1995; Mayer & Kumano, 1999). In the late 1980s, Project 2061 (American Association for the Advancement of Science, 1989) recommended that all students should know about "systems" as a common theme, and the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) suggests how student understanding of "systems" as a thematic idea should develop over the school years.

More recently, the National Science Education Standards (National Research Council, 1996) identified "systems" as a unifying concept that can provide students a "big picture" of scientific ideas as a context for learning scientific concepts and principles. Moreover, the idea of systems provides "a framework in which students can investigate the four major interacting components of the Earth system-geosphere (crust, mantle, and core), hydrosphere (water), atmosphere (air), and the biosphere (the realm of all living things)" (National Research Council, 1996, pp. 158-159).

Chen and Stroup (1993) emphasized several strengths of system theory for science education:

* Toward integration: General system theory (GST) provides a set of powerful ideas students can use to integrate and structure their understanding in the disciplines of physical, life, engineering, and social science.

* Engaging Complexity: Complexity is the fundamental trait of the everyday environment in which the student lives. Traditional science education has avoided engaging complexity by promoting curricula built upon overly simplified activities and frameworks. GST provides the tools for actively engaging complexity. This offers the possibility of bridging the gap between the world of the learner and the world of science education.

* Understanding change: The world as it is experienced is dynamic. To ignore the centrality of change over time is to present a picture that is alienated from reality. Traditional science education has tended to focus on static and rote sequences. The system theory offers the intellectual tools for learners to build understanding based on dynamics. (p. 448)

* They suggest that system theory "takes up the challenge of creating a powerful framework for discipline integration. As such it stands to provide a coherent alternative to the current pastiche of reform efforts based on vague or underdefined notions of what interdisciplinary science curricula might look like" (p. 457).

THE CHALLENGE

As Mayer and Kumano (1999) argued, system oriented science methods and content in school science curricula can effectively help teachers teach about basic physical, chemical and biological processes that act within Earth systems. It can demonstrate how basic processes operate within systems and show how systems are changed by human interventions. Using a system approach (e.g., Earth systems) as a conceptual approach to the organization of curricula can replace many current interdisciplinary approaches to science curricula or curricula integration. In particular, the Earth systems can provide a rationale and organizing conceptual theme for developing new science curricula for all students in the new global era. A recent case study (Lee, 2002) of a teacher who developed his own Integrated Earth Systems Science Curriculum by using an Earth system approach focused on locally relevant topics that lead to a global perspective; the interaction of water, land, air, and life (human); and the effect of human activities on Earth systems. The course has been very successful and well received by students. Others have developed individual activities that focus on the Earth system concept (i.e. Henriques, 2000). The challenge is to expand the systems approach to science curriculum areas beyond the Earth sciences.

WEB RESOURCES

"Digital Library for Earth System Education"
http://www.dlese.org/

"Earth Systems Education"

http://www.ag.ohio-state.edu/~earthsys/

"Earth System Science Education Alliance"

http://www.cet.edu/essea/

"Earth System Science Online"

http://www.usra.edu/esse/essonline/

Search the ERIC database

Note. Use "earth systems" as an Identifier

http://ericir.syr.edu/Eric/adv_search.shtml

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