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ABSTRACT

This symposium examines the science education research enterprise from multiple theoretical perspectives. The first paper, "Contextual Constructivism; The Impact of Culture on the Learning and Teaching of Science (William Cobern), focuses on broad issues of culture and how constructivism is affected by the context of culture. Culturally based beliefs of students and teachers are examined to determine the niche science finds in the cognitive and sociocultural milieu of students. This paper argues that the cultural foundation upon which science learning is built will provide direction for future constructivist research. The second paper, "Can Principles of Science Inform Instructional Decision Making?" (Richard Duschl) looks at conceptual change theory in terms of growth of knowledge frameworks from the history and philosophy of science tradition. This paper argues that educational researchers who seek to understand the dynamics of conceptual change have underrepresented the task and, therefore, the procedural knowledge involved. The third paper, "Anthropological Perspectives on Teaching and Learning" (Kenneth Tobin), is summarized briefly. The full paper presented an analysis of science teaching and learning from an anthropological view that incorporates semiotics. Myths, metaphors, beliefs, images, and personal epistemologies are important referents in the sense-making process and are used as a conceptual framework for analyzing teaching and learning. Implications are highlighted in the full paper for research, policy, teacher education, and classroom practice. The fourth paper, "Contextual Realism in Science and Science Education" (Ronald Good) is summarized. The paper's perspective is consistent with the current position in science education known as constructivism and combines a view of science known as contextual realism with a view of science learning that focuses on induction and prediction. The central question posed by this paper is how to help students achieve higher levels of understanding of the nature of science within the contexts commonly found in today's schools and communities, and what research is most likely to help in achieving this end. A symposium abstract and overview of the four papers introduce the collection. Two bibliographies provide 96 references. (KR)

THEORETICAL BASES OF SCIENCE EDUCATION RESEARCH

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A Symposium presented at the 64th annual meeting of the National Association for Research in Science Teaching, The Abbey, Fontane, WI, April 7-10, 1991.

Preface

As current editor of JRST I have the opportunity to read a great many papers on science education research. One of the common problems associated with many of these papers is the lack of a theoretical base that both informs and is informed by research. The main intent of this symposium is to focus attention on the importance of stating clearly identifiable theoretical bases associated with one's research.

The "papers" that follow are based on preliminary work sent to me early in the Fall of 1990 by Bill Cobern, Rick Duschl, and Ken Tobin. More complete papers will be available from each of the authors, either at the symposium or shortly after the NARST meeting. Any errors in this symposium overview should be attributed to me rather than Bill or Rick or Ken.

Ron Good

Theoretical Bases For Science Education Research

SYMPOSIUM ABSTRACT

Perspectives on the nature of science and science learning are guided by many theoretical bases. As science educators do research, it is very important to identify and follow a theoretical line that can be recognized and tested by fellow researchers.

At no time in the history of science education research has there been as much activity in using history and philosophy of science, various social sciences including psychology, sociology, and anthropology, and other disciplines to bear on our own discipline of science education. It is ironic that as nearly all science education researchers board the "constructivism express", we are searching in so many different areas for better means to make sense of science learning. Perhaps it is a sign that we are finally shaking the simplistic bonds of behaviorism/positivism and recognizing the complexity of science education. The nature of the enterprise called science is complex and science education is much more complex since knowledge of the social sciences must be combined with knowledge of the natural sciences. It is very important to recognize the enormous complexity involved in gaining a better understanding of science learning in the many contexts that can and do exist. The importance of context in science and science education cannot be over-emphasized, nor can the importance of developing clear theoretical bases on which research in science education can be tested.

Underestimating the complexity of knowledge restructuring in science education yields simplistic solutions for improving science curricula and instructional methods. Researchers in science education must help to identify strategies that science teachers and their students can use to better achieve the goal of conceptual change. One key to understanding how to help students construct knowledge that is more compatible with scientists' knowledge of nature is determining what counts as important evidence in the mind of the learner. Without this knowledge, science teachers are much less likely to experience success in helping students construct conceptual frameworks that are more compatible with scientists' knowledge of nature.

The nature of knowledge varies across the different contexts that we call science disciplines. Contexts within and across the natural sciences vary as do the contexts within and across the social sciences. Ways of knowing depend on what is to be known, as Ernst Mayr has shown so well within biology. Ways of knowing for the evolutionary biologist differ from the molecular biologist, just as ways of knowing for the anthropologist differ from the psychologist. Recognizing this complexity in the natural and social sciences will help science educators better understand the importance of context in studying the learning of science.

THEORETICAL BASES FOR SCIENCE EDUCATION RESEARCH

Overview of Papers

Research in science education should be guided by theory at the same time it affects theory development. Multiple theoretical perspectives are evident in current research, with constructivism being the most popular offshoot of the cognitive developmental theory of Jean Piaget, which was dominant during the 1960's and '70's. At the 1990 NARST meeting in Atlanta, Ernst von Glasersfeld's invited talk on constructivism seemed to be greeted positively and uncritically by nearly all in attendance. If this observation is correct, what does it mean for theory building and related research in science education? Is constructivism the new religion in science education?

This symposium examines the science education research enterprise from multiple theoretical perspectives. The first paper, by Bill Cobern, focusses on broad issues of culture and how constructivism is affected by the context of culture. Culturally-based beliefs of students and teachers are examined to determine the niche science finds in the cognitive and socio-cultural milieu of students. This paper argues that the cultural foundation upon which science learning is built will provide direction for future constructivist research.

The second paper, by Rick Duschl, looks at conceptual change theory in terms of growth of knowledge frameworks from the history and philosophy of science tradition. An emerging tradition in philosophy of science argues that a context of development is a necessary condition for accurate analyses of the dynamics of scientific thinking. This paper argues that educational researchers who seek to understand the dynamics of conceptual change have underrepresented the task and, therefore, the procedural knowledge involved, in precisely the same way that philosophers Kuhn and Lakatos underrepresented the dynamics of theory change.

In the third paper, Ken Tobin presents an analysis of science teaching and learning from an anthropological view which incorporates semiotics. Myths, metaphors, beliefs, images, and personal epistemologies are important referents in the sense-making process and are used as a conceptual framework for analyzing teaching and learning. A research program in this tradition considers schools as subcultures. In the context of science education, the focus is on the manner in which teachers and students make sense of their thoughts and actions in relation to one another. Implications are highlighted for research, policy, teacher education, and classroom practice.

The fourth paper, by symposium organizer Ron Good, is consistent with the current religion in science education known as constructivism and combines a view of science known as contextual realism with a view of science learning that focusses on induction and prediction. The ideal and actual worlds of science are contrasted, as are the ideal and actual worlds of science learning. Changes in the ideal and actual worlds of science influence science education and related research efforts. The central question posed by this paper is how to help students achieve higher levels of understanding of the nature of science within the contexts commonly found in today's schools and communities, and what research is most likely to help us achieve this end.

Paper 1: Contextual Constructivism: The Impact of Culture on the Learning and Teaching of Science

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Though rooted in neo-Piagetian research, constructivism is an avenue of research that departed from the neo-Piagetian mainstream twenty years ago and has continued on a distinct path of development. The departure was evident by the late seventies being clearly marked by two publications, Novak (1977) and Driver & Easley (1978). For constructivists, learning is not knowledge written on, or transplanted to, a person's mind as if the mind were a blank slate waiting to be written on or an empty gallery waiting to be filled. Teaching, furthermore, is mediating. A constructivist teacher works at the interface of curriculum and students to bring them together in a way that is meaningful for the learner. Constructivists use the metaphor of construction because it so aptly summarizes the view that individuals *build* knowledge. The original constructivist avenue can more accurately be called *personal* constructivism because of its focus on the individual.

More recently, researchers such as Solomon (1987) have taken constructivism in a new direction. Drawing from sociologists Mead (1934) and Berger & Luckmann (1967), Solomon argued that student ideas about nature stem "not from the logical processes of which science boasts, but from the "common sense" attitude that relies on being able to interchange perspectives and meanings with others" (1987, p. 60). Thus, Solomon studies the social interactions in classrooms. "As students interact with one another, with teachers... they develop ideas that, because they are held in common, create a universe of discourse, a common frame of reference in which communication can take place" (quoted by Solomon, 1987, p. 68). Thus, the crux of this new avenue is *context*; hence, *contextual* constructivism.

If one moves forward with the connotations of context one naturally arrives at issues of culture, where the term culture includes cognitive culture as well as social and material culture. Contextual constructivism thus leads to some different and rather interesting questions:

1. What do students and teachers <u>believe</u> about the world around them, especially the physical world?
2. How do students and teachers understand their own place in the world, especially their <u>relationship</u> to the physical world?
3. What is the <u>cultural milieu</u> in which these student and teacher beliefs, values, and relationships are grounded and supported?

4. What is the culture of science and how is that culture interpreted in the school science classroom?
5. What happens when student cultures, teacher culture, and the culture of science meet face to face in the classroom?

In other words, we suggest that it is important for science educators to understand the fundamental, culturally based beliefs about the world that both students and teachers bring to class, and how these beliefs are supported by culture; because, science education is successful only to the extent that science can find a niche in the cognitive and socio-cultural milieu of students. The need for this understanding becomes imperative when one considers the vast cultural diversity that is in the American educational system coupled with the fact that members of several cultural groups traditionally show little interest in science.

Carrying the metaphor to its logical conclusion, construction implies a foundation upon which the individual builds knowledge. That is what these questions are about, the cultural foundation upon which learning is built. These questions are about world view, the composite of fundamental beliefs one has about what the world is and how the world works. It seems to us that this is an appropriate direction for future constructivist research.

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Paper 2: Can Principles of Science Inform Instructional Decision Making?

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Objectives

The purpose of the proposed paper presentation is to argue for the inclusion of epistemological criteria describing scientific theory development as guidelines for the design and implementation of instructional tasks. The thesis drawn is that detailed, historically based descriptions of the processes associated with theory development can be used as principle knowledge criteria, in ways mathematics educators conceive of principled knowledge to guide instructional tasks that seek to induce conceptual change. The suggestion that these criteria are examples of principled knowledge is a controversial step toward the development of constructivist perspectives of teaching sciences.

Theoretical Framework

The adoption of cognitive perspectives of instruction and of learning has generated alternative perspectives of 1) the dynamics of learning and, in turn, 2) what it is that constitutes effective instruction. The basis of this alternative view is 'knowing' involves a process of knowledge construction (Carey, 1985; 1986; Hodson, 1988). This constructivist view of knowledge growth suggests learning is an activity requiring the restructuring, adaptation, and abandonment of knowledge claims. The conceptions of the constructivist view owe a good deal to philosophical positions that seek to describe and explain theory structure and development.

An emerging tradition (e.g., Suppe, 1989; Giere, 1988; Thagard, 1990; Laudan, 1984; Nersessian, 1987) in philosophy of science argues that a context of development is a necessary condition for accurate analyses of the dynamics of scientific thinking. The delineation of steps taken in theory and concept development in science (e.g., Thagard, 1990; Nersessian, 1989) have proven useful for cognitive psychologists (Resnick, 1989; Carey, 1986; Chi, 1990) and educational researchers (Vosniadou & Brewer, 1986; Duschl, 1990; Linn, 1987) interested in understanding the role of procedural knowledge in learning. Two outcomes of these research efforts are the emergence in the literature of a distinction between 1) principled knowledge and procedural knowledge and 2) weak and radical restructuring of knowledge claims. A difficult and yet unresolved problem in science education has been to locate the procedures or principles that invoke radical restructuring of knowledge claims.

Data Sources

The research on conceptual change (Gunstone, White & Fensham, 1988) suggests that learners' explanations and meanings of concepts are very resilient and resistent to restructuring. Carey (1985) suggests that there are two types of conceptual change-- weak restructuring of concepts within a domain of knowledge and radical restructuring of concepts to form new domains. Chi (1990) reports that failed attempts to bring about radical restructuring owe a great deal to our lack of understanding of 'what counts' as data in the mind of the learner. Garrison and Bentley (1990) take a philosophical stance and suggest that the idea of paradigm shifts, as proposed by Kuhn, is a viewpoint far more favorable to behaviorism than to cognitive psychology (p. 19). Duschl, Hamilton, and Grandy (Forthcoming) maintain that educational researchers who seek to understand the dynamics of conceptual change have underrepresented the complexity of the task -- and, therefore, the procedural knowledge involved -- in precisely the same why that Kuhn (1960) and Lakatos (1970) underrepresented the dynamics of theory change.

Research in mathematics education offers some potential solutions. In work carried out by Resnick (1989), Greeno (1988), Lampert (1986) and Leinhardt & Smith (1985) the importance of linking cognitive skills to the disposition to use them is stressed. The goal is to get students actively employing rather than just stating the rules/principles/strategies of mathematics. One approach to the problem of getting students to use strategies is the employment of principled knowledge teaching techniques.

Hence, the task of instruction requires students to actively engage in the reasoning to solutions employing select elaboration and scaffolding techniques introduced by the teacher. Basic to these approaches is creating a learning environment in which the process to a solution is valued more than the correct solution to a problem.

A critical element in the success of these teaching episodes is the background knowledge of the teachers and their ability to carry out cognitive tasks embedded within authentic activities. The research by Lampert and Resnick demonstrates the positive impact principled knowledge and knowing can have on mathematics education. Can a similar approach be taken in science education? My position is yes it can, and the strategic or principled guidelines come from evaluative criteria for evaluating theories and describing the development of scientific theories.

Point of View

A more robust version of theory (schema) restructuring than that proposed by Kuhn and then extended by Lakatos is one that adopts a piecemeal approach to such change (Laudan, 1984). What is gained by the piecemeal approach is an emphasis on the microstructures and microsteps embedded within the change processes. It is a version which owes a great deal to the efforts of historians of science. Thus, in opposition to Kuhn's Gestalt shift mechanism for change which argues for concommitant shifts in method and aim commitments when a shift in knowledge commitment occurs (radical restructuring), Laudan (1984) argues for temporally and conceptually separate shifts in commitments to knowledge claims, to methodological steps, and to the aims or goals of the research effort.

It is the microstructures of theory testing and theory development embedded in the commitment shifts scientists invoke for knowledge claims (i.e., theories), methods, and aims which can serve as principled and procedural knowledge guidelines for educators interested in describing and promoting conceptual change or knowledge restructuring. In short, educators have underestimated the complexity of procedures involved in knowledge restructuring. Philosophy of science, informed by history of science, provides developmental epistemological guidelines that can be used to select and sequence instructional tasks accordingly.

Implications

Reform recommendations about the empowerment of teachers and of learners in instructional settings have much to gain from research that identifies how the structures of knowledge can serve as principles to inform practice. The adoption of a principled way of knowing in science classrooms holds promise for determining what counts in the mind of the learner, as anomalous data. In turn, then, the potential to bring about radical restructuring of knowledge claims is enhanced, too. The recommendation to examine the microstructures of theory change also has implications for the design of curriculum. It is also consistent with the adoption of a depth approach to science instruction advocated by Project 2061 and other curriculum reform recommendations (Linn, 1987).

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Paper 3: Anthropological Perspectives on Teaching and Learning

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Teaching and learning are complex acts and cannot be meaningfully understood without considering the culture in which they occur. Teachers do not teach in isolation of the culture, and students certainly do not learn in isolation from others. Thus, when we consider what is happening currently in schools, we need to take into account the key elements of the culture as well as the thoughts and actions of the participants in acts of teaching and learning. What are the most salient of these cultural components? In our research program, we consider schools as sub-cultures and endeavor to understand what happens in those schools in terms of concepts such as myths, customs, taboos, metaphors, and beliefs. In addition, we carefully examine what happens in the school from the perspective of how the participants make sense of what they are doing. We assume that what happens is rational in the sense that possible actions are referred to referents to determine whether or not the actions are legitimate in the culture. Myths, metaphors, beliefs, images, and personal epistemologies are important referents in the sense-making process and are used as a conceptual framework for analyzing teaching and learning.

The paper will present an analysis of teaching and learning from an anthropological point of view which incorporates semiotics. From this perspective, the focus of the research is on the sense making process of the participants in a culture. In the context of science education, the focus is on the manner in which teachers and students make sense of their thoughts and actions in relation to one another. The nature of the observations made in classrooms, the questions that emerged, and the types of answers that were obtained will be discussed in relation to other views of life in classrooms. Implications will be highlighted for research, policy, teacher education, and classroom practice.

Paper 4: Contextual Realism in Science and Science Education

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Tying research in science education to theory is critical if we hope to build a foundation for future work. Whether the theory is drawn from psychology, philosophy, sociology, anthropology, linguistics, and so on, it is important that science education research be clearly tied to theory that can grow through testing.

Philosophy and history of science provide science educators with assistance in defining the nature of science. The continuum from positivism/empiricism to "anything goes" contains the many positions that science educators can choose from to define the science in science education. It is clear that the ideal and actual states of science change as knowledge grows (changes) in the various fields of science. It is also clear that science education must change as we learn more about ourselves through psychology sociology, anthropology, and so on.

The research that science educators do should reflect current learning theory if science learning is the focus of their work. The assumption used in this paper is that science learning is or should be the major focus of science educators' research. The words "science education" are taken to mean "education in science" or the learning of science (science as defined by those who do it and by those who study the enterprise called science).

One of the sources of confusion and, perhaps, of some of the disagreement over the nature of science, is the collective nature of science. As Ernst Mayr points out in Toward A New Philosophy of Biology (1988), philosophy of science has been mostly the philosophy of physics, with biology, particularly evolutionary biology, given little thought. The importance of context cannot be over-emphasized. The nature of knowledge and related methods of inquiry in evolutionary biology, as Mayr points out, are different than in molecular biology.

The nature of knowledge and related methods of inquiry are different within and across the various natural sciences, so when we speak of the nature of science it is very important to recognize that context matters a great deal. Perhaps we should remind ourselves of this by saying the "natures" of science.

Finding commonalities in methods and themes across the various natural sciences, as Project 2061 has recently done (Science for All Americans, 1989), is important for many reasons. For other reasons we must not lose sight of the importance of that which is unique to the different sciences. If philosophers and historians of science had emphasized evolutionary biology rather than physics, the literature and arguments about the nature of science would be different in many ways. An emphasis on context requires that we recognize the differences across and within the natural sciences.

Education in the natural sciences (science education) must reflect both the similarities and the differences across and within these disciplines. Further, science education must reflect our best understanding of how to help people learn science. In many ways this is a much more complicated job than simply doing science, for it means that we must understand both how people learn in different contexts and the nature of what is to be learned. The nature of the learner depends on the context just as much as the nature of science depends on the context. In an earlier paper (Toward A Unified Conception of Thinking: Prediction Within A Cognitive Science Perspective, 1989) I identified Richard Schlagel's book (Contextual Realism, 1986) as a framework that emphasizes the importance of context in science and how modern cognitive theory and related disciplines must be considered in philosophy of science. Broadening the context to include perspectives from other disciplines (e.g., anthropology) helps to underline the complexity of the science education environment in which contemporary researchers find themselves. Learning about science learning seems much more complex now than at any other time. This symposium emphasizes the importance of both recognizing this complexity and developing clear theoretical bases for science education research.