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ABSTRACT

Some interesting work currently being done in science education research is with scientifically misconceived ideas about the causes and mechanisms of natural phenomena. Though not stated explicitly, it can be inferred from the corpus of this misconception research that an assumption of homogeneity among students is made, even where there is gender, racial, and cultural diversity among students. Specifically, it is assumed that students come into secondary and college science classes with relatively homogeneous, fundamental views of the natural world, capable of assimilating and valuing modern scientific understanding when science knowledge is presented in traditional inquiry fashion. This paper is a theoretical work on the fundamental, epistemological structure of the mind, or more simply, world view. The researcher believes that it is a mistake to assume that there is worldview homogeneity in the typical classroom and that this assumption retards a more comprehensive understanding of factors that lead to science achievement and positive science attitudes. Specifically, the purpose of this paper is to present a logico-structural model of world view and to discuss its potential for use in science education research. Although this paper begins with a focus on science misconception research, it is intended that the relevance of worldview theory to other research interests become evident. (CW)

World View Theory and Science Education Research: Fundamental Epistemological Structure as a Critical Factor in Science Learning and Attitude Development

A research paper presented at the annual meeting of the National Association for Research in Science Teaching, San Francisco, March, 1989. This research was funded by a grant from the Sid Richardson Endowment at Austin College.

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Abstract

The concept of world view dates at least to the late 1800's and the work of Wilhelm Dilthey. It has been a subject mainly of interest to cultural anthropologists, perhaps most notably Ruth Benedict and Robert Redfield. Much more recently Brent Kilbourn introduced world view to the science education research literature, and subsequently the subject has been pursued by several other science education researchers. These have not used the foundation laid by cultural anthropologists but have used the philosopher Steven Pepper's root metaphor theory as the basis for their work. In the present theoretical paper it is argued that worldview theory has great potential as an integrator and generator of research in science education. However, this potential will not be realized using the Pepper approach since it greatly oversimplifies the concept of world view. The paper argues for adopting the work of cultural anthropologists, specifically Michael Kearney's logico-structural model of world view. This model depicts world view as a composite of seven universally found categories, the Self, NonSelf, Relationship, Classification, Causality, Space and Time. The paper argues that this model has the articulation necessary for the empirical study of world view as a factor in science education not only where there is obvious cultural heterogeneity, but also in situations generally considered culturally uniform. The theoretical context for this paper is constructivist epistemology. The paper includes a discussion of evidence for the theory presented and concludes with a worldview research agenda.

Some of the most interesting work currently being done in science education research is with scientifically misconceived ideas about the causes and mechanisms of natural phenomena, or as it is more simply referred to, misconception research. This type of research can be dated as early as the sixties (see Kuethe, 1963; Boyd, 1966); but it came into its own with the 1983 and 1987 international symposia on misconception research in science and mathematics education held at Cornell University (Helms & Novak). Researchers have demonstrated that students do not come into the science classroom with minds *tabula rasa*, but that students bring with them ideas and values about the natural world that they have formulated on their own or have acquired from previous educational experiences. As scientifically acceptable explanations, some of these ideas are nonsensical, others are quite close if not essentially correct. Some students come into class already holding a high view of science. Others come with value systems that will readily incorporate a high view of science given the proper circumstances. Others are prepared to resist. To date, misconception research has been limited to elucidating misconceptions in various subject areas and upon instructional strategies for replacing them with accurate scientific understanding. However, the significance of this research is that attention has been focused on the epistemology of students, whether they are young adults or children. This is in marked contrast to Piagetian researchers who, to paraphrase

Gareth B. Matthews, do not take children's puzzlings seriously (1980, p. 48).

As in any avenue of research, certain assumptions are required. Though not stated explicitly, it can be inferred from the corpus of misconception research that an assumption of homogeneity among students is being made, even when there is gender, racial, and cultural diversity among students. Specifically, it is assumed that students come into secondary and college science classes with relatively homogeneous, fundamental views of the natural world capable of assimilating and valuing modern scientific understanding when science knowledge is presented in traditional enquiry fashion. Therefore, when misconceptions are encountered an exact identification of the misconception is sought, plus methods for supplanting it with accurate scientific understanding. Generally it is not asked, "Is it possible that this scientifically misconceived idea is a logical deduction from some fundamental view of nature held by the student?" This question indicates that the researcher suspects that more is at issue than factors of pedagogy and student intelligence.

Indeed, seeking to know more about students' fundamental views of the world, their *epistemological macrostructures*, is a logical extension of misconception research. Furthermore, this is an extension that should help provide the needed theoretical framework for continued misconception research, as well as for

research regarding gender and cultural factors in science education. One perhaps is tempted to see epistemological macrostructure as an issue only in conjunction with gender and culture, but this tendency to assume general homogeneity amongst students keeps researchers from a more comprehensive understanding of factors that lead to science achievement and positive science attitudes. Furthermore, it may be the very assumption that blinds researchers to the root causes for the documented recalcitrance of misconceptions to standard science pedagogy (Ausubel, 1968; Osborne & Wittrock, 1983).

There are other researchers interested in students' epistemological structures (e.g., Driver, Guesne & Tiberghein, 1985, Driver & Easley, 1973; Fensham, 1980; Freyberg & Osborne, 1981). Gilbert and Swift (1985, p. 682) write that "an emerging 'invisible college' for what we have termed the 'alternative conceptions movement' (ACM) appears to be gradually emerging." Osborne and Wittrock (p. 489, 1983) write that

> over the last few years there has been a growing awareness among science educators of the importance, for learning, of the conceptions that children of all ages bring with them to science lessons.

They go on to list twelve aspects of physical phenomena that have been the topics of research adding that

> a most important feature of these studies is the attempt to establish the views children hold whether or not these views are congruent with those of scientists.

Novak, Gowin and Ault (1988) have pursued this line of research using Gowin's Vee Map methodology. However, the theoretical work

reported here differs in that its focus is the epistemological levels antecedent to the specific concepts that students hold about physical phenomena.

Each person has a fundamental, epistemological macrostructure which forms the basis for his or her view of reality (or nature). The more common term is *world view*. The concept of world view has not often been used in science education research likely for wont of a theory of world view that can direct its analytical use. The purpose of this paper is to discuss an adaptation of the Kearney model of world view as a powerful theoretical framework for directing science education research.

I have nct discussed the evidence that supports Kearney's theory, because in his book *World View* (1984), he has already done that far better than I could. The very fact that Kearney's theoretical work is based on empirical anthropological research rather than on more speculative philosophical analysis gives it a veracity lacking in other approaches to world view (e.g., Pepper, 1942). Of course Kearney is not without his critics and I would refer the interested reader to reviews by Dundes (1984) and Wilk (1985). Any researcher functions within a world view. Kearney openly says that his is significantly informed by Marxist materialism. Yet aside from some polemics in his writings, his worldview model is not inherently Marxist. Neither is the model essentially materialistic. It becomes so only for those who like

Kearney view mechanism as not merely a method, but as a metaphysic. I reject both Marxism and materialism, and what follows is an attempt to use a worldview model as part of a mechanistic method for exploring how a student comes to understand, value and accept the scientific enterprise. In my work the Kearney worldview model has to do with epistemology, not ontology (see MacKay, 1987). In fact it is my expectation that worldview research will help clarify the distinction between mechanism as a method (epistemology) and mechanism as a metaphysic (ontology).

Critical Assumptions

With respect to the Kearney model of world view, the principal assumption is that all human activity proceeds from a cognitive root, even affection. This model is inherently cognitive. It is also important to note that the concept of world view has no common sense counterpart, anymore than do the models we call photons or genes. Any worldview model is an abstraction derived from certain observed phenomena, but is not a picture of those phenomena.

Most would grant that in ethnically diverse classrooms a **prima facie** case can be made for worldview variations as a factor in the education process. The principal assumptions in my use of worldview theory in science education research are that the students in most, if not all, science classrooms have subtle, worldview variations; and that these variations are an important

factor in science achievement and attitude development among students. This paper differs from many others in science education research in that I assume that studies in anthropology can be as important to science education as have been studies in the history and philosophy of science. The primary significance of these assumptions is that one would not embark on this avenue of research without them. Having made them, the research thus derived will ultimately speak to their veracity.

The terminology used in this article is that of the cultural anthropologist. Synonyms for world view that occasionally appear in the education literature are root metaphor, world hypothesis, view of nature, view of reality, and perceptual framework. For clarity, I use *world view* as a noun and *worldview* as an adjective.

The Concept of a Scientific World View

It is essential at the onset to emphasize that world view refers to something that is subconscious in the minds of most adults, and surely all children. When thinking about world views we usually do not think about individuals. The concept of world view is most often associated with civilizations, religions, and eras (see Quigley, 1961). One speaks of a Western world view, an Eastern world view, medieval world view, or scientific world view. Americans have difficulties understanding the problems of the Near East because the modern, Western world view is so different from the traditional, Islamic world view. In fact,

awareness of world view is most acute when we step out of our own culture and into another.

With the rise of modern science came a new way of looking at the world. The modern scientific world view is a uniquely Western phenomenon born out of the intellectual tumult of the 16th to 18th Centuries in Europe. With the rise of Newtonianism a mechanistic world view triumphed amongst the literati over its competitors, the Aristotelian, "world as an organism" view, and the Neo-Platonic, "mysterious universe" view (Kearney, 1971). The triumphant mechanistic view exemplified by the philosophical arguments of Rene Descartes and the experimental work of Newton and Boyle became the basis of modern science. It is a reductionistic view that sees the explanation of the whole in the parts, where machine-type analogies are considered appropriate for explaining natural phenomena. And though modern physics is modifying the classical scientific world view, it remains a thoroughly empirical view that stresses the importance of testable hypotheses concerning natural causes. In modern America, a primary goal in science education is the development of a scientific world view, especially with regard to scientific ways of thinking.

Since its birth the phenomenon of modern science and its attendant world view have slowly spread beyond European borders. In 1967, George Basalla presented a three-stage model that describes this expansion and growth of science in nonscientific societies. In a new area, science is at first dependent upon

older science and scientists. For example American science was for many years dependent upon European science. Basalla suggested that for the new science to become independent, seven tasks needed to be completed. The first task and the one most pertinent to the subject of world view is that a

> resistance to science on the basis of philosophical and religious beliefs must be overcome and replaced by positive encouragement of scientific research (p. 617).

While philosophical and religious beliefs are not identical with world view, because they are so intimately linked with world view (they are an important part of the content of a world view), we may conclude that the emergence of an independent science requires a scientifically compatible world view. The people of nonscientific, nontechnological societies often have world views that are incompatible with scientific thinking. It is not that they are nonrational (Horton, 1967), but that their rationality based on a different world view results in a nonscientific way of thinking. For such a society to develop an independent science, the world view of a significant portion of its people must change.

Figure 1 graphically represents world views in scientific and non-scientific societies. As examples we may take respectively the United States and a non-Western, developing nation (assume equal population sizes). The X-axis represents a hypothetical scale of worldview compatibility with scientific thinking. The Y-axis represents the hypothetical frequencies of

the scientifically compatible world views in the two example nations. At first one might think that the worldview frequency distribution for a scientific society such as the United States should be drawn with less variation. However, the United States is a pluralistic nation, and is becoming more so. There is a high school in Houston that is reported to have 87 nationalities represented in its student body (Wilson, 1988).

The historic American subcultures of African-Americans, Native American Indians, and women are all under-represented amongst science students and in science-related occupations (Behringer, 1985; Haukoos, 1986; Hueftle, Rakow & Welch, 1983; Malcom, George & Matyas, 1985; Vetter & Babco, 1988). Other subcultures have been transplanted from nonscientific societies. Furthermore, throughout the whole of American society there is significant interest in decidedly unscientific practices such as astrology, to wit Mrs. Reagan. Taken together, this suggests worldview variation even within what is normally considered a scientific society.

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INSERT FIGURE 1
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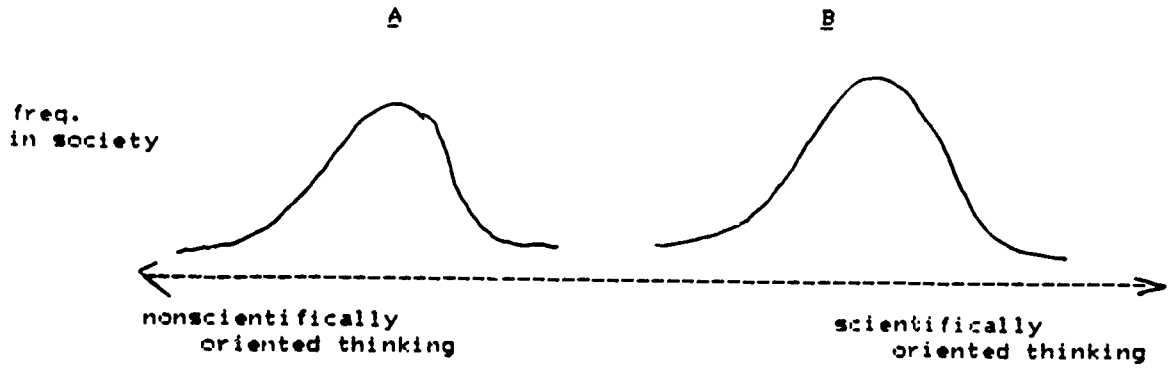
Figure 1 helps us to see that a primary task among developing nations is shifting the distribution of worldview variations sufficiently toward scientific compatibility so that the society can sustain independent science (Dart, 1971). For the United States the task is much different. Given the basic science education goal of developing within students a scientific

Graphic Representation of world view
in Scientific and non-Scientific Societies



A = nonscientific society
B = scientific society

Fig. 1

world view, many would argue that the American education task is to move the distribution center further to the right, while simultaneously reducing heterogeneity. This presupposes that the current, dominant scientific world view is the best one for supporting the scientific enterprise. Others disagree and seek through education the reconstruction of the scientific world view in different modes, e.g., a feminist mode (Coughlin, 1984; Harding, 1986; Levin, 1988).

Another view of the American task presupposes nothing about the current, dominant scientific world view. Instead, the task is to build bridges between the enterprise of science and the worldview variations within the populace. This is the position taken in this paper.

Root Analysis of a Misconception

The relevance of worldview theory is most easily seen in misconception research. In a typical misconception study the researcher might investigate students' understanding of the concept *ecosystem* by asking students why some organisms consume other organisms in a given pattern or sequence. Responses such as "It's God's purpose," and "Organisms eat other organisms to preserve their species," are considered misconceptions (Marek, 1986). The researcher might then attempt to displace the misconceptions by employing Ausubelian cognitive bridges, i.e., the introduction of a lesson using statements intended to connect

new material to what the students already know (Ausubel, Novak & Hanesian, 1978). Such attempts to make learning more meaningful do help, but to date research shows the effects to be limited. Based on worldview theory, one can argue that misconception is a more complicated phenomenon than previously considered, and that cognitive bridges as currently construed will never be completely effective.

Figure 2 shows two distinct categories of misconception. The first category is the relatively simple case of uninformed naivete, inadequate instruction or misinformation that leads to factual misunderstanding. In this category the student's world view is not the issue. This is the general assumption in current misconception research. However, worldview theory points to a second category. A misconception can be an explanation logically deduced from an alternative world view. Because this misconception has intuitive appeal for the student, assimilation of what is considered proper scientific understanding is hindered. Or, a student may have an alternative world view which in principle is capable of assimilating scientific understanding, but does not esteem scientific explanations of physical reality. Thus, the student does not retain them. Third, though a student's alternative world view might not actively hinder science understanding or interest, meaningful learning requires that the science concepts be linked to the student's world view. The failure to establish such links results in the rejection or non-retention of the science concept. In the second category,

the student's ideas are not properly called *misconceptions*, for they are logically grounded in the student's view of nature. They are alternative conceptions, only some of which are also *science* misconceptions. Take the example of the student who responds, "It is God's purpose." For this student the teleological why is apparently more important than secondary, mechanistic, causal factors. A great injustice is done to the student by labeling this response a misconception.

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INSERT FIGURE 2
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Defining World View

World view refers to the culturally-dependent, generally subconscious, fundamental organization of the mind. This organization manifests itself as a set of presuppositions or assumptions which predispose one to feel, think, and act in predictable patterns. Kearney refers to world view as:

> ...culturally organized macrothought: those dynamically inter-related basic assumptions of a people that determine much of their behavior and decision making, as well as organizing much of their body of symbolic creations ... and ethnophilosophy in general (1984, p. 1).

To be rational means to think and act with reason, or in other words to have an explanation or justification for thought and action. Such explanations and justifications ultimately rest upon one's world view, one's presuppositions about the world. Or in other words, a world view inclines one to a particular way of thinking. According to Kearney a world view:

Root Analysis of a Misconception

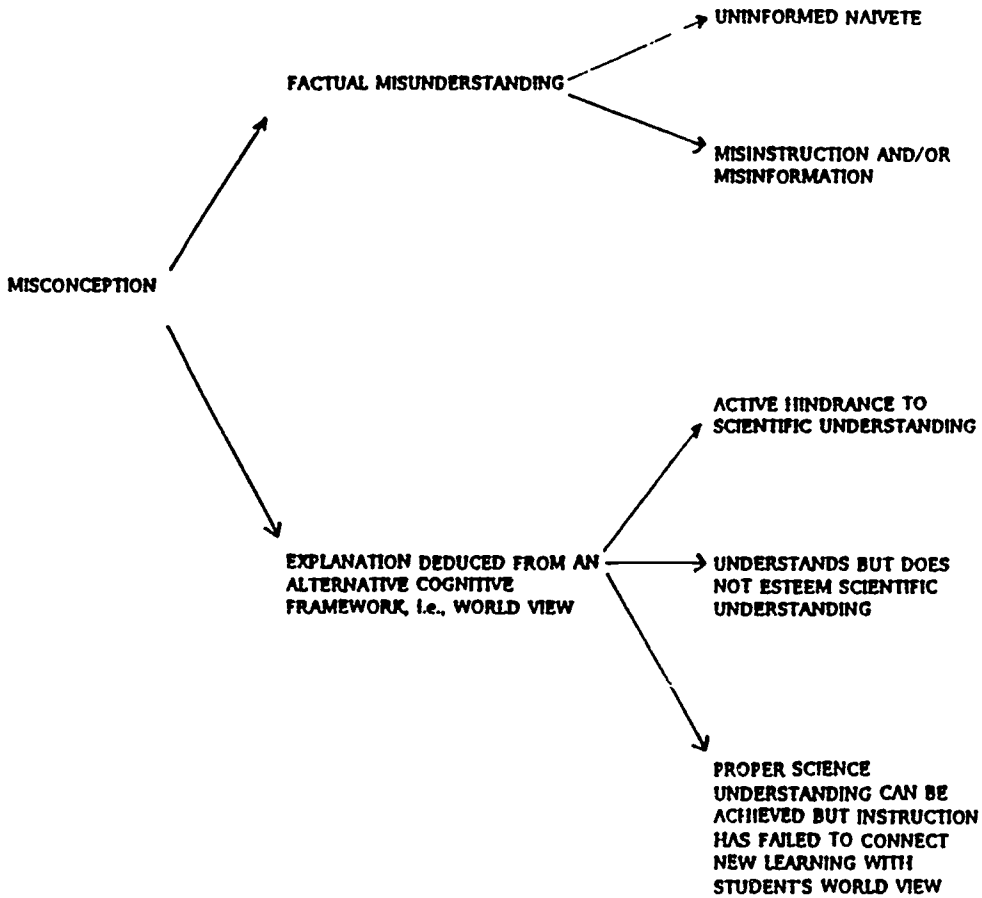

Figure 2

> ...consists of basic assumptions and images that provide a more or less coherent, though not necessarily accurate, way of thinking about the world (1984, p. 41).

Specifically, a world view defines the self. It sets the boundaries of who and what I am. It also defines everything that is not me, including my relationships to the human and non-human environments. It shapes my view of the universe, my conception of time and of space. It influences my norms and values (Kraft, 1978, p. 4).

Often one thinks of a world view as religion or philosophy, for example the Christian world view or the realist world view. Religion is indeed an especially powerful formative force on the mind of a growing child, greatly influencing the contours of a child's world view. But in that there are many other environmental factors that influence a child, religion and philosophy are also part of the specific content of a world view, thus for example the significant differences and similarities between African and Western Christians. Hiebert (1976) refers to religion and philosophy as the visible expressions of a world view. In Wallace's descriptive prose:

> ...a world view is not merely a philosophical by-product of each culture, like a shadow, but the very skeleton of concrete cognitive assumptions on which the flesh of customary behavior is hung. World view, accordingly, may be expressed, more or less systematically, in cosmology, philosophy, ethics, religious ritual, scientific belief, and so on, but it is implicit in almost every act (1970, p. 143).

According to anthropologists the assumptions that compose a world view have five functions (Kraft, 1974). They explain the how and

why of things, and why things continue as they do. They validate "...goals, institutions, and values of a society and provides them with a means for evaluating all outside influences as well as activities and attitudes within the society" (1974, p. 4). They reinforce people "...at points of anxiety or crisis in life providing security and support for the behavior of the group " (1974, p. 5); and both encourages and prescribes behavior.

And finally, worldview assumptions function as integrators. They allow one to order and systematize sense perceptions. As Kraft writes,

> This system makes it possible for a people to conceptualize what reality should be like and to understand and interpret all that happens day by day in this framework (1974, p. 5).

Finally, there is an adaptive function. A world view is "...resilient and reconciles differences between the old understandings and the new in order to maintain a state of equilibrium" (1974, p. 5). A world view helps one maintain a sense of mental order and balance in a world of change via the dialectical interaction between our extant worldview assumptions and environmental changes.

Cultural anthropologists study world views to learn more about people and their cultures. They want to know why one group acts and thinks this way, while another group acts and thinks a different way. For educators the importance of world view is identified in two assumptions:

> that the best immediate understanding of behavior is offered by understanding the thoughts that underlie the behavior, and...other things being equal, the economy of human thought and the nature of culture are such that cognitive

> assumptions at work in one area of life, say economic production, will also organize thinking in others, say ... ideas about human nature (Kearney, 1984, pp. 3 and 4).

In other words we assume that what we think has a great influence on our actions; and furthermore, that even very different areas of thought are influenced by what might be called generic, cognitive assumptions. Knowing something about students' world views should enable an educator to better understand student attitudes, achievement and behavior in the classroom.

To this point I have used two terms when refering to the content of a world view, *assumptions* and *presuppositions*. *Assumption* is Kearney's (1984) preferred term while *presupposition* is shortened from Collingwood's (1940) *absolute presupposition*. Because it is generally necessary to use the term *assumption* for other purposes, e.g., research assumptions in an investigation, I find it less confusing to use the term *presupposition* when refering to worldview content. For the sake of brevity I have dropped the adjective *absolute* though I consider Collingwood's distinction between absolute and relative presuppositions to be an important one. It is a distinction that merits further attention, but in another paper.

The Formation of a World View

Figure 3 is an attempt to illustrate the theoretical relationship that world view has with cognition, learning,

perception and behavior, and environment. The driving force behind the development of a world view is our need to relate to the outside world. As aptly stated by Ross (1962, p. x), man's "...experience is useless unless interpreted ..." Therefore, beginning in childhood, each person interacts with his or her physical and social environment, and through this myriad of environmental interactions, worldview presuppositions are unconsciously constructed. The process occurs over a long period of time, with the formative, childhood years being of most importance. Through the years of schooling, formal education contributes to worldview development; and in turn, a world view provides a foundation upon which cognitive frameworks are built during the learning process.

At some point of maturity (e.g., as an adult) the malleableness of a world view begins to decrease. It becomes resilient in the face of change providing an adult with cognitive stability. However, as noted above world views have an adaptive function which allows even adults to adjust to new environments. While worldview presuppositions are strongly held, they are not immutable. The strength with which a mature world view is held appears to be inversely related to the degree of heterogeneity in a culture. The more heterogeneity, the less strongly a world view is apt to be held. This whole process of worldview development and change is what Kearney calls "dialectical constructionism" (1984, p. 3), and it shares much with Piaget's genetic epistemology (1971) as well as with Ausubel's

constructionist theory of learning (Ausubel, Novak & Hanesian, 1978). In human mental architecture, world view is the foundation upon which cognitive and perceptual frameworks are built.

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INSERT FIGURE 3
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At this point it is essential to recognize the difference between a *lived* world view and an *articulated* world view, terms coined by philosopher John Kok (1988). Lived world view refers to the same concept of world view defined above. It conveys the sense that a world view is a communally shared, epistemological framework essential for daily life. This idea dates to the late 1800's and Wilhelm Dilthey who coined the term *Weltbild* or world picture. He argued that one's Weltbild developed in the context of one's *Lebenswelt*, i.e., the world in which one lives, presumably by a process similar to that described in this section. Dilthey however, further theorized that on the foundation of one's Weltbild, a person may go on to construct a *Weltanschauung* or articulated world view (Holmes, 1983). Quite opposite of a lived world view, an articulated world view is formed in a process that is "conscious, coherent [and] unambiguous" (Kok, 1988, p. 20). Plato's dialogues, Aristotle's treatises, Calvin's *Institutes* each sets forth an articulated world view. Of more central interest here is the notion of a scientific world view which in its common usage refers to an *articulated* world view. In this article the term

The Dialectical Development and Evolution of World View, adapted from Kearney 1974, p.45

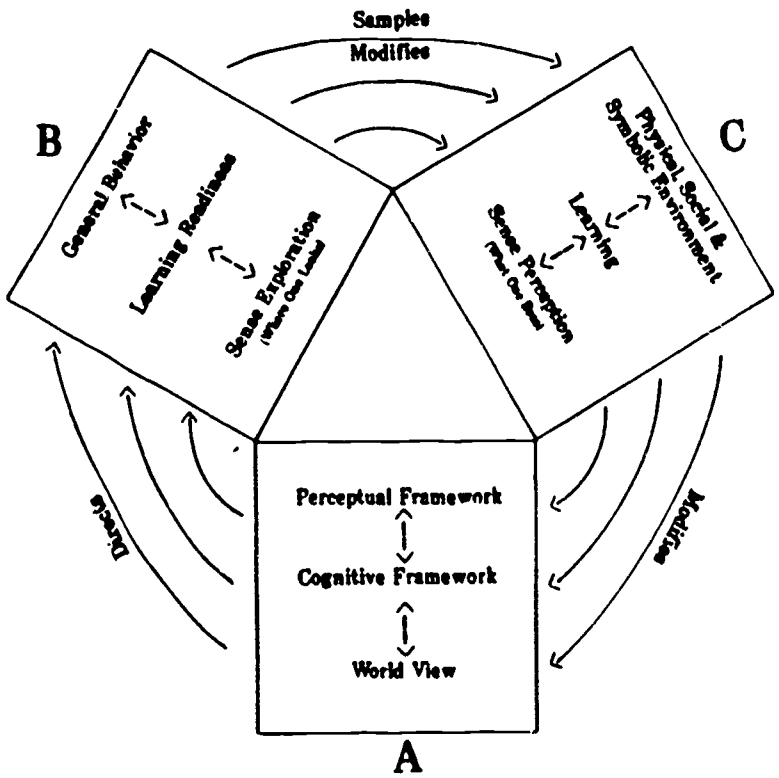

Figure 3

world view always refers to a *lived* world view because a lived world view is considered to be antecedent to any articulated world view. An articulated world view must be considered part of the cognitive and perceptual framework depicted in Figure 3, though in reality the distinction between the two is often obscured. An elucidation of the dialectical relationship between these two levels of world view will be an important issue in science education research, though not an simple one. These two aspects of world view were the cause of heated discussion among anthropologists at the 1968 Wenner-Gren Conference on World Views with no resolution (Jones, 1972).

World View in the Science Education Literature

To date world view is something only occasionally referred to in the education literature. Anderson (1988) recently has used world view in a discussion of cognitive styles and multicultural populations, specifically referring to non-Western and Western world views. Duschle (1988) used the term in a discussion of the problem of scientism in science education.

Brent Kilbourn (1974) pioneered the use of this concept in empirical science education research. Noting Robert's comment that "... virtually every science teaching program tries to get youngsters to adopt a scientific way-to-explain..." (1972, p. 1), Kilbourn proceeded to analyze secondary, biology textbooks for implicit projections of world views. With the exception of

Kilbourn's 1984 article in which he summarizes his earlier work and a 1988 paper by Proper, Wideen and Ivany, there has been no further empirical education research where world view is involved as a key construct. Kilbourn hints at the reason for this lack of research activity when he talks about the tremendous complexity of world views (1984, p. 36). From the literature of anthropology and philosophy, Jones (1972) lists thirteen different synonyms for world view, commenting that,

> Critics suspect that a concept so variously named is itself somewhat vague, and this suspicion doubtless explains why some students of culture prefer to ignore the notion of world view altogether...(p. 79).

The vagueness of these terms is such that we have done little more than name a hypothetical entity, and this doubtless explains the limited use of world view in education research.

Kilbourn based his research on Pepper's philosophical treatment of world view published in a book titled *World Hypotheses* (1942). Pepper identified six hypotheses which are metaphors for the ways in which people explain things. They are metaphors for causality. Kilbourn and researchers after him have equated these metaphors with world view, though Pepper does not use this term himself. Thus, Kilbourn concluded that most biology textbooks project a mechanistic world view based on his observation that Pepper's root metaphor *mechanism* most closely matched the majority of explanations given in the textbooks examined.

The difficulty with doing research based on a concept of world view derived from Pepper's work is that the above mentioned

ambiguity is not appreciably reduced. This can amply be seen in the Proper, Wideen and Ivany study (1988), a study which purportedly analyzed the world views science teachers projected in their classrooms. They found that an individual teacher will at times use explanations corresponding to more than one of Pepper's root metaphors (p. 554); and concluded that an individual teacher at times projects different world views. The observation is not surprising, but it makes little sense to claim that a teacher's world view, that is, the teacher's "culturally-dependant, generally subconscious, fundamental organization of the mind" changes from time to time during the class. These researchers cannot be using the term world view as it has been historically understood. The problem lies with Pepper's root metaphor theory. Pepper's theory is about causality; and though causality is an important part of a world view, the two are not one and the same. Later in this paper an alternate interpretation of the Proper, Wideen and Ivany data will be offered.

The principal value of the Kilbourn and the Proper, Wideen and Ivany studies is that they raise important epistemological questions. However, since they suffer from semantic confusion the further use of world view in education research requires a theory of world view that more articulately, more operationally defines this fundamental, cognitive macrostructure with all of its possible variations. For this one must look to the literature of cultural anthropology.

World View and Cultural Anthropology

World view is a term more familiar to cultural anthropologists than to educators, yet even for anthropologists the lack of an adequate theory of world view has been a problem. Kearney (1984) writes:

> Although world view is one of the central subjects of American cultural anthropology, there is surprisingly little theoretical literature concerning it... (p. 1). Although world view is a subject of immense importance in the social sciences and philosophy, a coherent theory of world view is nonexistent (p. 9). This lack of a conceptual framework has been one of the main obstacles to the study of particular world views and their cross-cultural assessment (p. 1).

Kearney's research is a response to this problem. He has attempted to provide a theory which defines a worldview construct with sufficient articulation so that it can be used in the cross-cultural study and assessment of world views. It is my contention that there exists in American society significant worldview variation and that this variation influences the process of education, particularly science education. Therefore, Kearney's worldview theory has important implications for educational research as well.

Kearney begins with a historical review of the concept of world view. The general paradigm used by American anthropologists doing worldview research has been that of *theme*. This monothematic, configurationalist approach is an,

> ...attempt to discover and describe the underlying 'pattern,' 'configuration,' 'basic personality,' 'ethos,' or 'world view' of a society. What all of these concepts have

> in common is that they refer to an hypothesized mental principle that organizes in a distinctive way nonmaterial elements...of a given society. These mental constructs are assumed to shape social and cultural behavior and the material and nonmaterial results of this behavior..." (Kearney, 1984, p. 23)

Cultural anthropologists' attempts to identify underlying cultural themes fall into two traditions, one built upon the work of Franz Boas (1911) and the other Robert Redfield (1941,52). The Boasian tradition includes such anthropologists as Ruth Benedict (1934) and Margaret Mead (1928). We may take Benedict's *Patterns of Culture* as typical of this tradition. She felt that by careful analysis one could find in each culture a single psychological theme that fundamentally orders each culture's world view, a premise heavily influenced by Gestalt psychology. Pepper's (1942) root metaphor theory also falls within the Boasian tradition.

Redfield, whose work forms the basis for the second tradition, also used Benedict's total culture approach to world view research. However in contrast, he considered the search for a single, overarching theme that would describe a culture to be an oversimplified approach. His solution was to look at a culture's world view as a composite of worldview universals (Kearney's terminology). With this very important advance in worldview research, he maintained the total culture concept while interjecting a way to recognize and study variation within the culture. His principal universals are the unitary *Self* and the

tripartite *Other*, composed of Human, Nature, and God. According to Kearney:

> Redfield's concept of world view is mainly descriptive. Insofar as he speculated on the causes for differing world views he did so very generally...he did not attempt to explain why a certain type of society may have one world view, nor how world views change. Nor did he attempt to explain what connection there is between world view, environment, and behavior (1984, pp. 38 and 39).

Michael Kearney's work is in the Redfield tradition, but his contribution to worldview research is an articulated model of world view that moves worldview research beyond the level of description to the level of analysis.

The Kearney World View Model

The Kearney model begins with the idea that a world view is an organized set of fundamental, cognitive presuppositions about reality. He assumes that this organization is shaped by the,

> ... internal equilibrium dynamics among [the worldview assumptions]. This means that some of these assumptions and resultant ideas, beliefs, and actions predicated on them are logically and structurally more compatible than others, and that the entire world view will 'strive' toward maximum logical and structural consistency. The second and main force giving coherence and shape to a world view is the necessity of having to relate to the external environment (p. 52).

In other words, a world view tends to be internally consistent, in that presuppositions are logically integrated and universals are structurally integrated; hence, the model is termed *logico-structural*. A world view is externally valid in that the human need to relate to the external environment fosters coherence.

Kearney's ideas are similar to Redfield's in that he suggests that all world views are a structural composite of seven, basic cognitive categories or universals: Self, Other, Relationship, Classification, Causality, Space, and Time. These universals he likens to the diagnostic categories used by physicians:

> Although the doctor is confronted with a variety of patients, he can presumably describe the most significant medical facts about them in terms of...features common to all patients, e.g., blood pressure, pulse, respiration" (p. 65).

In principle groups of people and even individuals can be identified by worldview variations which result from the content variation in worldview universals. Logically consistent presuppositions about reality are the content. Each universal is composed of a hierarchically arranged set (or sets) of assumptions, or presuppositions, at the end of which is a final absolute presupposition or 1st order presupposition, an ultimate presupposition beyond which there are no others. One might think of a 1st order presupposition as akin to Aristotle's final cause. At the opposite end, these hierarchies blend into the cognitive frameworks with which educators are more familiar.

Collingwood provides an amusing story in which both ends of a hierarchy are apparent:

> .... if you were talking to a pathologist about a certain disease and asked him `What is the cause of the event E which you say sometimes happens in this disease?' he will reply `The cause of E is C'; and if he were in a communicative mood he might go on to say `That was established by So-and-so, in a piece of research that is now regarded as classical.' You might go on to ask: `I suppose before So-and-so found out what the cause of E was,

> he was quite sure it had a cause?' the answer would be `Quite sure, of course.' If you say, `Why?' he will probably answer `Because everything that happens has a cause.' If you are importunate enough to ask `But how do you know that everything that happens has a cause?' he will probably blow up in your face, because you have put your finger on one of his absolute presuppositions...But if he keeps his temper and gives you a civil and candid answer, it will be to the following effect. `That is a thing we take for granted in my job. We don't question it' (1940, pp. 31 and 32).

At one end of the pathologist's mental framework is his knowledge of diseases and scientific research. At the other is a 1st order presupposition (Collingwood's absolute presupposition) in the worldview universal, Causality.

At this point one may wish to ask how world view and belief may, if at all, be distinguished. Beliefs seemed to be implied in the terms *Christian world view, Islamic world view*, or *secular world view*. Ketner (1972) in his dissertation *An Essay on the Nature of World Views* argues that the basic worldview concepts are in fact fundamental beliefs. Kearney rejects this position citing Needham's (1972) contention that *belief* itself is "...a concept particular to the Western world" (1984, p. 51). The arguments are rather esoteric and I do not believe that they are significant for research in education. I would only add that there is a range of consciousness with regard to worldview presuppositions, and the less conscious one is of worldview presuppositions, the less belief-like and more objective one's worldview presuppositions appear. Collingwood's pathologist would no doubt consider his causality presupposition to be

something much more certain than mere belief for which he would admit doubt.

Two 1st Order Universals

Universe (or cosmos) is the English language term for ultimate inclusiveness. Within the universe an individual's primary point of reference is himself or herself, i.e., the Self. The functioning of any human society is dependent upon self-identification and culturally determined notions of the nature of self (Hallowell, 1955). Every self (or a person's sense of self) exists and interacts within an environment, i.e., the Other. Thus the ultimate inclusiveness is composed of the Self and all that is not the Self, i.e., the Other. These two are the 1st order universals and together form the principal axis of a world view (Kearney, 1984, pp. 68-70). This axis can be seen in Figure 4 which is Kearney's diagrammatic summary of his model.

****
INSERT FIGURE 4
****

The adjectives 1st, 2nd, and 3rd order are my own, not Kearney's. I have added them because I find that they help to clarify the organization of three sets of universals. For the same reason from this point on I also have substituted the term *NonSelf* for Kearney's term *The Other*.

The nature of Self varies between two polar extremes. At one pole are the individuals whose Self is continuous with the

Kearney's Logico-Structural World View Model

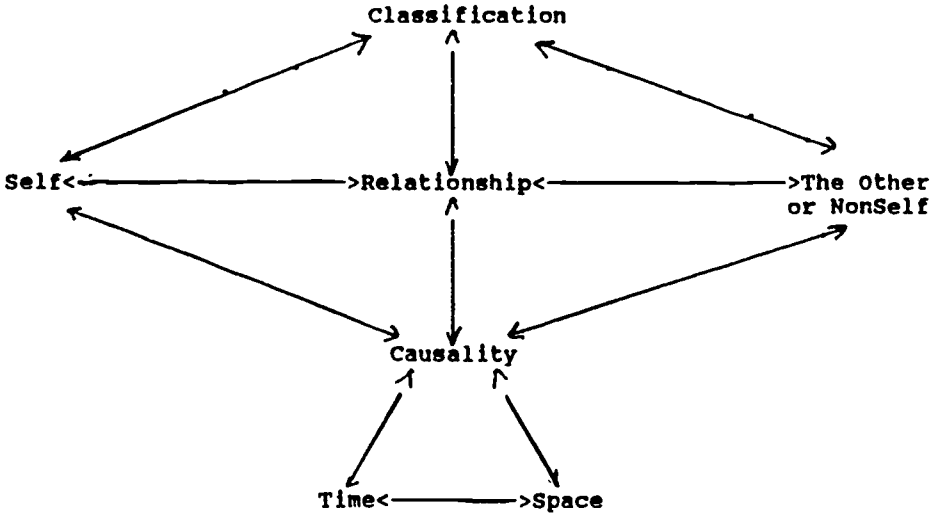

Figure 4

cosmos. These individuals identify themselves with the NonSelf. The distinction between Self and NonSelf is minimal. In a sense, all is Self. At the other pole nothing is Self. For these individuals the Self has become so depersonalized that they feel they have ceased to exist. In American society we call individuals at the first pole, mystics; and at the second pole, psychotics. Piaget has argued that from birth normal cognitive development is based on the gradual, progressive elaboration of a distinction between Self and NonSelf (Piaget, 1969).

As stated above, the NonSelf is everything in the Universe except the Self, and can be divided into domains of equivalent, nonequivalent, or hierarchial taxonomic status. The simplest division is into domains of human environment and physical environment, or society and nature (see Figure 5). For most people however, Redfield's tripartite division is more appropriate: Society, Nature, and the Supernatural (or God). Some of the bitterest controversies in American public education can be traced to these differences in the Self-NonSelf axis.

****
INSERT FIGURE 5
****

Three 2nd Order Universals

One's sense of Self and NonSelf is dependent upon the interactions between Self and NonSelf. They are structurally integrated, thus, the first 2nd order universal is Relationship, i.e., the relationship between the Self and NonSelf. For

Self-NonSelf Axis

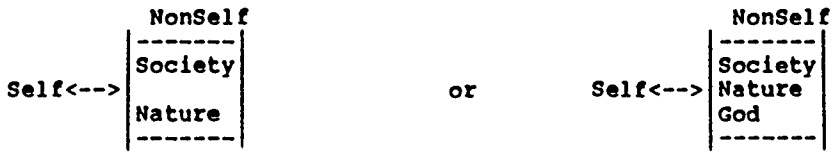

Figure 5

example, a child raised in a warm, secure home develops a confident sense of self and knows the world (i.e., the NonSelf) to be orderly and nonthreatening, whereas an abused child grows up with low self-esteem. Or, a child raised in an environment of unexpected trauma may come to see himself as a powerless being living in an unpredictable world.

Fundamentally the relationship between the Self and NonSelf can be one of harmony, subordinance, or dominance. In actuality there is likely to be mixing. For example, the Self-NonSelf relationship with regard to the individual and society may be one of harmony, while the individual-nature relationship one of dominance (Kearney, 1984, pp. 72-78). Historically, a relationship of dominance derived from the Genesis account of creation was crucial to the development of experimental science (Hooykaas 1972, Glover 1988). The dominance theme continues to be important in science, though not without problems (White, 1962; Young, 1974). It is implicit in locus of control research conducted by science educators that a dominant relationship between Self and NonSelf is better than a relationship of subordinance (Brooks and Houndshee, 1975; Scharmann, 1988).

The Self-NonSelf split is the most obvious case of Classification, the next 2nd order universal. Kearney writes:

> Within a cognitively differentiated universe the most fundamental classification categories are Self and the Other; this is the reason they are treated as universal (1984, p. 80).

After the elf-NonSelf classification, come classifications within the NonSelf domain. Figure 5 shows two Classification methods for the NonSelf, but there are many. A third possibility is the pantheistic fusion of God and Nature as found in classical Greek thought and some Eastern religions. Yet another Classification of the NonSelf is between the real and unreal. Figure 6 represents the NonSelf domains for a theist and atheist. In this example "real" and "unreal" are attributes of the various domains into which the NonSelf is classified, but not domains themselves. For the theist some of the content of the supernatural domain is real, but for the atheist, the entire domain is unreal. Kearney rightly points out that one must know the attributes of a NonSelf-domain as well as the content:

> ...it is possible that two people may conceptually group...ghosts, spirits, the Devil. Knowing this grouping alone tells us little about their respective world views. However, if we know that for one person these items are grouped together as elements of folk tales and superstitions, while for another sources of sickness and sin, we gain insight into the associated dimensions of Causality and Relationship in their respective world views. (1984, p. 82)

We could easily replace Kearney's anthropology example with ones drawn from a high school science classroom. There may well be times when a science teacher and a student conceptually group nuclei, atoms, and molecules. The attribute for the teacher is submicroscopic reality, while for some students it is simple unreality. For one it may be significance, while for the other it is insignificance. The science teacher and the student are

each using classification categories that reflect his or her attitudes and presuppositions about the nature of reality.

****
Insert Figure 6
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Kearney develops his notion of Causality, the third 2nd order worldview universal, from a Piagetian perspective (1984, pp. 84-89). Because of that and because causality is a prominent feature in science education, the worldview universal Causality is more readily understandable to educators. Kearney employs Durkheim's definition of causality:

> The first thing which is implied in the notion of the causal relationship is the idea of efficacy, of productive power, of active force. By cause we ordinarily mean something capable of producing a certain change. The cause is the force before it has shown the power which is in it; the effect is this same power, only actualized (Durkheim 1965, p. 406).

Kearney believes that an individual constructs his or her world view based on the dialectical forces in one's life, that is between Self and NonSelf, especially during formative childhood years. Therefore he incorporates in his theory Piagetian stages of development where the nature of cause and effect changes for a child with his or her growth and experience. Following Piaget (1969), Kearney sees the Causality universal developing through periods of participation, animism, artificialism, finalism, and force.

> ...in feelings of 'participation,' there is an assumed affinity of Self with external objects...closely allied with this is the notion of 'animism,' which endows things with consciousness and life. In the third form, 'artificialism,' there is the uncritical assumption that objects obey will and intention, and in doing so are organized and act for the

The Attributes, Real and Unreal

Theist

NonSelf-domains	Real	Unreal
Supernatural	God	ghosts
Nature	people	dreams

Atheist

NonSelf-domains	Real	Unreal
Nature	people	God

Figure 6

> good of men...that things exist for and are organized for man is the `finalistic' assumption. To the extent that this notion exists, the world is seen as teleological. The fifth type of adherence is the notion of `force' or `power,' which is attributed to things such that they make efforts as do muscles (1984, p. 87).

According to Piaget, mental development involves the gradual development of a mechanical view of causality in conjunction with the gradual elimination of these five notions, although adherences often continue into adulthood. The extent of the adherence is a function of an individual's ability to completely distinguish between Self and NonSelf, i.e., "...dividing off the internal world from the external..." (Piaget 1969, p. 246).

Kearney accepts Piaget's dialectical view of mental development and use of mental stages, and employs Piaget's adherences as aspects of the Causality universal useful for describing and comparing world views. However, he rejects Piaget's conclusions as being culturally determined (also see Buck-Morss, 1966; Cole & Scribner, 1974; Dasen, 1974). Piaget's French Swiss children developed mechanical viewpoints precisely because they were French Swiss, and not for example, Nuer or Hausa. Taking mechanical causality as the hallmark of advanced mental development would doom the majority of the world to mental underdevelopment. Robin Horton's paper "African Traditional Thought and Western Science" (1967) provides a powerful example of complex, formal thought in traditional people in contrast to Western, scientific thinking. He effectively blunts the

ethnocentric view of mental development characteristic of many Westerners.

Science education research has been dominated by Piaget's concepts of concrete and formal thought, and the development of cognitive processes from concrete to formal. The misconception researcher is interested in students' alternative explanations of natural phenomena, and thus inherent in misconception research is a change of focus from the concept of concrete/formal thinking to the concept of adherences. The next step is to investigate the epistemological frameworks which make the adherences more intelligible and certainly less pejorative.

At this point it is instructive to return to Pepper's root metaphor theory and its use in the Proper, Wideen and Ivany study (1988). They found that their biology teachers used explanations representing four root metaphor categories: formism, mechanism, contextualism, and organicism. For example, when the subject was classification the tendency was for the teachers to use formal explanations, but mechanical explanations with genetics and cell biology (p. 554).

Such observations are predictable using the logico-structural model of world view where there is an articulation between Self, Causality and NonSelf. As one would expect, the world (NonSelf) for these teachers is composed of many categories. At some appropriate level a categorical distinction in the teachers' epistemological framework is made between multicellular organisms and individual cells, including important

cellular molecules. The biology teachers' multicellular category is likely to be further divided according to similarities and differences among organisms, in other words, according to a standard phylogenetic taxonomy. In this case the articulation between Causality and NonSelf is that structural features determine classification, thus the formism detected in the classroom when the subject is something like phylogeny. Similarly, at the cellular level the biologist uses many more concepts from physical science where mechanical explanations predominate. In this case the articulation between Causality and NonSelf is that phenomena at the cellular level have mechanical causes, thus the mechanism detected in the classroom when the subject is something like genetics. Clearly, the teachers in the Proper, Wideen and Ivany study do not have variable world views. What they have is a variable concept of causality that is rationally related to the their understanding of the world. The root metaphor theory does not allow one to readily see this.

Two 3rd Order Universals

The 3rd order universals are Space and Time. There are many examples of how people view space differently. Ideas about space are a common difference between urban and rural dwellers. Unlike his rural cousin, a person who lives in the city often has little practical awareness of the compass directions east, west, south, and north. For the city dweller, direction is generally a matter of uptown, downtown, left and right. On the other hand, a walk

of a *short distance* for the rural dweller is likely to translate to a much longer distance for the urban dweller who is accustomed to more compact space. In the science classroom, spatial distances often are very large or exceedingly small. In either case it is not the space common to the every day experiences of most children; thus an important aspect of science education for young children is the enrichment of their notions about space.

Time, the second 3rd order universal, is a more complicated structure. Within a world view Time can have one of three basic orientations, past, present, or future, each of which is a different first-order presupposition. Historically there has been a strong future orientation among white Americans, in part traceable to Puritan and Calvinistic influences in Colonial America. Success in American education generally requires such an orientation. Kearney notes that a future orientation is "...compatible with scholastic achievement in that such a student is more able to resist immediate distractions and focus energies toward...good grades, degrees, etc." (1984, p. 95).

Kluckhohn and Strodbeck (1961) note that Spanish-Americans are much more present-oriented, in contrast to the future-orientation of many Anglos. The here and now is more real than anything that may happen tomorrow. The stereotype of the unreliable Latino can be traced to this very different cognition of time. A worldview Time universal can also be past-oriented. Kluckhohn and Strodbeck note that this is the case with both the

Chinese and Mormons. Time oriented to the past is manifested in ancestor worship by the Chinese and the Mormon interest in genealogies "...by which they attempt to discover spiritual links with unknown ancestors" (Kearney 1984, p. 97).

In addition to orientations of time, there are different images of time. Some people have an oscillating image of time where time either runs in circles or zig-zags. According to Kearney:

> The essential feature of this image of time is that time is seen as rhythmically swinging back and forth between recurrent markers. Such an image occurs most strongly in technologically simple preliterate societies (1984, p. 99).

Alternatively, the image of time can be linear, like a timeline that a history teacher might use. Time moves from the past into the present and on into the future, one-way and irreversible. And since time that has past cannot be recovered, and the present also will soon be gone, it behooves one to look to time yet to come. In other words "...a linear image of time is structurally compatible with a future orientation" (Kearney 1984, p. 101). The co-occurrence of these first order presuppositions is common in the West, and can be traced back through the Judeo-Christian tradition to the early Hebrews. In Genesis there is a specific creation event from which time starts. It proceeds through Jewish history looking toward the coming of Messiah. The Christian tradition adopted the Jewish sense of history, except that for Christians time points toward the second coming of Messiah and the culmination of all time (Glover, 1984). These

first order presuppositions in the Time universal formed an important distinction between the Medieval world view and the world view of Classical Greece and Rome; and were crucial for the development of modern science in Europe (see Foster, 1934; Klaaren, 1977).

In addition to the orientation and image presuppositions in the Time universal, there are important attributes (Kearney, 1984, pp. 102-106). Time can vary in depth or range. For example, the future can be a few months, a few years, a few decades, or far more. One likely consequence is that short-range planning is preferred by those who have *shorter* futures. Another attribute is pace. For some people time walks; for others, it runs. If it runs, there is a greater need for the precise measurement of time. Furthermore, faster time generally occurs in a world view along with linear and future-oriented time.

I have already mentioned that a future orientation serves a student well. I conclude this discussion of time by noting that in the science classroom, time has further importance. The methods of science are such that time has a very specific meaning and is used with great precision. One can easily see how a student's non-scientifically compatible notion of time would be challenged in a science classroom. For some students, that challenge may result in confusion or even l nder meaningless many aspects of science.

At this point one might suggest that the universals Space and Time are actually no more than attributes of the NonSelf. Certainly, Space and Time are always thought of in conjunction with some aspect of the NonSelf. However, unlike the attribute *real/unreal*, some fundamental form of space/time cognition is common to all people (Kearney, 1984, pp. 89-92). Note that in Figure 4, Causality is bracketed by the universal Relationship on one side, and Time and Space on the other. Our understanding of Causality is dependent upon both the relationship between the Self and NonSelf, and upon our understanding of Space and Time. These four universals are intimately related. Only with some notion of space and time, plus some notion of how we relate to the external world, does a sense of Causality become conceivable (1984, pp. 89-107).

I stated earlier that the primary difficulty with the Boasian and Redfield worldview traditions was oversimplification. Their approaches do not facilitate analytical research, but are used primarily for description. Even at that, the configurationalist approach to world view glosses over many differences. There is some truth in the statement that the Western world view is mechanistic, but there are many degrees of mechanism and many interactions with other factors. Kearney's theoretical model with its seven interacting universals, provides the analytical tool for studying world view at the individual level and for studying subtle worldview variations, without

sacrificing the ability to draw broad generalizations about world view in a society. If we see similarities in the Causality universal then we may agree with Pepper that the West has a mechanistic orientation. However, the logico-structural model with its six other universals keeps one from glossing over substantial intra-worldview variation.

Scientifically Compatible World Views

At this point I would like to suggest that speaking of a scientific world view is to make a configurationalist statement which really does not tell us much. Nor do we say much more by substituting mechanical for scientific. We still have a monolithic view that glosses over substantial differences, such as the differences between the scientists B. F. Skinner and Fritjof Capra. With Kearney's world view model one can develop a more detailed, and thus more accurate, picture of a scientifically compatible world view which can accommodate the occurrence of such different scientists as Skinner and Capra.

If we take Kearney's position that world views are composed of seven integrated universals, it readily becomes apparent that there can be many world views and even more worldview variations, of which many will be scientifically compatible. Consider an American scientist and an Indian scientist. While we may be tempted to say that they both have the *scientific world view*, in fact their world views will be quite different (at both lived and articulated levels). This is illustrated by the two frequency

graphs in Figure 7. Let us assume that there are worldview presuppositions and attributes pertinent to science. Figure 7-a is a hypothetical frequency distribution of Indians and Americans on a hypothetical measure of these pertinent presuppositions and attributes. Our scientists would appear far to the right indicating the presence of these science-related presuppositions and attributes. By this indicator the two scientists are similar and many would say they have a scientific world view.

Now consider Figure 7-b which is a hypothetical frequency distribution of Americans and Indians on a hypothetical measure of Eastern presuppositions and attributes. The American scientist would fall on the left along with most Americans, scientist or not. While elements of his world view may be similar to elements of an Indian world view, overall he is a Westerner. The Indian scientist however, will fall to the right reflecting his Indian background. It may well be that his scientific training has changed some of his Indian presuppositions. To the extent that this has happened, he would fall more to the middle of Figure 7-b; but a significant difference would still remain between the two scientists.

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INSERT FIGURE 7

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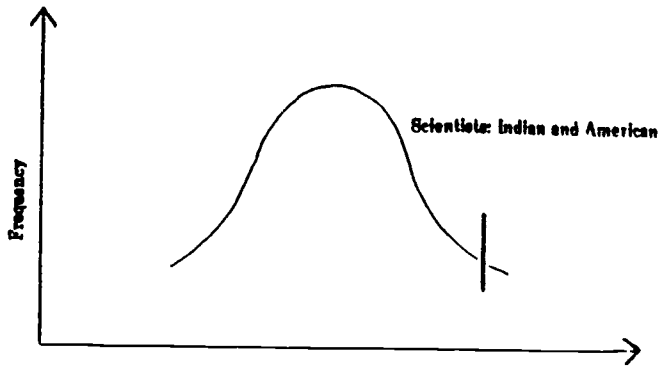
Therefore, according to Kearney's model we should not expect one, single scientific world view. There will be content within the seven, worldview universals that is fairly constant within a

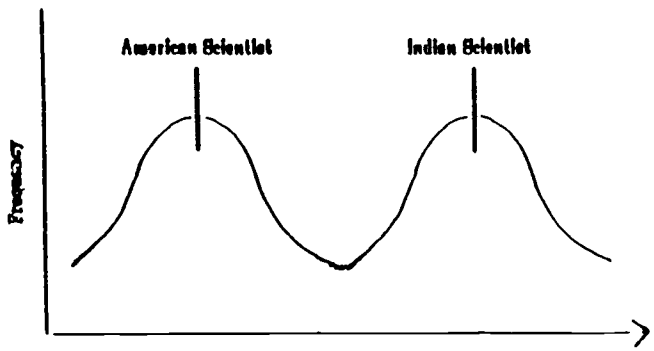
Frequency of Americans and Indians
on a Science Worldview Scale



Presuppositions and Attributes Pertinent to Science

Figure 7-a

Frequency of Americans and Indians
on an Eastern Worldview Scale



Eastern Presuppositions and Attributes

Figure 7-b

group of people considered to have a *scientific world view*. This is content pertinent to the enterprise of science. There will also be content differences. Depending on a person's background those differences may be rather large, as would be likely between Indian and American scientists, or rather small, as would be likely between two American scientists. The distinction between world view and worldview variation or variant of a world view may be likened to the distinction between language and dialect. Thus for our two scientists it probably would be more accurate to say that one has a scientifically compatible variant of an American world view, while the other has a scientifically compatible variant of an Indian world view.

That the differences between any two American scientists are small is a result, first, of being born and raised in America. Second, the two probably will be white males from middle class backgrounds. Furthermore, they also will have had their science-inclinations developed through years of similar schooling experiences. However, the worldview variations among all high school and college students will be much greater. Major variations are likely to stem from racial, ethnic, gender, and religious differences, as well as from economic class, geography, and family-type differences. These are potential, significant influences in science education.

This leads us to the questions, What are the presuppositions and attributes of a scientifically compatible world view? What

presuppositions and attributes are scientifically neutral? What presuppositions and attributes actively hinder scientific understanding and science attitudes? Obviously the answering of these questions would be a significant undertaking. At this point, as an example, I will only attempt a partial answer to the first question.

Collingwood's pathologist provides an example of a necessary first order presupposition in the Causality universal if a world view is to be scientifically compatible. The presupposition is that all effects, **E**, have causes, **C**. This presupposition is modified by an interaction with a first order presupposition in the Classification universal, i.e., there are different classes of cause. The pathologist undoubtedly recognizes several classes and to these classes he will apply attributes such as *usage*. Because he is a pathologist we can be sure that of the various classes of cause he assumes always to exist, he considers some to be appropriate for science and others not. Eventually this avenue of reasoning leads to an informational level where the pathologist has stored knowledge of specific causes for specific effects, e.g., virus X causes disease. This is a much narrower, more defined level of epistemological structure than the level of universals at which we began. The work on meaningful learning by Novak (1977) and Ausubel (1963) concerns epistemological structures at this level of an individual's total mental framework. However, a scientifically compatible world view does

not require the lower, informational levels. It only requires that presuppositions and attributes be in place so that when specific information is confronted, such as the effects of viruses, the information will be meaningful.

While the above example speaks of science knowledge, it could as well have been science processes, or what is often called scientific thinking. Briefly, in the universal Causality our pathologist has a first order presupposition concerning ways of knowing. There will be an interaction with Classification and the result will be a category of knowing that is appropriate for science. In that category will be the knowledge that the scientific way of knowing involves observation, theory, experiment and so on.

Before leaving this section I need to say that the example of cause and effect may trouble some readers. Indeed the contention that cause-and-effect causality has disappeared from modern physics has gained a degree of popularity. This surely is a philosophically erroneous deduction from modern quantum mechanics. As Fermilab cosmologist John L. Dykla has recently written:

> All modern science is predicated on the philosophical assumption that its subject is comprehensible...Of course, the advent of quantum mechanics in the twentieth century has compelled reappraisal of the deterministic paradigm of earlier science. Still, the activities of physicists are grounded in a belief in the existence of objective laws that correlate our observations of natural phenomena and allow at least some limited measure of successful prediction (1989, p. 169).

Even if we grant that in physics there has been a complete change in the understanding of causality, the rest of science still lives in a rather Newtonian universe. Furthermore, it is difficult to conceive of a science education program not based on a fairly traditional notion of causality. The banishment of Newtonian cause-and-effect causality would itself indicate a significant worldview shift in the general American populace.

The thrust of this section is that the Kearney worldview model leads science education researchers to three significant questions: What are the presuppositions and attributes of a scientifically compatible world view? What presuppositions and attributes are scientifically neutral? What presuppositions and attributes actively hinder scientific understanding and science attitudes? The significance of the questions is that the answers have the potential to improve our understanding of what is and is not a science misconception, to improve our definitions of appropriate scientific attitudes and improve our attitude research approaches, to better inform locus of control studies, and to in general, provide a broader, more coherent framework for cognitive studies.

The above passages on causality are a notably incomplete response to these questions, and serve only to further illuminate the questions. A complete set of answers will likely come through the study of the various models used in extant science education research on science attitudes and the nature of science. However, this research relies heavily on works in the

philosophy of science. Worldview theory will require that researchers pay more attention to studies in the history and sociology of science as they seek to answer these questions.

Application to Misconception Research

The power of the logico-structural model of world view lies in its research utility for the analysis and understanding of worldview variation not only where there is a **prima facie** case for such variation, but also within what is usually considered a single worldview group. As an example, in this section I want to explicitly apply worldview theory to a piece of science misconception research, where epistemological homogeneity is tacitly assumed.

Consider the example of misconception research in which the researcher investigated students' understanding of the concept *ecosystem* by asking them why some organisms consume other organisms in a given pattern or sequence (Marek, 1986). Responses such as "It's God's purpose," and "Organisms eat other organisms to preserve their species," are considered misconceptions, but are they? A worldview analysis begins by assuming that the students' responses are meaningful to the students, if not to the teacher. The responses are indicative of epistemological presuppositions within the worldview universals NonSelf, Causality, and Classification. To clarify this consider Figure 8 which is adapted from Bube's structural diagram of the universe (1971).

This is a convenient way of showing the NonSelf broken down into categories, or subdomains (all of which could be further subdivided). The first two columns contain parallel sets of categories, the first column showing more general terms and the second more specific. The third column shows a corresponding set of intellectual disciplines. The existence of a category in the NonSelf not only makes a particular discipline meaningful, but also the concepts of causality associated with that discipline.

****
INSERT FIGURE 8
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The student who gives "God" as an explanation for a natural phenomenon does so because there exists important theological categories in the student's classification of the NonSelf (though this is not to imply that the student is a self-conscious theologian). We can also assume that the student's biological categories are relatively weaker. In contrast, biology instruction primarily involves the categories of cell, plant and animal. Some other categories in Figure 8 may also be involved on occasion, but certainly not theological categories; in other words, biology instruction is functionally atheistic.

Furthermore, the biology textbook and classroom teacher will employ a rather restricted definition of cause. They say that one can explain (i.e., give the cause) an event E when one knows that event E occurs only when the material conditions C occur, where the conditions C are a restricted set of categories within

Categorizing the NonSelf

(adapted from Bube, 1971, p. 34)

General Categories	Specific Categories	Intellectual Disciplines
Ultimate	God	Theology/Philosophy
Human	Society	Sociology
	Man/Woman	Anthropology and Psychology
Living but nonhuman	Animals	Zoology
	Plants	Botany
Simple Life	Cell	Biology
Material but nonliving	Nonliving matter	Physics and Chemistry
	Molecules	
	Atoms	
	Elementary Particles	
Nonmaterial	Energy	Origins

Figure 8

the NonSelf domain (Ross 1962, p. 64). Again, the instruction is functionally atheistic because the restricted set does not include theological categories (Kilbourn, 1974; Proper, Wideen & Ivany, 1988).

The student's use of God as an explanation is evidence of a significant disjunction between aspects of the student's world view and that which is projected in the classroom. The categories of the NonSelf important to the student are the very ones deliberately shunned in the classroom. In Aristotelian terms, the student's interest is in final causes, not the efficient causes of biology instruction. This worldview analysis allows us to see that the student's response is not at all a misconception, but a meaningful response based on the student's epistemological framework. It also allows us to see the failure of the classroom instruction. Instruction has not helped the student articulate theological and biological categories in such a way that both become meaningful for the student.

Like the student above, the student who responds, "organisms eat other organisms to preserve their species" is showing an interest in theological or philosophical categories. It may be that unlike the first student, the second student knows that citing God as a causal agent is inappropriate in a science classroom. Nevertheless, lacking sufficient articulation between theological and biological categories, the student gives a meaningful, teleological response, not a biological one. On the other hand, there may be a nontheistic philosophical basis for

this response. Further investigation would be required to make a determination. What we can conclude is that, our students may well learn from classroom instruction that big fish eat little fish, but their own world views provide the explanation. This example illustrates the immense difference between understanding and explanation (Strike, 1972).

Novak (1977, pp. 25 and 26) states that "...meaningful learning occurs when new information is linked with existing concepts..." in the learner's cognitive structure. Advance organizers are intended to provide such links. However, the typical advance organizer is a product of a mechanical view of causality and a naturalistic view of the world, and thus would be of limited value for the above students. To be effective, an advance organizer must link instruction with appropriate presuppositions within a student's world view. In this example the teacher would have to introduce a greater range of Classifications, discuss their relations, and the reasons for limiting them in the science classroom. In this example the goal is not to substitute classifications since there is no indication that the students' world views actively hinder science learning. The teacher's goal would be to enrich the students' world views by developing or refining worldview classifications.

The above scenario will have to be justified by research. It does have much that is appealing. From worldview theory we can infer detailed, testable explanations for the answers given by the students. We can infer explanations for the

ineffectiveness of typical, science instructional strategies with these students. Finally, we can infer that deep cognitive bridges that reach back to the students' worldview presuppositions will be instructionally more effective, and that can be tested. In sum, there is in worldview theory significant, potential explanatory power for misconception research generated data.

Evidence for the Theory

In contrast to the thematic approach to world view, the sensitivity and richness of the logico-structural worldview model allows rational justification for the expectation of worldview variation in the typical school classroom. Of course this then raises the question of empirical evidence. And if the evidence is forthcoming the question then becomes, do these variations actually exert a significant influence on science achievement and attitude as predicted by the theory?

These questions require an instrument for detecting the hypothesized worldview variations. In another paper I have reported on the development of just such an instrument (Cobern, 1989). The approach involved focusing on the Causal universal and deducing that worldview variation implies that different types of causal explanation will be unequally acceptable among different students. The instrument, referred to as the Test of Preferred Explanations (TOPE), is a paper-and-pen instrument largely comprised of fictional episodes each followed by two

explanations of different type. The explanations were classed either as more scientifically compatible or less scientifically compatible, where scientific compatibility was determined by philosophic analysis. Data collected among college freshmen showed considerable variation as predicted by the theory. Furthermore, students indicating no interest in science were more likely to choose the scientifically less compatible explanations than were the students with science interest. The students with science interest were in turn less likely to accept the more scientifically compatible explanations than were professional scientists.

The above evidence in support of the theory is compelling but by no means conclusive. Additional support can be inferentially derived from the constructivist epistemology of Novak (1982) and Gowin (1981). Ault et al. writes,

> several directions in recent science education research point to the importance of understanding the organization of content in cognitive structure...Novak (1982) interprets research over the past several years at Cornell...to favor the view that assimilation of new knowledge is most closely related to the development of cognitive structure...(1984, p. 443).

World view is the foundation for cognitive structure as indicated by the position given to world view in Figure 3 (also see Figure 1 in Ault, Novak & Gowin, 1984, p. 442). Therefore by extrapolation from the evidence noted by Ault et al. (1984) for the importance of cognitive structure in learning can be applied to world view. Clearly this is circumstantial evidence, nevertheless this line of inference, the evidence provided by

Kearney (1984), along with the work of Cobern (1988) provide a significant preliminary indication that the theory is not only sound but investigatively fertile.

A Research Agenda

The first item on a research agenda has to be the continued pursuit of basic corroboration of the theory, specifically hypothesized relationships between world view and science education. This may be approached by refining the TOPE study (Cobern, 1988). TOPE is intended to be a preliminary discriminating device. If in future research it is used prior to more incisive investigative techniques such as techniques involving the Interview Vee (Ault, Novak & Gowin, 1988), one can expect improved results.

The content of TOPE is based on presuppositions in the Causal Universal deemed necessary to scientific explanation. Research of greater breadth will require a more thorough defining of the parameters, i.e., the gross anatomy, of a scientifically compatible world view. Researchers will have to identify the logico-structurally related presuppositions and attributes in all seven universals that are of importance to science in order to answer the questions: What does science require of students' fundamental belief and thought structures? What epistemological foundation must be in place in order for science to be meaningful? To be more specific, one might ask, what presuppositions and attributes concerning causality (or about

time or space) should students have? This is a *concept mapping* type of problem except that one is working with much more fundamental epistemological structures. A fruitful approach may be to work with Collongwood's (1940) notion of absolute and relative presuppositions.

The current method in science education research for defining the nature of science, and this includes defining a scientific world view, is to derive a definition from the philosophy of science. This was the approach in the TOPE study. However, determining the necessary and sufficient aspects of a scientifically compatible world view is not a purely philosophical question about the nature of science. Instead of philosophical analysis, the researcher must inquire into worldview variation among scientists. There are successful scientists drawn from the ranks of women, African-Americans, Christians, non-westerners as well as from white, male Americans. What do these people have in common that allows them to value and successfully participate in the scientific enterprize? It bears repeating that the goal is not to identify the definitive scientific world view, but to determine the necessary and sufficient aspects of a scientifically compatible world view.

Of course, defining the parameters of a scientifically compatible world view returns us to the issue of *lived* versus *articulated* world view and the confusion of the two concepts.

In the existing education literature the usage of the term world view suggests articulated world view, but it is clear that the authors intend that their notions about science become part of students' and teachers' lived world view. Unfortunately this involves science educators in the *scientism* which Duschle (1988) so appropriately denounces. A vital item then on any worldview research agenda must be the clarification of these terms and the relationship between the concepts involved.

Having in hand the parameters of a scientifically compatible world view in logico-structural terms will allow researchers to address the problem of identifying a broad range of worldview variations vis-a-vis a scientifically compatible world view. This likely will require innovative techniques such as the fictitious episodes used in TOPE items. The Dart and Pradham mapping technique has potential for use in studying presuppositions in the Space universal of students. These researchers, interested in readiness to understand and use scientific abstractions, compared maps showing home and school drawn by American and Nepalese students (Dart and Pradham, 1967; Dart, 1971; also see McCormack, 1988). Another technique with potential for wider use has students respond to illustrations. Osborne and Gilbert (1980) used this method to explore students basic understanding of force. A good source of potential techniques can be found in White (1979) which describes various methods for exploring students' cognitive structures. Few of

these methods and techniques were developed specifically for worldview investigations and none are based on the logico-structural model; nevertheless, many can readily be adapted for this purpose.

Assuming students with worldview variations are identified, investigation can then turn to the effects of such variations on science achievement and attitude. Of particular interest will be the worldview analysis of cultural groups such as women, African-Americans, Asians and Hispanics vis-a-vis science education. Clearly the Belenky, Clincy, Goldberger and Tarule study *Women's Ways of Knowing* indicates the potential fruitfulness of an investigation of a feminine-oriented world view. I suspect that ultimately an analysis of scientifically compatible worldview variations will show that the worldview variations of groups such as women, African-Americans and Hispanics are not incompatible with science, only with the way science is often taught.

An underdeveloped area in science education research is the role of affect or emotion in science learning and attitude development. However, Novak has written recently that an

> emerging trend in the psychology of learning is greater emphasis on the role of feelings or emotion in learning, and the interplay between an individual's self-concept and choice of learning strategies and/or domains of science (1989).

A researcher wishing to approach the issue of affect from a worldview perspective would be well advised to focus attention on the Self-Relationship-NonSelf structure. There is the potential

that an investigation of this structure will lead to an understanding of the presuppositions about Self, about nature, and about one's relationship with nature that form the epistemological foundation for the emotions related to science achievement and attitude. Done in conjunction with gender issues this could be a very important line of inquiry.

A further way of seeking theory corroboration and to further articulate the theory is to reexamine extant misconception research in the light of logico-structural theory. Researchers should find a mixture of the classes shown in Figure 2, that is true misconceptions that involve no worldview variations as well as alternative conceptions derived from worldview variations.

It has been argued by Novak (1982) that the data resulting from a Piagetian research paradigm can better be explained by the constructivist epistemological paradigms of theorists such as David Ausubel. That may well be the case but it is also possible that some Piagetian research may profitably be redirected by constructivist theory such as that presented here. Susan Buck-Morss has noted that while Piaget rejected ideologies of biological racism a universal application of Piaget's developmental theory,

> cannot account for the frequent chronological 'lag' in test performance of non-Western samples and the fact that members of some cultures never 'reach' certain levels of logical operations (1975, p. 261)

and thus there is a racist implication. Perhaps placing developmental theory within the framework of worldview theory would circumvent this difficulty.

At some point it must be asked, what does all this mean for classroom instruction, if anything at all? Is it possible, and if so is it feasible, to develop effective worldview-informed, instructional strategies and materials? Already some writers have implied that science education should be used to influence students' world views (e.g., Proper, Wideen & Ivany, 1988). The logico-structural theory of world view implies that in the short time span of a typical classroom setting attempts at influencing student world views are not likely to be successful. Indeed, we already know that the classroom setting does not appreciably influence student views on the nature of science (e.g., see Lederman, 1986; Lederman & Zeidler, 1986), which should be an easier task than influencing world view. What we can predict now is that influence is only likely to be achieved over a long period of time; and that influence aimed at enhancing or further articulating students' world views is more likely to be successful than attempts at overt change.

In summary, the science education researcher interested in worldview theory must first be able to describe a scientifically compatible world view (at least in part), and then be able to distinguish between students with and without such a world view. Only then can one address the question of worldview variation as a factor in science achievement and attitude. The specific

research questions I have posed in this concluding agenda and elsewhere in the paper are only a beginning. Ultimately the value of worldview theory as a research framework in science education rests on its integrating effectiveness and on the fruitfulness of the research directed by fundamental questions generaced by the theory.

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