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ABSTRACT

In recent years researchers have had a keen interest in scientific misconceptions and conceptual change. This paper describes approaches that can be used to provide a greater understanding of how students understand reality. The objective is to map belief space or terrain of belief regarding nature, i.e., to map the qualitatively different conceptualizations of nature held by students, including their perceived relationship to nature, and causality. The primary method used is the semi-structured interview. Interview sequence #1 explores the essence of nature that starts with landscape photographs and questions. Subsequently, 3 devices are employed to elicit conversation beyond what the questions and photographs could accomplish. These involve three sets of words and sentences (word sort, statement sort, and dyad comparisons) that relate ideas about nature and utilize a think aloud protocol. Interview sequence #2 explores the person's perceived relationship with nature. Sequence #3 investigates the understanding of cause. (PR)

World View - Reality as Viewed by Students: A Synopsis of Methodology

Scientific Literacy and Cultural Studies Project (SLCSP)

Working Paper No. 101, 1991

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> I use the term "scientific literacy" to denote the functional understanding of scientific concepts and the inquiring mental attitude that the school tries to develop... each individual develops a pattern for thinking about natural phenomena that may be called a personal natural philosophy... this natural philosophy reflects and perpetuates the prevalent cultural attitudes... Only in a small minority of students does the natural philosophy overlap substantially with modern scientific attitudes... (Karplus, 1963, pp. 837-8)

As seen in this 1963 quote of Robert Karplus, scientific literacy has long been viewed to include scientific attitudes and both the ability and willingness to use scientific information and thinking in everyday life. More recently these attitudinal goals have been reaffirmed by the AAAS' *Project 2061* and the National Research Council's *Fulfilling the Promise*, agencies of preeminent status in the American scientific community. The call for improved science education in 1963 was in response to Sputnik. In 1991, it is in response to America's failing economic competitiveness in world markets. It was then, and is now, a response to poor levels of science achievement and attitude among students. Attempting to improve the results of science education makes perfect sense, but there are significant obstacles. Very few students seem to take science seriously. How does one attract them to science? When students do study science and pass, how can we know that their attitudes and fundamental beliefs about the world have been influenced? In other words, how do we know that along with their knowledge their natural philosophies have been influenced? A number of years ago, a dedicated teacher wrote:

> In common with so many others, I used to think that we could get rid of... 'stupidities' by suitable talks on natural science... as if natural science could subvert [students'] traditional lore or philosophy. We destroy in this way their natural sciences, but their fundamental concepts concerning the universe remain *unchanged*... (Temples, 1959, emphasis added)

In recent years researchers have had a keen interest in scientific misconceptions and conceptual change. Temples noted from his experience that teaching science did not necessarily result in the literacy that science policy makers had in mind. I recently completed a study with nursing students that supports Temples' view that students can learn science without it significantly affecting fundamental views of reality. My study involved nursing students who had successfully completed a series of college science courses. Yet, in open interviews about the essence of the natural world these students showed little evidence of scientific thinking.

Listening to Students

The obstacles confronting more effective science education require that the philosophical background of science education be reexamined, but that is not the subject of our research at this time. The obstacles confronting more effective science education also require a greater understanding of how students understand reality. This is our basic research question. We have chosen world view theory to provide the terms or concepts needed for understanding someone's view of reality (Cobern, 1991).

Our objective is to map belief space or terrain of belief regarding nature, i.e., to map the qualitatively different conceptualizations of nature held by the students, including their perceived relationship to nature, and causality. Such conceptualizations are called outcome space by Marton (1988) and belief space by Jones (1972). The findings are descriptive categories and brief narratives derived from modified naturalistic inquiry (Lincoln & Guba, 1985), interview technique (Kvale, 1983; Spradley, 1979), and constant comparative analysis and grounded theory development (Strauss, 1987). The intention was to develop working hypotheses, in the form of interpretive statements, through an emergent design as advocated by Cronbach (1975), Lincoln & Guba (1985), and Strauss (1987).

It is possible that our questions could be approached with a naturalistic inquiry where students would be observed in a number of settings over a lengthy period of time. However, fundamental beliefs while having a wide range of influence, operate a quite subtle levels (Jones, 1972). It would take a very long time indeed to gather a relatively small amount of pertinent data. Thus, our choice of methodology is more direct. Our primary method for collecting data is the semi-structured interview. To encourage a person to talk at length about nature, relationship to nature, and causality, we use elicitation devices. Our current devices are not the only ones that could be employed in research such as ours, and not the only ones we will ever use. In principal, any device that elicits sincere responses to the issues of interest would do. Our particular devices are based on world view theory and informed by our historical studies of Western culture (Glacken, 1967; Merchant, 1983; Thomas, 1983). There is an etic perspective in our research. However, our perspective only serves to initiate discussion. We do not analyze data using etic codes. As much as is humanly possible, we allow the coding to come emmically from the transcripts.

The quality of the devices is directly proportional to device efficacy at prompting discussion on the issues in question. Nevertheless, within each elicitation device there is planned redundancy. If one aspect of a device is ineffective, a parallel aspect may be more effective. For example, the word sort in the first interview sequence contains several synonyms for several terms.

The data of our research is not a set of answers to questions. The elicitation devices are not measurement instruments. The data of our research is comprised of the text transcriptions of interviews. The spoken words of the informants in regard to the issues in question are our data. We use three interview sequences. There is one each for the issues of the essence of nature, one's relationship with nature, and causality.

The analysis of interview transcripts is done by coding chunks or pieces of information within the transcripts. Initially the transcripts of the different interview sequences are treated separately allowing for follow up interviews within two weeks of a primary interview. After that, however, the interview transcripts are viewed as a single body of data. We do this because there is significant overlap of issues among the comments made by the informants.

Based on the codes, inferences are drawn that lead to our interpretation of how students

understand reality. These are presented in narrative and concept map forms. We are very much concerned to demonstrate that interpretations have validity:

a. The study of each aspect of world view, such as one's understanding of the essence of nature, involves at least three elicitation devices allowing for the triangulation of text code analysis.

b. As codes emerge they are entered into a lexicon and concordance. As a researcher proceeds through the task of coding a transcript, the rules of constant comparative analysis and hermeneutics are observed. A code is not assigned to specific lines of text until the meaning of those lines is considered in the light of the entire text. The meaning of the lines must match the meaning assigned to a code as stated in the lexicon. The meaning of the lines must also be similar to the meaning of lines under the code as given in the concordance.

c. The process of coding one text after another proceeds iteratively. The lexicon grows with the addition of new codes and concordance grows with the addition of new lines. There is also development as the code definitions are refined in response to new text material. Initially, validity is protected by the constant comparison of new coding with the lexicon and concordance. A computer program that allows one to track codes and to create concordances greatly enhances the accuracy and speed of this process.

d. Furthermore, coding is independently done by two researchers who then caucus to iron out coding disagreements. A third researcher then checks their consensus coding against the lexicon and concordance. The final coding is a consensual agreement of the three.

d. The final protection of validity is member-checking. Once a narrative has been developed from text analysis, the narrative is discussed with the person interviewed allowing the researchers to hear that person's appraisal of the researchers' interpretive work.

Interview Sequence #1: The Essence of Nature

Primary Interview: 45-60 mins.
Follow up Interview: 30 mins.

We wish to ask what is nature like. Is it knowable or mysterious? Is it orderly? Is it pleasant? Is it dangerous? To get a person to talk about the essence of nature, the interview involves three sorting/think aloud tasks. The words and statements are based on our studies of Western culture and represent perspectives of aesthetics, religion, order, control, and knowledge.

An interview begins with a focusing event. Informants view a set of naturalistic

landscape photographs depicting nature at micro and macroscopic levels, including outer space, and nature as both benevolent and malevolent. After a few moments to examine the photographs, the informant is asked the grand tour question, "how would you define nature, that is, the natural world?"

Subsequently, three devices are employed to elicit conversation beyond what the grand tour question and photographs could accomplish alone. These involve three sets of words and sentences that related ideas about nature. The elicitation devices are structurally informed in that they are based on the view that conceptualizations of nature are rooted in the world view category NonSelf, and that in Western culture there are a limited number of ways in which nature has been and is now conceptualized (Cobern, 1991b). The structure in the devices partially overlap allowing the informants to be persistently engaged by concepts relevant to the issues, thus minimizing the potential for unrecognizable insincere comments. Overlap is built into the devices allowing triangular analysis of codes to improve the trustworthiness of interpretation. While thinking aloud, each informant sorts the words and sentences according to how accurately they corresponded to the informant's personal views. The interviewer, consistent with Spradley (1979) and Kvale (1983), is there to ask probing questions and to encourage the informant to speak freely and at length.

Word Sort

The following three groups of words are used as a word sort elicitation device. Each word is printed on a 3x5 card. The words from all three groups are mixed and then randomly divided into three new groups. The informant is shown each group of cards separately and asked to divide the cards into two groups labeled "would use" and "would not use" with respect to nature. The interviewer combines all the "would use" cards into one group and the "would not use" cards into another. The informant is then shown these two groups one at a time and asked to preform a ranking task. As the informant ranks the cards the interviewer encourages the informant to talk about his or her decisions.

(Chaos/Order)

orderly	chaotic
knowable	mysterious
understandable	puzzling
steady	changeable
secure	dangerous

alternative words

balanced	unstable
reliable	variable
stable	volatile

(Aesthetic/Materialistic)

beautiful	firm
attractive	concrete
appealing	real
pleasant	solid
delightful	tangible

alternative words

enchanting	substantial
fascinating	perceptible
pretty	materialistic
wonderful	

(Sacred/Prosaic)

divine	ordinary
holy	common
sanctified	normal
spiritual	routine
special	prosaic

alternative words

purposeful	everyday

Statement Sort

The following three groups of statements are used as a word sort elicitation device. Each statement is printed on a 3x5 card. The informant is shown all 18 cards and asked to divide the cards into two groups labeled "would use" and "would not use" with respect to nature. The informant is then shown these two groups one at a time and asked to preform a ranking task. As the informant ranks the cards the interviewer encourages the informant to talk about his or her decisions.

1. I see in nature the work of God.
2. I find in nature a spiritual quality.
3. Nature is the result of purpose and things happen in nature because of purpose.
4. Nature is an everyday part of life that I generally do not think much about.
5. I see beauty in nature.

6. I have an pleasant emotional response to nature.
7. I view nature as something solid, substantial and reliable.
8. Nature is the material, concrete world around us.
9. The natural world is all there is, all there ever was, all there ever will be.
10. Nature is difficult to understand.
11. To me nature is mysterious.
12. Nature is something that should be studied so that we can learn more about it.
13. It is important to understand how things work in nature.
14. Nature is a very important resource: water, energy, food, materials for making things.
15. Without the things that we get from nature we could not enjoy the lifestyle we have today.
16. I believe nature needs to be protected.
17. I am concerned about pollution and the damage it does to nature.
18. The material world of nature is the only real world there is.

Dyad Comparisons

In the third device respondents compare random combinations of two sentences, choosing one to retain and one to be replaced by a third randomly drawn statement until twelve statements have been compared. This is essentially a ranking task with last sentence chosen being rank #1. However, as with the above devices, the third incorporates the think aloud procedure and it is the informant's verbalizations that are of interest.

1. Nature is important because it is the real world around me.
2. Nature supplies the energy and materials needed by people.
3. Nature is something substantial.
4. We study nature so that we can live more harmoniously with nature.
5. The more we know about nature the better we can understand our relationship with nature.
6. By carefully studying nature we are better able to control our natural environment.
7. Our first consideration must be the protection and preservation of nature.
8. Nature is important because it appeals to my sense of wonder and beauty.
9. We study nature so that we may understand how events in nature function.
10. Because nature is our environment, we must preserve it.
11. Our first consideration must be the needs of people that can be met by the resources in nature.

12. Nature has an enchanting quality.

The interview sequence ends with two follow up questions:

Why is there a natural world at all?
How do you account for the natural world as it now exists?

Interview Sequence #2: Relationship with Nature

Primary Interview:	45-60 mins.
Continuation of Primary Interview:	30 mins.
Follow up Interview:	30 mins.

We are basically asking 1) to what extent people see themselves as a natural part of nature; 2) whether or not people are perceived as being qualitatively different from other aspects of nature; 3) to what extent, if any, control over nature by people is appropriate. The interview description given for the first interview sequence applies here as well.

An interview begins with the grand tour question, "If there is any kind of order in the world, where do people fit in that order?" The informant's response is followed with three elicitation devices.

Card Sort and Label

The object here is to gain insight into the informant's view of the relationship between people and other aspects of nature. The informant is shown forty 3X5 cards each with an image from nature. There are five images per each of the following groups:

a. Physical geography: mountains, ocean, beach, river, rocks, sky.
b. Mammals: people.
c. Mammals: various large and small mammals, including sea mammals.
d. Birds
e. Fish
f. Insects
g. Reptiles
h. Plants: trees, bushes, and flowering plants

The cards are mixed and the informant is asked to sort them into whatever groups desired, thinking aloud as s/he does so. The informant is also asked to give each group a label or name. The informant is then asked if there is any arrangement of the groups that s/he finds particularly meaningful. The arrangement is noted by the interviewer.

Once finished the informant is asked if any of the groups can be combined to make a larger and more general group. Again, the informant thinks aloud.

People vs Nature

The objective here is to gain insight into the informant's valuation of nature. Do we protect it all costs? Is it there for our use? Are there special circumstances that allow use that otherwise should not be tolerated?

The informant is shown four passages that describe an intended action (fictitious or quasi-fictitious) against non-human nature, the reasons for the action, and the probable consequences for people and non-human nature. The informant is asked to decide whether the action should go forth and why? The passages below are typical of what we use. There are more kept as backups in the event that an informant has little to say about one or more of the first passages presented.

1. The California condor is a large bird that was near extinction a number of years ago. The last wild birds were captured by scientists and raised in captivity. Now the scientists have raised enough birds so that some can be returned to the wild in a remote area of California. However, monitoring the birds to insure that they survive in the wild will cost $1.5 million per year for the next 20 to 30 years. The public must decide if saving the condor is worth this great expense.

   What are the important factors? What difference does the amount of money make? Does the kind of animal make a difference?

2. Scientists at a university are planning to build a new observatory. This is a building with telescopes needed for observing stars, planets, and other things in the night sky. The problem is that a particular type of squirrel lives where the scientists intend to build the observatory. The observatory may ruin the squirrels' natural home. If it does, this type for squirrel will die out. The public must decide whether to support the observation project or to help save the squirrels.

   What are the important factors? Would it make a difference if the science was of another type? For example, medical research? Does the type of animal matter? What if it were some type of insect?

3. Medical scientists are working on a cure for various diseases. Their experiments require the use of rabbits. The rabbits do not suffer pain in the experiments, but they do die. There is a group of people who feel that experiments with animals are wrong. They are trying to pass laws that would prohibit animal experiments. Would you support such laws?

What are the important factors? Would it make a difference if the science was of another type? For example, something that was non-medical? Would your views change if the experiments were done with a different type of animal? For example, rats.

4. A resource can be used only by destroying the immediate environment in which the resource exists. At this point we must assume the damage will be permanent but it can be confined to an area of several miles. The resource is vital to the maintenance of nearby jobs. Should we close the resource plant because of environmental damage and sacrifice the jobs? Should we sacrifice the local environment so long as the damage can be contained?

   What factors are of importance? Does the number of jobs make a difference? What if one of the jobs was yours? What if the resource was vital to the cure of what otherwise would be a terminal illness?

Important Contributions

The object here is again to gain insight into an informant's valuation of nature. Here, however, the informant is faced with both nature-oriented and nature-neutral descriptions. Further, the nature-oriented descriptions involve three different perspectives on nature.

The informant is given a hypothetical situation. The president is going to give an award for an outstanding contribution to our society. Ten people have been nominated. The informant is asked to rank the people from most deserving to least deserving of the group. As always, the informant is asked to think aloud. Once finished, the informant is asked whether there is any situation in which s/he would change the rankings. Nature oriented and nature neutral descriptions are represented in approximately even numbers (6 to 5). The nature oriented descriptions are divided between nature as resource, knowledge of nature, and ecology.

Nature neutral:

1. This person has helped many people, from ordinary citizens to company presidents and politicians, to understand what it means to take the right, moral, and ethical action regardless of personal consequences.

2. This person has helped many people, especially families, to get along with each other and to help each other. This person has improved the home life for countless numbers of children.

3. This person founded a business that created many jobs and helped to save a city that was withering away due to unemployment.

4. This person helped a city to solve some very difficult problems of racism and poverty.

5. This person wrote a piece of music that has brought pleasure to people all over the country.

Nature as resource orientation:

6. By studying tropical plants, this person has found the cure for a terrible disease.

7. This person invented a new procedure for extracting resources from the earth. These resources are crucial for the manufacturing of items, from cars to radios, that improve our quality of life.

Knowledge of nature orientation:

8. This person has made a major discovery that helps us to understand the extremely small particles that make up all matter. Scientists consider this one of the most important discoveries of the 20th century.

9. This person has made a major discovery in the heredity of animals, that is, a discovery having to do with how traits in the parents are passed on to the offspring. The discovery solved a problem that has puzzled scientists for 50 years.

Ecological orientation:

10. This person has made a major discovery concerning the influence of people in cities on the forests and grasslands around a city, and the influence of the forests and grasslands on the people. Because of this person's work, cities all over the nation are establishing "greenbelts" in and around populated areas.

11. This person has helped thousands of people to understand that people are a part of nature just as much as birds and deer, mountains and deserts are a part of nature. This person has brought about a significant change in peoples' attitudes about nature.

The interview sequence ends with two follow up questions:

What does it mean to be human? To be a person?
Are human beings animals? Explain.

Interview Sequence #3: Understanding of Cause

Primary Interview: 45-60 mins.

Continuation of Primary Interview: 30-45 mins.
Follow up Interview: 30 mins.

Our approach to causality derives from the contention that a scientifically compatible world view must include presuppositions in the Causal universal that are appropriate to scientific explanation. Obviously, there are many ways one can understand explanation. For our purposes we use Pepper's (1942) root metaphor theory which essentially says that explanations can be understood as examples of six metaphors: animism, mysticism, formism, mechanicism, contextualism, and organicism. Science textbook explanations are typically formistic/mechanistic. The intent of the interview is to give informants a chance to talk about explanations that are personally meaningful.

Preferred Explanation Style

The primary problematic feature of any discussion of explanations is that the interview itself must not be appear to be a test of scientific knowledge. Ignorance of scientific concepts does not necessarily indicate fundamental beliefs antithetical to science. We, thus, make the following assumption:

> When a student is faced with an unfamiliar phenomenon, he or she is more likely to accept an explanation that is more consistent with his or her world view than an explanation of the phenomenon that is less consistent.

If one presents a student with an unfamiliar phenomenon and two explanations, one cast in a scientific style (formistic/mechanistic) and the other not, one would expect students with scientifically compatible beliefs to choose the first explanation more frequently than students with variant beliefs. This suggests that an interview be structured with *unfamiliar phenomena* as items for discussion.

Unfortunately, one can never be sure who is familiar with what. An alternative procedure that avoids this problem is to create descriptions of fictitious or quasi-fictitious phenomena. For the current study we use 17 such descriptions with several others for backup purposes. An informant is told that the descriptions are not necessarily factual and that the interview is not a test of knowledge.

We assume that presuppositions amenable to scientific explanation are present in a student's world view if a student frequently chooses explanations that are scientifically compatible. Thus a scientifically compatible explanation is needed for each description. Obviously the explanations for the fictitious phenomena are also fictitious. The explanations for the obscure phenomena items also are fictitious in order to avoid confounding affects of students who might happen to be knowledgeable about the obscure phenomena. The criteria for designing a fictitious, but scientifically compatible explanation is from Pepper (1942), Braithwaite's *Scientific Explanations*, and to a lesser extent Aicken's *The Nature of Science*.

To be acceptable in science a explanation must be empirical and above all, testable. A scientific explanation always involves natural causes and tends to be mechanistic and reductionistic. Thus the scientifically-more compatible explanations were designed to be:

1. natural
2. rational
3. mechanistic/reductionistic
4. hypothetical/deductive
5. experimental
6. epistemologically dynamic/tentative.

Any scientific explanation is also a part of a theoretical structure or system composed of many explanations, generally on different levels of explanatory power. Scientific explanations are not given in isolation (Martin, 1972), however with the exception of one description that relates experimentation to theory, all of the descriptions contain ad hoc explanations. The notion that explanations should be related to other explanations in an explanatory system is not unique to scientific thinking however, and thus was not included as a criterion for the description in this interview.

The foil in each item was a rational explanation designed to be scientifically-less compatible or simply scientifically unacceptable. The criteria for composing such explanations were basically the opposite of the criteria for designing the scientifically-more compatible explanations. An attempt was made to write rational explanations that were holistic rather than reductionistic, plausible though non-testable. None of the explanations used in the interview is scientifically compatible because all are fabrications. However, it can be argued that when the explanations are considered hypothetically some are more compatible with science than others.