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ABSTRACT

This study seeks to investigate the interrelationships between three areas of science education: (1) the nature of science (NOS); (2) socioscientific issues; and (3) critical thinking. More specifically, the research addresses three questions: (1) How do high school biology students conceptualize the meaning and interpretation of data, cultural embeddedness, and tentativeness as demonstrated by viable, opposing positions in the context of a socioscientific issue? (2) How does NOS understanding affect the manner in which students handle socioscientific issues? and (3) How do critical thinking skills influence the development of ideas concerning NOS? Understandings of some aspects of NOS seems to be moderately related to critical thinking ability. (Contains 47 references.) (MM)

Investigating the Crossroads of Socioscientific Issues, the Nature of Science, and Critical Thinking

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Investigating the Crossroads of Socioscientific Issues, the Nature of Science, and Critical Thinking

In recent years, the nature of science (NOS) has become a fundamental component of science education programs. One need look no further than the documents that guide current reform efforts to see the significant position that NOS occupies in science education (for a review see McComas & Olson, 2000). An equally important goal in science education has become the promotion of learner appreciation for the interdependence of society and science. Consider, for instance, the following recommendations offered by standards documents in the United States: "all student should develop understanding of science and technology in local, national, and global challenges" (National Research Council (NRC), 1996, p. 193); "students should know that ... progress in science and invention depends heavily on what else is happening in society, and history often depends on scientific and technological developments" (American Association for the Advancement of Science (AAAS), 1993, p.19). Whereas many authors have addressed NOS relative to science education (Abd-El-Khalick & Lederman, 2000; Harding & Hare, 2000; Lederman, 1992; Lederman & Zeidler, 1987; McComas, Clough & Almazroa, 2000), research and discourse concerning the incorporation of socioscientific issues in the science classroom is just beginning to flourish (Kolstø, 2001a ; Patronis, Potari & Spiliotopoulou 1999; Zeidler, Walker, Ackett, & Simmons, in press).

Both NOS understanding and socioscientific issue awareness contribute to scientific literacy, which to many is the ultimate goal of science education (AAAS, 1990; NRC, 1996). In fact, at least one interpretation of scientific literacy necessitates the integration of NOS and socioscientific issues. In the report that operationalized scientific literacy, a scientifically literate person is described as one who "uses scientific knowledge and scientific ways of thinking for individual and social purposes" (AAAS, 1990, p. ix). If a person is able to use "scientific ways of thinking" then she necessarily understands the nature of science; and if she is applying them to "individual and social purposes", then she is considering socioscientific issues. In other words, the nature of science informs debate surrounding socioscientific issues. These two themes, which are integral to modern science education, are implicitly associated with one another. Exploring how students conceptualize the nature of science using a socioscientific issue as a contextual backdrop and how NOS understanding influences decision-making with regards to a socioscientific issue are two of this study's goals.

Obviously, the reform movement and the standards documents it created did not initiate all science education goals. Whereas NOS and socioscientific issues are relatively new aspects of science education, critical thinking has been a goal of science education for decades, perhaps since the field's inception (Chapman, 2001; Zimmerman, 2000; Zohar, Weinberger & Tamir, 1994;). It is difficult to consider a legitimate science education program that does not at least attempt to promote critical thinking. That critical thinking forms an integral part of science as a way of knowing is hardly a contentious issue, but coming to consensus on what exactly critical thinking entails may inspire disagreement. Dewey (1910) suggests that critical thinking is evaluative in nature; that is, it involves the active consideration and analysis of claims, suppositions, procedures and influences about whatever it is that the agent is thinking. Given this notion of critical thinking, it seems reasonable to hypothesize about the relationship between critical thinking skills and aspects of NOS. We can legitimately argue that developing a mature epistemology about science requires the evaluation and analysis of claims and influences. For instance, to appreciate the empirical nature of science, one must understand what constitutes data; and it seems likely that critical thinking skills are involved in the evaluation of information in order to identify data.

This study seeks to investigate the interrelationships between these three areas of science education: the nature of science, socioscientific issues and critical thinking. More specifically, the research will address the following three questions:

1. How do high school biology students conceptualize the following aspects of NOS in the context of a socioscientific issue: the meaning and interpretation of data; cultural embeddedness; and tentativeness as demonstrated by viable, opposing positions?
2. How does NOS understanding affect the manner in which students handle socioscientific issues?
3. How do critical thinking skills influence the development of ideas concerning NOS?

Theoretical Framework

Question 1: How do high school biology students conceptualize the following aspects of NOS in the context of a socioscientific issue: the meaning and interpretation of data; cultural embeddedness; and tentativeness as demonstrated by viable, opposing positions?

Although debate exists about certain aspects of NOS, scientists and science educators can agree that the scientific enterprise possesses a set of general characteristics that separates it from other disciplines or ways of knowing. Lederman and Zeidler (1987) describe NOS as the values and assumptions inherent to the development of scientific knowledge. Other authors have made attempts to specify a consensus view of these "values and assumptions" (McComas & Olsen, 2000; McComas, Clough, & Almazroa, 2000). Among the constructs that are central the consensus view of NOS are the following ideas. Some scientific knowledge is relatively stable; whereas, less substantiated knowledge is tentative and subject to change given new evidence or reinterpretation of existing evidence (Harding & Hare, 2000). Science relies on empirical evidence, and scientists employ creativity in order to obtain and interpret this evidence. Scientific research and cultural norms mutually shape one another. The pursuit of scientific progress often encounters (or creates) ethical and moral considerations.

In order to elucidate an in-depth understanding of student perspectives, this study focuses primarily on three aspects of NOS: its empirical basis, cultural embeddedness, and tentativeness. Individual aspects of NOS may possess contextually variable significance; NOS components may be more or less important when considering them from different contexts. For instance, biology students charged with reconstructing evolutionary phylogenies confront the issue of parsimony whereas science's cultural embeddedness may be more obscure. In this study, we choose to investigate NOS in the context of the global warming debate. The issue of global warming lends itself to discussion of data use and interpretation, cultural influence on the progress of science, and the evolution and inconsistency of some scientific ideas; therefore, we focus on these areas in our investigation of student conceptualizations of NOS.

Science education researchers have focused on assessing student understanding of NOS for at least the last half century (Lederman, 1992). During this period, significant effort has been devoted to the design, validation, and use of quantitative instruments for measuring NOS conceptions (Aikenhead, Fleming, & Ryan, 1987). Consider the following list of tests that have been used in this capacity: Science Attitude Questionnaire (Wilson, 1954), Test on Understanding Science (Klopfer & Cooley, 1961), the Nature of Science Scale (Kimball, 1967), the Nature of Scientific Knowledge Scale (Rubba & Anderson, 1978), and the Views on Science-Technology-Society (Aikenhead & Ryan, 1992). In efforts to quantify and statistically analyze student understanding, researchers necessarily impose their own a priori assumptions and interpretations within the assessment instruments they produce. Although these tests have played (an still do play) an important role in NOS research, they limit access to the detailed NOS conceptualizations held by learners. In more recent years, the growing acceptance of qualitative methodologies has enabled science educators to look more closely at student and teacher ideas about NOS without the constraints of standardized instruments. Qualitative inquiry certainly has limitations as well, but findings based on this type of methodology can add to the overall picture of NOS's role in science education, which still remains incomplete (Lederman, 1992). This study adds to the body of qualitative assessments of student understanding on the three distinct areas of NOS discussed earlier.

Question 2: How does NOS understanding affect the manner in which students handle socioscientific issues?

The interconnections between science and society have been well documented in the literature (Aikenhead, 1985; Kolstø, 2001a; McComas & Olsen, 2000; Yager, 1996; Zeidler et al., in press). The science-technology-society (STS) movement has been built around the notion that the mutual influences science, technology, and society exert on one another are both important for science curricula and personally relevant for students exposed to that curricula. If students identify the interdependence of science and the society in which they personally participate, they will find the science content to be relevant and will be more apt to engage in meaningful learning (McComas, 1996). While this assumption may hold true in some science classroom scenarios, the approach fails to emphasize a critical area of socioscientific interactions: moral and ethical implications. Many of the questions faced by modern society require more than the recognition that science plays a central role in their solutions; these dilemmas require the consideration of moral and ethical implications that accompany scientifically based decisions (Zeidler et al., in press). In this study, we employ the term socioscientific issue because it more accurately reflects the moral and ethical dimensions of STS interactions.

This research question addresses the influence of NOS understanding on student perceptions of a socioscientific issue. Socioscientific issues are controversial, in part, because they require individuals to adopt a position or choose a solution with an unclear outcome. This can create an uncomfortable situation for the individual, one that requires her to draw on content knowledge from science and other disciplines, moral reasoning, and *content-transcending-knowledge*. Kolstø (2001a) defines content-transcending-knowledge as "knowledge, or skills and attitudes that do not have their focus on the products of the scientific community. . . The focus *is* shifted from knowledge in science toward knowledge *about* science" (p. 292). The claim is that a person's understanding about the epistemology of content knowledge will influence the application of the content knowledge. In other words, nature of science conceptualizations affect the interpretation of scientific knowledge upon which decisions about socioscientific issues are made. This study seeks to understand how NOS understanding can influence an individual's decision-making with respect to a socioscientific issue.

Question 3: How do critical thinking skills influence the development of ideas concerning NOS?

Researchers have argued that scientific process skills, also termed scientific inquiry skills, are dependent on critical thinking (NRC, 2000; Schwab & Brandwein, 1962; Tamir & Lunetta, 1978; Zohar et al., 1994). This implies that in order to participate in science, one must possess requisite critical thinking skills. An extension of this claim is the suggestion that developing a sophisticated conceptualization of the nature of science also requires critical thinking. If critical thinking skills do in fact involve the consideration of beliefs and knowledge in terms of the evidence which supports them, as Dewey (1910) suggests, then an individual's understanding of the nature of science should be impacted by her ability to think critically. Developing a personal epistemology of science requires the consideration of how scientific knowledge comes into being, which by the definition just proposed is critical thinking. In other words, we are suggesting that a person's understanding of NOS is contingent on critical thinking skills. This study seeks to investigate the validity of this assertion. If NOS understanding is related to critical thinking, then individuals with comparable critical thinking skills may be more likely to share common notions about the nature of science than they would with vastly different critical thinking skills. The relationship between NOS and critical thinking may have significant implications for science teaching. If developing mature epistemologies of science requires critical thinking skills, then teachers should consider the critical thinking abilities of their students as they incorporate NOS instruction into the curriculum.

Design & Procedures

Sample, Instrumentation, and Data Collection

The study's inquiry focused on biology students from a relatively large (~2000 students) urban/suburban high school located in the Southeastern United States. A diverse population attends the school including students from economically depressed inner-city neighborhoods and moderate income suburban neighborhoods. Eighty-four students identified through a combination of convenience sampling and sampling typical cases (Patton, 1990) participated in the study. Thirty-nine females and 45 males comprised the sample. The students represented intact groups from four biology classes taught by the same teacher. In this particular school, biology is a mandatory course typically taken by second year students; however, some first and third year students enroll in the class because of scheduling problems or retention. The students ranged in age from fourteen to seventeen years old. The sample included average to below average achieving students as most honors students had taken an advanced section of biology in their first year of high school. By concentrating on a relatively large sample taken from the same school and teacher, we sought to develop a picture of an "average" high school science student from this school without obscuring the issue with multiple instructional strategies used by different teachers.

Each student was presented with a fictitious "Science Brief" (see Appendix 1), which chronicled a gathering of several environmental scientists interested in the global warming issue. The brief reported that two groups emerged from the meeting with opposing views on the issue, and each faction constructed a summary of their position. Both summary statements followed a short introduction. One statement, entitled "Global Warming: An Impending Environmental Crisis," reported that global warming is caused primarily by humans and a very real threat to the environment. The other statement, entitled "Global Warming Myth: Evidence Against Environmental Crisis," presented evidence suggesting that the current warming trend is a natural event and poses no real threat to the environment. Although the "Science Brief" was created specifically for this study, the data in both position statements were accurate, and the persuasive comments were consistent with rhetoric used to defend and attack global warming. It is important to emphasize that this particular issue was identified and selected by consensus of the researchers because: 1) it contained information consistent with core NOS issues relevant to this investigation (viz. data use and interpretation, cultural influences on the progress of science, and the evolution and inconsistency of some scientific ideas); 2) it did not necessarily require technical knowledge in order to comprehend and critically evaluate the issues under consideration; 3) it did not prohibit the use of specific content knowledge; 4) the issue was pedagogically appropriate for the range of students represented by the sample; and 5) similarly constructed socioscientific issues have been found to reveal various patterns of thinking in prior studies (Pedretti, 1999; Ramsey, 1993; Zeidler et al., in press).

The articles were constructed as equally as possible; that is, each contained the same amount of data and persuasive argumentation. Some of the data offered were actually identical in both reports but was accompanied by different interpretations. Each position statement included a graph selected to support its argument. Several adult reviewers including high school science teachers reported that the articles were comparable. In order to minimize the effect of article order, half the students received forms with the "Global Warming" position situated first while the other half read the "Global Warming Myth" position first.

After reading the articles, students responded to a series of open-ended questions. The questions were constructed to elicit student conceptualizations of pertinent NOS issues (i.e. empirical, tentative, and social aspects), factors that influence socioscientific decision-making, and patterns of critical thinking. The questions used are below.

1) Are data used to support either position? If so, describe the data and how they are used?
2) Do societal factors (issues not directly related to science) influence either position? If so, describe how these factors influence each argument. If not, describe why these factors would not influence each argument.
3) Why do the two articles, which are both written by scientists discussing the same material, have such different conclusions?
4) Which article is more convincing? Please explain your response.
5) Which article has more scientific merit? Please explain your response.

Each question was followed by a lined area that covered a half page for student responses. The directions on the instrument also encouraged students to complete their responses on the back of the paper if the designated space was too small, and several of them did. While we realized that some science educators may take issue with the description of societal factors offered in question 2, we also anticipated the practical problem of question comprehension. We do not disagree that societal factors are intrinsically bound to science, but many of the participants would be unable to decipher the question without the prompt provided. Subsequent analyses of both questionnaire and interview data did not reveal any overt problems based on the inclusion of this hint. The administration of the instrument was not limited by time, but all students finished the questionnaire within fifty minutes.

In order to supplement the data analysis of questionnaire responses, interviews were conducted with a sub-sample of the students. Because we were interested in the relationship between critical thinking and NOS conceptualizations, we produced a focused sample (Lincoln & Guba, 1985). We sought a sample that represented low, middle, and high abilities with respect to critical thinking. In order to detect differences in critical thinking abilities and construct the desired sample for the interviews, we administered the Watson-Glaser Critical Thinking Appraisal (WG) (Watson & Glaser, 1980). All of the student participants completed the WG one week prior to reading the global warming articles and responding to the written questions. The WG assesses an individual's ability to recognize problems and evidence; evaluate inferences, abstractions, and generalizations; and coordinate all of these factors. It is composed of the following five subtests: inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. The composite score is derived by summing scores from all of the subtests. Reliability for the instrument was assessed by measures of internal consistency, stability over time, and correlation between scores on alternate forms. Split half reliability coefficients ranged from 0.69 to 0.85. The correlation between responses from the same individuals separated in time by three months was 0.73, and alternate form reliability was calculated to be 0.75. The validity of the instrument was estimated by correlating scores from other mental aptitude tests with WG scores. Otis-Lennon Mental Ability Test scores from students in the grades represented by the present study correlate significantly ($r = 0.61$ to 0.81) with WG scores (Watson & Glaser, 1980). Given the complex nature of critical thinking and the limitations of assessment instruments, some authors have raised legitimate concerns about the reliability and validity of the WG; however, they also have noted that it is the best single instrument for evaluating the construct of critical thinking (Berger, 1985; Helmstadter, 1985; Woehlke, 1984).

Students were stratified into three groups based on their WG scores: students in first group scored in the top 25th percentile of the sample, students in the second group scored between the 25th and 75th percentiles, and the students in the final group scored within the lowest 25th percentile. Ten students from each group were randomly selected to participate in individual interviews. The one-on-one interviews were conducted by one of the investigators who had not previously interacted with the students. During the interviews, which occurred approximately one week after the questionnaire administration, students were offered a chance to reread the "Science Brief" before responding to the same questions they had seen on the questionnaire. We posed the same questions in order to encourage verbal elaboration of the ideas originally formulated while working on the written questions. All interview proceedings were recorded and transcribed for later analysis.

Data Analysis

In order to explore the three areas of primary interest, we analyzed the qualitative data in a manner consistent with the constant comparative method detailed by Lincoln and Guba (1985). Validity and trustworthiness were established through triangulation of multiple data sources (questionnaires and interviews) and independent examination of the data by the three investigators. Each author began by reading the interview transcripts and written responses to look for general patterns related to NOS understanding, socioscientific decision-making, and critical thinking. No a priori hypotheses or categories were assumed so as to maximize sensitivity to the patterns that emerged from the data. In a series of successive meetings, authors compared, modified, and provided support for the categories that each had independently derived. When all of the authors agreed on the validity of a category and its status was sufficiently supported with direct quotations from the student responses, it was included in the final taxonomies presented in this report. We assumed that students would provide more detailed responses during the interviews than the written questionnaires because of the ease with which most high school students approach verbal communication as opposed to written communication in an academic setting. Contrary to our expectations, student responses were more expressive and revealed more complete lines of rationale in the written responses than in the interview transcriptions. The combined influences of an unfamiliar interviewer, a novel setting, and the perceived pressure of a tape recorder may have accounted for the relatively limited remarks offered in the interviews. In the qualitative analysis that ensued, we examined both interview and questionnaire responses, but because of their richer content, we chose exemplars from the questionnaires to support the constructed taxonomies.

Student responses provided a strong data set for the exploration of NOS conceptualizations and socioscientific decision-making; however, they did not address critical thinking to the extent that we had planned. We originally hypothesized that the questions posed in response to the global warming position statements would elicit answers that revealed patterns of critical thinking. During the qualitative analyses, we specifically looked for evidence of critical thinking in interview and questionnaire responses, but it was difficult to find any consistent patterns among several subjects or even within the multiple responses of a single subject. We are not suggesting that the students did not engage in critical thinking during the treatment, but the questions we posed did not sufficiently elicit responses that would make the analysis of critical thinking fruitful. The data with respect to critical thinking was not rich enough for the formulation of trustworthy analyses, so the proposed qualitative investigation of the link between NOS and critical thinking became impossible. However, the taxonomic categorization from one question (the first question addressing data use) possessed an arrangement that could be used to explore NOS and critical thinking. Typically, it is unnecessary and inappropriate (Lincoln & Guba, 1985) to substantiate qualitative taxonomies with quantitative measures such as frequency counts. However, because the taxonomy produced for question 1 was hierarchical in nature, we concluded that it would be appropriate to calculate the frequencies for each level. This quantitative information provides readers with a more complete description of the sample. Given the nature of these categories and our interest in the relationship between NOS and critical thinking, we performed a post hoc correlation analysis between response level to question 1 and WG scores.

Results and Discussion

Conceptualizations of NOS

The questions to which students responded addressed three aspects of the nature of science. We will discuss student-generated ideas about each of these aspects separately (implications about the generalized notions of NOS will be discussed in the next section). For each taxonomic category described, we will provide exemplars that represent the comments, which define the category. All of the bulleted responses are direct quotations taken from the open-ended questionnaires that each student completed.

The Empirical Nature of Science

The first question asked students to identify and explain the use of data in both position statements. Although the structure of this question did not provide insight into whether or not students can explicitly articulate the empirical basis of science, it did address how students perceive empiricism. In order to fully appreciate the empirical nature of science, an individual must understand what constitutes data and how it can be used. A person may be able to report that scientific knowledge is based on empirical evidence; however, if that person is confused by what data is, then their assertion means very little. For example, the student who accepts unfounded opinion and predictions as viable forms of data does not possess a well-developed notion of the empirical basis of science. Working from these assumptions, we explored student conceptions of the empirical nature of science by analyzing their comments about how data was used to support each position in the global warming articles.

Although we did not approach the analysis of question one with the aim of generating a ranked order of responses, we found such a hierarchy. Responses revealed a range of levels beginning with misunderstanding the nature of scientific data (level A) and progressing towards sophisticated ideas about the role of data (level D). Level A responses revealed confusion over the nature of data. Rather than identifying and discussing data, these responses summarized the articles, or described predictions made in the articles. Students who provided level B responses identified a piece of data, which suggested data recognition but failed to provide an explanation about what the data means or how it is used. Many responses in this category casually mentioned one or both of the graphs presented without describing their meaning or significance. Level C responses identified data and provided a partial description. Answers forming this category displayed a more advanced understanding than previous levels because they moved beyond simple recognition by providing at least a simple discussion of data meaning or significance. Whereas a typical level B response stated that the graphs are forms of data, level C responses identified graphs as data but also addressed their meaning. The most sophisticated responses formed level D; students providing these answers not only described data from both position statements, they also explained the use of that data.

Level A: Data confusion

- The data is that global warming can be very dangerous. For example, polar ice caps would melt & 70% of Florida would flood.
- A group of scientists met on February 7-11, 2001, to talk about global warming. Some scientists noted mounting evidence that supports global warming as a serious problem; whereas, other scientists refuted their colleagues that presented evidence to suggest that the earth's temp is not increasing.

Level B: Data recognition

- There are graphs and facts supportive facts about the articles that tell about the greenhouse effects and the atmosphere.
- Data found on global temperature changes and they found this information by satellites and weather patterns.

Level C: Data recognition and partial description

- The data in these article are used in different kinds of graphs. The description of the data is that the annual carbon dioxide concentrations every 10 years has gone up by 310-370 (ppmv). On the other graph it shows how the global temperature changes have really never been constant. They have always been different. Going from cold to hot, cold to hot.
- The climate and weather data show worldwide temperature increases on the order of 0.6C. It also tell in what the CO_2 increase and decrease carbon dioxide and other greenhouse gases released from the earth's surface trap solar energy.

Level D: Data recognition, description, and explanation

- For the position that humans are causing global warming, they used a bar graph with data on how much carbon dioxide there is in the environment. This is then tied into the fact that carbon dioxide, along with certain other gases produce a greenhouse effect when in the environment. This traps heat against the earth, raising our surface temperature. On the other position, they have data showing that the past 160,000 years temperatures have fluctuated much, showing that this is just part of an ongoing trend.
- The data used to support the first selection are the annual carbon dioxide concentrations throughout recent years. There has been a pretty steady increase. They also measured climate and weather worldwide which show increases on the order of 0.6C over the last

decade. They measured snow cover, glacial recession and loss of arctic ice. The second selection did a wider range of data showing global temperature changes that were happening thousands of years before the present year. They also used a more accurate way of obtaining information which was by satellites.

Discussing the relative proportions of statements in taxonomic categories derived from qualitative research is typically unnecessary (Lincoln & Guba, 1985); however, given the nature of both the sampling methodology and classification scheme, it is appropriate to report the distribution of responses in each level of the question 1 hierarchy. Because four "average" biology classes from the same teacher comprised the sample, looking at the percent of responses in each category provided us with a more accurate picture of the students participating in this study. Categorical proportions helped us to understand this sample and may help educators relate the findings of this study to their own unique settings. Table 1 displays the relative proportions of each level derived from question 1 responses.

Table 1. Question 1 categories

Level	Description	Number Of responses	Percents
A	Data confusion	15	17%
B	Data recognition	27	30%
C	Data recognition & partial description	38	43%
D	Data recognition, description & explanation	9	10%

The information in Table 1 suggests that over 80% of the students were able to at least identify data in articles they read, and therefore have some basis for understanding the empirical nature of science. The 17% that displayed confusion about what data is are most likely unable to grasp the empirical nature of science. While it is encouraging that a majority of students seem to know what data is, the 30% of students that comprise level B present very naïve conceptualizations of data. Students with this level of understanding may be able to affirm that science is based on empirical evidence but probably do not fully comprehend the significance of this claim. It seems probable that only the students making up levels C and D possess enough requisite understanding of data and its use to apprehend conceptual aspects related to science's empirical nature.

The Social Embeddedness of Science

The second question to which students responded addressed how social factors influence scientific issues. The issue of global warming provides an excellent context for exploring student ideas about the interaction between science and society. Individuals with a mature understanding of NOS would find it very difficult to deny the influence of society on this issue, and both position papers include information that is traditionally classified in the social domain. Three major categories emerged from the examination of student responses concerning the impact of society on the issue of global warming.

One group of responses show a clear understanding of the influence of societal factors on science at least with respect to global warming. Students discussed four different ways in which society exerted an influence. They frequently cited economic influences; in fact, they identified several distinct economic factors including personal, business and national interests. In another class of responses that fell in the social influence category, students discussed the personal perspectives that individuals take as they assess the issue of global warming. These responses suggested that the judgments one makes are often contingent upon the social positions and beliefs she holds. Other students affirmed social influence based on cause or effect. Human society has created the problem of global warming, or the issue will produce consequences that affect society.

<u>Social Influences on Global Warming</u>

A. Economy
- Yes, it influences a lot because on one side they talked about how much money it would cost us in generally and everybody can relate to that. *(Personal)*
- I think that societal factors influence each argument because for example second article might have been supported by the leading car company or something like that. Therefore that company wants to make lots of money by selling cars and they are going to look for scientists who have a different opinion on greenhouse effect so its going to be profitable for the car company to cover the truth. *(Business)*
- Yes, in the first argument they bring up the fact that "a solution" for global warming was to cut "greenhouse emissions to 10% below 1990 levels" but that would have devastating effects on the economy. It would cost United States over $200million dollars a year. *(National)*

B. Personal Perspectives
- Yes, I think some [societal factors] do. Some like religion. A lot of people closely follow religion and believe everything that is written & said. Other things might be money. People with a lot of money don't care about what happens to the earth.
- Some people think scientist are the scum of the earth. Animal lovers are saying the chemicals are killing all kinds of animals. Then there are people who say we would not have made it to 2000 without them.

C. Societal Causes
- Yes, social factors do influence both position, because people use all kinds of transportations which cause green house gases to get to their jobs.
- Yes, societal factors influence both positions. Pollutions that is put into the atmosphere has an effect on the global warming effect and if the temperatures will change or not. Since we get more pollution every year, maybe that has something to do with the temperature going up every year.

D. Societal Effects
- Another societal factor is the heat that in times may cause higher tensions leading to bitter conflicts in society. The sun will also cause sunburns more often and lead many people to have skin cancer.
- It [global warming] changes our environment & everything surrounding us, also. And plus it would be a big change, etc.

Whereas some students noted the influence of societal factors, others denied interactions of this sort. We titled this category of responses "scientific isolation;" students in this group provided answers that suggest science is unaffected by society. That is, science stands alone as a discipline insulated from other aspects of society. Consider the statements below which exemplify the collection of remarks that form this category.

Scientific Isolation

- No, the reason I say no is because if not related to science it should have no say so in what is going on with global warming.
- No, what does money and racial issues have to do with the environment. Nothing!

The final major category does not directly inform the issue of society's influence on science. These responses revealed a misinterpretation of article titles. In an effort to make both position statements as similar as possible in structure and format, we created parallel titles: "Global warming: An impending environmental crisis" and "Global warming myth: Evidence against environmental crisis". Rather than reading the latter title as an indictment against warnings about global warming, some students interpreted it as a declaration of the article's falsehood. They concluded that because "myth" was in the title, the article which followed was fictional. The following quotes typify comments that compose this category.

Myth Confusion

- My answer is yes and no. Yes to the second position because myths are fake and are not true most of the time. So myths would have to do with societal factors. Not to the first position because it is more fact and data. It is not a myth or made up by societal factors. It is research results from real scientists and real data.
- Yes, societal factors influence the position because the global warming myth was influenced but it didn't have enough supportive facts or details to back it up.

Although the "myth confusion" responses fail to inform us about how students perceive the social embeddedness of science, they do call attention to potential pitfalls of NOS and socioscientific issue research. It has been reported that the language used by teachers and researchers can be seriously misunderstood by the intended audience (Munby, 1976; Zeidler & Lederman, 1989). Teachers and students may use the same words, but those same words do not always carry the same connotations. Lederman (1992) points to this problem as a primary rationale for conducting qualitative research with students on issues as complex as NOS understanding. Methodologies that prohibit researchers from obtaining a comprehensive picture of student understanding will be unable to reveal these types of misinterpretations resulting in invalid research conclusions.

Because the categories from the previous section (the empirical nature of science) were reported along with the proportion of students making up each category, we deem it important to discuss why this type of data is not being reported for the social embeddedness of science or any of the other taxonomic categories that will follow. The data recognition categories were hierarchical and mutually exclusive; whereas, the other taxonomies presented herein are not ranked nor are they necessarily mutually exclusive. (For example, a single subject may provide responses that form two distinct categories.) Lincoln and Guba (1985) assert that it is inappropriate to substantiate qualitative taxonomies with quantitative measures. The validity and trustworthiness of qualitative categories should be established by the use of exemplars and "thick description" rather than an arbitrary statistical measure. Imposing quantitative measures on qualitative categories encourages the error of reification, undue faith in a conclusion because of quantification. For the purposes of this research, the number of students in each category is far less important than the category itself. We are not claiming that every collection of biology students would display the same ideas in the same relative proportions as revealed in this sample. Rather, we are presenting a description student conceptualizations that are clearly evident in this data. The aim of qualitative research such as this is not generalization to all similar situations; however, it does direct the attention of researchers and practitioners to potentially important trends.

The Tentative Nature of Science

The enterprise of science operates under the implicit assumption that scientific knowledge develops, builds upon itself, and changes over time. Scientists would not devote their lives to the pursuit of knowledge if they had no chance of adding to or changing prevailing paradigms. Philosophers may wrangle over the mechanisms of scientific change (Kuhn, 1962; Laudan, 1977), but the manifestations of scientific tentativeness are relatively easy to see. The fact that researchers disagree about scientific issues implies that the ontological status of scientific knowledge cannot be fixed and unchanging. If scientific knowledge was completely static, scientists would have no grounds for conflict. This study challenged students to consider opposing viewpoints on the same issue with very similar data sets and develop an explanation for the observed controversy. In its section on scientific habits of mind, which encompass many aspects of NOS, *Benchmarks for Science Literacy* (AAAS, 1993) suggests that by eighth grade students should understand that multiple and equally viable interpretations can be produced from the same data set. Presumably, high school students should be able to do so as well.

The third question to which students responded asked them to explain how groups of scientists evaluating the same data could produce such divergent conclusions. Student responses formed four main categories. As in the second question, confusion about the term "myth" in the title of one position statement created problems for some students. Consider the following exemplars, which explain the inconsistency by asserting that the "myth article" was fabricated.

<u>Myth Confusion</u>

- Even though both articles are written by the same scientists materials but different scientists, the conclusion is different because one of them is more on global warming data and research and the other is more on global warming myths. Now even though they are talking about the same thing they will be totally different answers. Lets see, myths [compared] to data and research!
- The reason they have different conclusions is because one is base on facts and the other is based on myth.

Another category of responses identified data concerns as the source of deviation between the two positions. Students reported two types of data concerns: the data itself was different and the analysis of data was different.

<u>Data Concerns</u>

A. Different data

- Maybe because these two different descriptions were at different times. Maybe each discussion had different data available and people brought up different ideas in that sense maybe different solutions of goals to global warming.

- Because even though there both talking about different material, one is on temperature changes & the other is about C. Dioxide concentration.

B. Different data analysis

- They have different conclusions because of the way in which they view and process all the information the have. One group says because the temperature went up 0.6C in a decade global warming is trouble, while the other sees temperatures raise 0.6C as a indications of hot weather to come.
- Both groups have pretty much the same data from sensors and test, etc. But both are looking from different angles and processing the data in opposite ways.

A third main category of responses suggested that the conclusion of each position statement resulted from the opinions and personal beliefs of its author. It should be noted that this category and the previous one are consistent with the findings of Zeidler, Walker, Ackett, and Simmons (in press) when they asked a similar question on an NOS questionnaire.

Beliefs and Opinions

- They have such different conclusions because they are two different groups of people stating their position and what they feel is the cause and effect. Both groups approached the subject according to their beliefs, bringing different conclusions.
- They have different conclusions because in science there is no one right answer. The scientist may also have different conclusions because its is their belief or opinion on this subject.

In the final taxonomic grouping, students explained the opposing conclusions by differentiating between each author's intent. They claimed that each article has a different focus or purpose thereby producing different results.

Different Foci

- In the first article they are trying to prove that the ozone layer all the atmosphere isn't being destroyed due to fuels and in the other article they are trying to find a solution to the problem.
- They both have almost the same idea going still the second has the idea that the icebergs will melt and flood many countries. The first article to describe how the temperature change. The 2nd is telling us about how to solve the problem.

Socioscientific Issues and NOS

The final two questions to which students responded after reading the global warming position statements did not specifically address a component of NOS. Instead, they solicited student opinions about the scientific merit and persuasiveness of each article. Although scientific merit is not what science educators typically consider a discrete component of NOS (McComas & Olsen, 2000), an individual's NOS understanding will likely affect his contemplation of merit. Consider the influence of the NOS aspects explored as a part of this study. An individual, who appreciates the empirical basis of science, will consider the data upon which a scientific argument is built in determining its merit. If the individual also understands the position of science relative to society, she will be able to recognize social influences on an argument while offering judgment on its merit.

Scientific merit as well as persuasiveness are also significant for the consideration of socioscientific issues. These aspects of a position will guide an individual towards a decision about the socioscientific issue she is contemplating. To understand how students interpret these concepts in the context of the global warming issue, we asked them to identify the most convincing and meritorious articles with rationale for each decision. Given the similarity of the articles, student responses to the questions of merit and persuasiveness provided insight into what factors affect decision-making with respect to a socioscientific issue.

For the question of scientific merit, student responses formed four primary categories. Some students found one of the positions personally relevant and based their decision on this fact. Others perceived that one article possessed more or better data and information than the other, while some equated merit with better explanations. A final group of responses suggested that both positions were equally meritorious. Refer to the following quotations for support of each of these categories.

<u>Scientific Merit</u>

A. Personal Relevance

- I think the second article (Global warming: An impending environmental crisis) is an overall better article. It explains what we are doing wrong. It also explains what will happen if we keep this up (like 70% of Florida being flooded). This article would make me want to change some of the things I'm doing.
- The article with an impending environmental crisis. It said that global warming will surly cause a variety of other problems such as increases in the number of disease-carrying insects. It will causes disease such as malaria, which is carried by mosquitoes. This we need to know so we could do something about it or avoid in some way.

B. Better Data and Information

- the first one does you can tell they have done a lot more research. They have more accurate numbers and many more professionals backing them up.
- The global warming myth has more scientific merit. It tells you about the climate data the water vapor it has more information more details to it than the other. It gives you different percentages has a graph that is easily understood.

C. Better Explanation

- Global warming myth: Evidence against environmental crisis, I think has more scientific merit because it has a lot more descriptions & explanations on what is happening and what is going to happen if it is continued.
- I think it would be the first one because it explains more about what causes it.

D. Both Articles are Equally Meritorious

- I think that both have the same amount of scientific merit. Both have strong arguing points and both could be right. It all depends on what you think.
- Both articles have scientific merit to me because they provide graphs and information that answers how, what, when and where giving a detail description explaining "why".

Students were also asked to report which article they found more convincing and provide a rationale for their decision. As in the previous question, students cited personal relevance as an issue which affected their decision. Some students also referenced the quality of information that each article presented; these responses were reminiscent of the "better data and information" category from the last question. This pattern of responses suggested that for some students scientific merit and persuasiveness were synonymous. However, one category emerged that was not present in the merit question; many students declared the most convincing position was the one which complemented their own personal beliefs. The article which aligned most closely with preexisting opinions was deemed more convincing. Consider the quotations below which exemplify each of these categories.

<u>Persuasiveness</u>

A. Personal Relevance

- Since living in Florida and the thought of it being flooded more that 70% I would say that the first one is a bigger concern to me.
- An environmental crisis seems to speak more about the threats of UV rays and gas accumulations. It also states that global warming will increase the number of disease-carrying insects. The fact that malaria will increase by over 65% that's a little scary.

B. Information Quality

- The impending environmental crisis is more convincing because it uses years that are in this century which is probably more accurate. It also gives data that are the result of global warming such as glacial melting which is also true since the sea level did increase.
- I find "Global Warming Myth" to be the most convincing because they provide more information such as a graph which shows global temperature changes and other studies listed in the article.

C. Previous Personal Beliefs

- Global warming myth: evidence against environmental crisis. I think there is no such thing as global warming. People talk about global warming in the summer when it is hot, but in the winter when we are having record lows there is not talk of global warming.
- I think the article An Impending Environmental Crisis because it states every fact and I also think we need to do something about our environment.

Finally, as we examined interview transcripts, we noticed an interesting pattern of responses for the two questions concerning merit and persuasiveness. Whereas we expected most students to choose the same position in response to both questions, several students chose a different article for each question. While it is possible for a position statement to possess more scientific merit and yet be written less persuasively, the pattern interested us because of the structural and linguistic similarities shared by the articles. We looked for evidence of this pattern in the larger data set of written responses. Of the students who provided a single response to each question (students who did not answer one of the questions or selected both articles for one question were excluded from this calculation), 40% (30 of 75) chose a different article for each answer. This suggested that a large portion of the sample did not consider scientific merit to be a convincing factor in the consideration of socioscientific issues. These results are consistent with the findings of Zeidler, Walker, Ackett, and Simmons (in press) who conclude that students often compartmentalize scientific knowledge versus personal opinion.

NOS and Critical Thinking

At the study's outset, we planned to use student responses from the questionnaires and interviews to look for patterns of critical thinking. The goal was to then compare patterns of critical thinking with how students understood aspects of the nature of science. The questions we asked elicited valuable information about NOS understanding but they did not encourage students to offer responses that revealed patterns of critical thinking.

However, because the classification scheme that emerged from question one was hierarchical, we pursued a post hoc correlation analysis between the question 1 categories and scores from the Watson-Glaser Critical Thinking Appraisal. Responses to question one, which addressed data recognition and description, were classified in a series of ranked levels (from A to D). The levels were numerically transformed so that the most sophisticated conceptualizations of data were assigned the highest numbers (A=1, B=2, C=3, D=4). The mean from the WG was 43.55 with a standard deviation of 7.20. Scores on the WG approximated a normal distribution (kurtosis=0.42, skewness=0.33) with no outliers (as determined by a box plot). Because the scatter plot of data levels and WG scores did not reveal evidence to suggest a nonlinear relationship, we calculated the Pearson r correlation coefficient. The correlation produced a moderate coefficient ($r=0.405$, $p=0.0004$) that suggests a significant positive relationship between critical thinking and the understanding of data. Students with high WG scores were more likely to give Level D responses than those with low WG scores. This result suggested that critical thinking is a normative factor in understanding the empirical nature of science.

Implications for Science Education

NOS in the Science Classroom

This study reveals the range of views concerning the nature of science teachers must work with in the classroom. Although the investigation examines only three of many aspects of NOS, students exhibited diverse ideas. While the present sample may not be representative of all high school biology classes, it does provide insight into how some students conceptualize NOS and socioscientific issues. Some of the results are startling and highlight the need for instructional attention, whereas other findings suggest that students generally understand certain NOS concepts.

The fact that just under half of the students sampled were not able to accurately identify and describe data is alarming. Science teachers, including the one who taught the classes from this sample, frequently use the term "data" during the course of instruction; however, these results suggest that only some students understand its full meaning. Munby (1976) terms student-teacher language agreement "conceptual coherence"; this study provides an example of "conceptual incoherence". Lederman and Zeidler (1987) indicate that teacher knowledge about NOS does not necessarily result in student gains on NOS; the question of data descriptions exemplifies this claim. Despite the fact that a teacher understands the nature of data and its application and uses the term in class, students may still possess naïve ideas about what data is. Most students could at least differentiate the data presented in the articles from other types of information, but some equated predictions and opinions with data. Students with the latter convictions will find it difficult if not impossible to appreciate empiricism, a fundamental aspect of science. Given the central role of data in science and the potential misconceptions as described in this study, we suggest that teachers assess student understanding and implement instruction to aid the development of sophisticated conceptualizations. This type of direct instruction whereby teachers explicitly teach NOS concepts has been successfully applied and is advocated by other researchers (Abd-El-Khalick & Lederman, 2000; Bell, Lederman & Abd-El-Khalick, 2000).

The investigation of other aspects of NOS did not reveal results as alarming as the consideration of data. In general, students appreciated the social embeddedness of science.

Many were able to identify societal factors that influence the global warming debate such as economics, personal interests, social causes and effects. However, a minority of students held the position that science was isolated from social influences. Here again, direct instruction may be the most effective way of dealing with this misconception. Teachers could present other issues with obvious societal connections and explicitly discuss the interactions. Students displayed a general understanding of the tentative nature of science as well. Most students seemed very comfortable with the fact that researchers can produce vastly different conclusions given different ideological positions or types of data.

Because the nature of science continues to be an important goal for science education (AAAS, 1993; NRC, 1996), teachers need new and creative methods for addressing the various aspects of NOS. As this study demonstrates, the global warming issue can be effectively used for student investigations of science's empiricism, tentativeness, and cultural embeddedness. The abundance of socioscientific issues that currently face society provide ample opportunities for the development of learning experiences that address other aspects of NOS as well. The position advocated here has been supported by other studies and commentaries that focus on NOS and socioscientific issues (Bell, 1999; Kolstø, 2001a; Zeidler et al., in press).

Socioscientific Issues in the Science Classroom

Whereas research on the nature of science has flourished for several decades, socioscientific issues have not attracted a great deal of attention. Given the number of these issues in modern society as well as their cultural significance, they should assume a primary role in science education. It is difficult to read a newspaper or watch a newscast without encountering socioscientific issues. Media attention alone should not alter the trajectory of science curricula; however, regardless of the media's input, the children occupying today's classrooms will be asked to make decisions about socioscientific issues for the rest of their lives. We believe the recent influx of socioscientific issues such as stem cell research, cloning, and environmental concerns is a pattern that will continue throughout the next several decades. Technological advancements in all areas of science particularly genetics and medical sciences increase the probability for the advent of even more issues. Whether science teachers infuse socioscientific issues into their curricula or not, students will have to face them as they become participating members of society. Given this prediction, it seems not only appropriate but necessary for science education programs to prepare students for socioscientific decision-making. To deal with issues of this sort, students need to know how to recognize and interpret data; they must understand how multiple societal factors impact different positions; and they need to appreciate the fact that stakeholders often hold divergent opinions. The moral and ethical dimensions inherent in socioscientific problems should also be addressed in the science classroom.

This study produced results that enlighten the question of how individuals reason about socioscientific issues in three ways. First, many students reported that the most convincing position was the one which most closely aligned with their prior beliefs. Although it is not the goal of science educators to inspire students to disavow themselves of their personal views, an educator's goal should be to challenge students to consider alternative views and dissect the rationale of their own opinions. This kind of thoughtful reflection prepares students to develop their own views and decisions. In order to achieve this level of instructional result, teachers will have to do more than just present students with alternative interpretations of the same issue. Learners need extended opportunities to actively reflect on various aspects of an issue as well from the multiple perspectives that surround the issue. Research on misconceptions and conceptual change suggests that the position advocated in this report is time-consuming but can produce effective results (Chinn & Brewer, 1993; Zeidler, 1997).

A second finding that informs the issue of socioscientific reasoning is student reliance on personal relevance. In response to questions about both merit and persuasiveness, students cited personal relevance as an important factor. Many students were drawn to one position statement because it discussed consequences to which they could relate. Patterns of responses suggest that some students make evaluative decisions based on predicted personal relevance as opposed to contemplation of the evidence presented. This result is supported by Kolstø's (2001b) study of information evaluation by high school students considering a socioscientific issue. He reports that some of his subjects validate knowledge claims that identify risk factors regardless of the source or content. While it is not inappropriate for learners to be interested in personal consequences, rational decisions should be based on more than fear resulting from predicted outcomes. Here again, an instructional program that encourages students to adopt multiple perspectives would be beneficial.

The final result relative to socioscientific issue education is the tendency for students to dichotomize personal beliefs and scientific knowledge. Forty percent of the respondents claimed that the most scientifically meritorious article was less convincing. This result coupled with the issue of personal relevance just discussed suggests that socioscientific decision-making relies on many factors unrelated to science, an idea that harkens back to Kolstø's (2001a) *content-transcending-knowledge*. Again, we are not implying that teachers should try to change the decisions students make; however, teachers should encourage students to integrate scientific knowledge into their decision-making processes. Unfortunately, research in this area and practical suggestions for teachers trying to accomplish this are sparse. Science education needs the development of a research program to investigate the many factors that influence socioscientific decision-making and implications for education.

NOS and Critical Thinking Research

This study's investigation of the link between NOS conceptualizations and critical thinking is exploratory in nature. Although the findings are not well substantiated, they do imply a pattern worthy of further research. The moderate correlation between the relative sophistication of one's ideas about scientific data and critical thinking skills suggests a possible relationship between these two variables. While this research certainly cannot ascribe critical thinking as a requisite skill for sophisticated views on NOS, the relationship uncovered could inspire future studies that examine the issue with more precision. We think that qualitative analyses specifically designed to detect the link between NOS and critical thinking would be rewarding. The key to this research will be designing a research context that encourages students to display both NOS understanding and critical thinking skills.

NOS, Socioscientific Issues and Science Literacy

The suggestions provided in this section call for changes in science curricula that are consistent with the standards guiding science education reform (AAAS, 1990; AAAS, 1993; NRC, 1996). This curricular shift requires modifications not only in elementary and secondary classrooms but also in teacher preparation programs. Teachers need training in order to effectively integrate NOS and socioscientific issues in their classrooms. Programs to help deliver NOS instruction have been successfully developed and implemented (for an example see Clough & Olson, 2001), and we argue for the continuation of these efforts. However, the development of pedagogical techniques for socioscientific issues has not been as much a priority. Teacher training programs need to help preservice candidates transform the socioscientific issues they hear about in the news into instructional opportunities. The successful completion of this task requires an understanding of science content, the assumptions held by students, potential reasoning patterns of students (like those revealed in this study), and moral development trends (Kolstø, 2001a). This certainly is a demanding list of skills for teachers to master, but the inclusion of this list in teacher prep programs is not an unrealistic goal. If teachers have any chance of promoting science literacy among all their students, then they have to be trained in content knowledge, student ideas and reasoning, and moral development. Socioscientific issue instruction provides a vehicle for the articulation of all of these factors.

In this study, we investigate the relationship between three components of science education: the nature of science, critical thinking, and socioscientific issues. The findings complement results from other qualitative studies on student conceptualizations of NOS. The study also produces a novel result which deserves additional empirical attention: the understanding of some aspects of NOS seems to be moderately related to critical thinking ability. Finally, the relationship between NOS and socioscientific issues is explored. Findings indicate that socioscientific decision-making is influenced by a variety of factors related to NOS such as data interpretation and social interactions including individuals' own articulation of personal beliefs and scientific knowledge. Researchers need to continue addressing how traditional science education topics such as NOS and critical thinking interact with each other as well as socioscientific issues, and serious efforts need to be made in order to integrate these findings into teacher training programs.

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Science Briefs

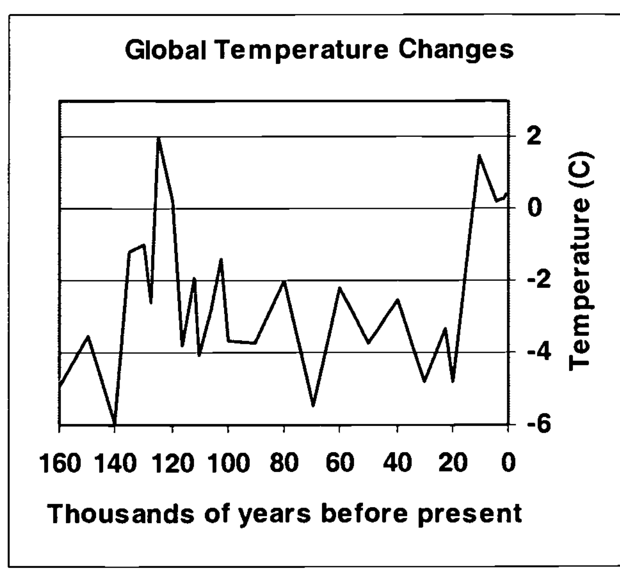
WASHINGTON - An international group of environmental scientists met in Washington, DC on February 7-11, 2001 to discuss the issue of global warming. During the course of debate, two divergent groups emerged. Several scientists noted mounting evidence that supports global warming as a serious problem; whereas, other scientists refuted their colleagues and presented evidence to suggest that the earth's temperature is not increasing as a result of human-induced activities. Each group issued a report summarizing their position; the statements follow below.

Global Warming Myth: Evidence Against Environmental Crisis

By studying the history of the earth, the scientific community has discovered the dynamic nature of climate and weather. Global weather patterns are in a constant state of change as evidenced by alternating ice ages and warmer periods. Temperature fluctuations are a natural part of the earth's climate (see figure 2). Recently, global warming has garnered a great deal of unnecessary attention. Ground-based monitoring indicates that worldwide temperatures have only increased by 0.6 C over the last decade which is consistent with the natural warming trend the earth is currently experiencing. Climatic data collected by satellites, which is the most accurate way of obtaining this information, reveal no long term temperature increases caused by human activity.

The so-called greenhouse gases include carbon dioxide, water vapor, and methane are all naturally occurring parts of the atmosphere. In fact, 95% of all greenhouse gases is water vapor. Therefore, alarmist concerns about rising carbon dioxide levels are unfounded. Long-term prediction is another problem with the global warming hypothesis. Global warming proponents claim that computer models predict sea level rise, but alternate predictions also exist. If temperatures actually increase, evaporation over oceans and lakes will also increase resulting in more clouds. Additional cloud coverage will shield the earth from solar radiation which counteracts rising temperatures.

The myth of global warming has been propagated by scientists focused on sounding alarms without data to substantiate their positions. Unfortunately, proposed "solutions" to global warming will have devastating effects on the global economy. A meeting of international government officials and environmentalists met in Kyoto, Japan and suggested that developed countries like the United States reduce greenhouse gas emissions to 10% below 1990 levels. These drastic reductions will stifle industry and negatively impact the national economy. The proposed changes will cost the US over $200 million annually. In the best interest of us all, we must acknowledge natural, long term patterns of climate change and resist the inaccurate proposals of special interest groups.



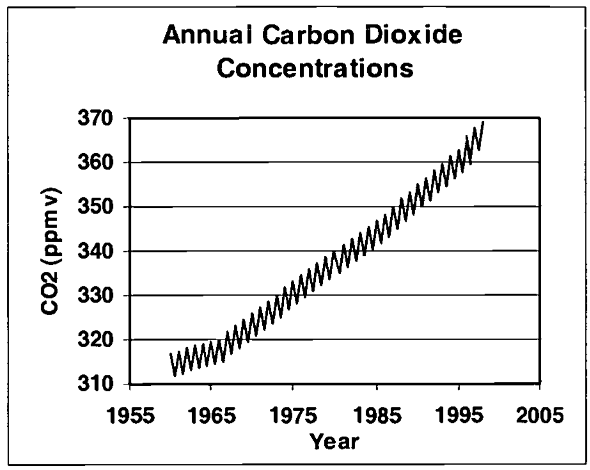
Source: NOAA, 1999.

Global Warming: An Impending Environmental Crisis

Carbon dioxide and other greenhouse gases (methane, chlorofluorocarbons, and ozone) released from the earth's surface trap solar energy that would otherwise be reflected away from the earth. The effect of these "heat trapping" molecules is to raise the earth's surface temperature. British researchers have recently recorded increases in atmospheric heat as a direct result of greenhouse gas accumulation. Some of these gases occur naturally and help shape the earth's natural climate. However, human activities, most notably the burning of fossil fuels like oil, gas and coal, have significantly increased the concentration of atmospheric carbon dioxide since the middle of the 20th century (see figure). Climate and weather data already show worldwide temperature increases on the order of 0.6 C over the last decade. More revealing measurements of climatic change like snow cover, glacial recession and loss of arctic ice reveal an even more drastic picture.

Given the current pattern of greenhouse gas accumulation, computer models predict a widespread environmental catastrophe. Even minor global temperature increases will trigger glacial and ice cap melting, which will lead to rises in sea level. Rising oceans will submerge millions of acres of coastal areas around the world. For example, as much as 70% of the Florida peninsula could become flooded. Global warming will surely cause a variety of other problems such as increases in the number of disease-carrying insects. It is predicted that cases of malaria, which is carried by mosquitoes, will increase by over 50% worldwide. Changes to local ecologies will lead to extinction of an untold number of plant and animal species.

Attacks on the science of global warming have been levied by researchers funded by the oil and automobile industries. These businesses benefit from the release of greenhouse gases and are quick to deny evidence without evaluating its scientific merit. They propagate public confusion around the issue to preserve their own economic interests. Taking responsible steps to reduce greenhouse emissions will cost industries as well as individual consumers, but the cost of environmental degradation that will ensue without changes will far outpace any industrial or private losses.



Source: NOAA, 1999.

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