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ABSTRACT

This study assessed the level of scientific and natural resource knowledge that 4th, 8th, and 11th grade students in Maine possessed concerning acidic deposition. A representative sample of public school students (n=175) was interviewed on 12 concept principles considered critical to a full understanding of the acidic deposition problem. These included geological, meteorological, ecological, political, and economic concepts. Student knowledge was rated for each concept principle on a scale of complete, high partial, low partial, or no understanding. Common misconceptions were also noted. Generalized correct concept statements of current student knowledge was reported as well as generalized missing concepts. The results suggest some implications for teaching about acidic deposition and the design of environmental education curriculum materials based upon student knowledge. Ways that can help teachers better teach students about current environmental problems and thus help learners gain an appreciation for the complex and multidisciplinary nature of science and the environment are discussed. (Author/TW)

An Assessment of Student Knowledge in Fourth, Eighth and Eleventh Grades of Science and Natural Resource Concepts Related to Acidic Deposition

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ABSTRACT

This study assessed the level of scientific and natural resource knowledge that 4th, 8th, and 11th grade students in Maine possess concerning acidic deposition. A representative sample of public school students (n= 175) was interviewed on twelve (12) concept principles considered critical to a full understanding of the acidic deposition problem. These included geological, meteorological, ecological, political, and economic concepts. Sudent knowledge was rated for each concept principle on a scale of: complete, high partial, low partial, or no understanding. Common misconceptions were also noted. Generalized correct concept statements of current student knowledge as reported as well as generalized missing concepts. Our conclusions have implications for teaching about acidic deposition and the design of environmental education curriculum materials based upon student knowledge. This information can help teachers better teach students about current, environmental problems and thus help learners gain an appreciation for the complex and multidisciplinary nature of science and the environment.

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INTRODUCTION

Science and Environmental Education can be taught as an integral unit to help students learn about environmental problems, appreciate the complexity of these issues and help overcome the popular belief that science is only for scientists. The incorporation of environmental issues into the present science curriculum can increase the relevance of science topics. It is our hope that this research will lead to better teaching and the design of meaningful curricula addressing the problem of acid deposition. The information can be incorporated into existing courses in earth science, biology, chemistry, social studies, and/or current events.

RATIONALE

Learning is the comprehension and acceptance of concepts which are intelligible and rational to the learner. Learning is not simply the acquisition of a set of correct responses anymore than science is simply a collection of laws and principles. Meaningful learning can be considered a process of conceptual change which occurs in two distinct phases, assimilation and accommodation[1] . Assimilation occurs when the learner uses existing concepts to deal with new phenomena. Accommodation occurs when the learner has existing concepts which are inadequate to allow comprehension of a new phenomena, and must reorganize existing conceptual frameworks. Therefore, a critical condition for meaningful learning is for the teacher to determine what the learner already knows. Of the many variables that influence learning in science, the learner's relevant background knowledge and his or her existing internal conceptual framework are two of the most important[2,3,4]. Once this information is obtained, then teaching strategies may be based on what the learner knows in order to add new knowledge to the conceptual framework; existing concepts must be integrated with the new information and incorporated into the framework.

In this study, the modified clinical interview approach is used to determine the relevant concepts already established in the cognitive structures of the students sampled[5,6,7]. This process is crucial in discovering existing conceptions, missing concepts and misconceptions which are essential to the meaningful learning process, especially in the area of science and the

environment[8]. This approach guarantees the availability of relevant anchoring ideas in student cognitive structure, and helps provide a vehicle for the student to understand the relevance of existing concepts which are a necessary condition for meaningful learning[9].
The rationale for this study includes the importance of having appropriately established concepts already available within the cognitive framework of a learner. This helps make potentially logical new concepts meaningful, providing stable anchorage for new concepts. The more inclusive concepts of a discipline are the anchoring concepts or subsumers, helping learners identify already existing relevant content in their cognitive structure, indicating both the relevance of the existing structure and the material to be learned. The principle function of the study is to bridge the gap between what the learner already knows and what he needs to know to be successful at meaningful learning.

One specific application of this study is in the area of misconceptions. Misconceptions show remarkable consistency across diverse learners, and are resistant to change by traditional instructional methods. Traditional curriculum does not typically facilitate an appropriate reconciliation of pre-instructional knowledge with the content of instruction[10,11]. This study is designed to help overcome the severe limitations imposed when teachers and curriculum do not take the students preexisting knowledge structure into consideration before the presentation of new concepts.

RATIONAL FOR SPECIFIC TOPIC OF ACIDIC DEPOSITION

Acidic deposition, commonly referred to as acid rain, is a major chronic problem that is slowly changing the environment. Maine and the entire Northeastern US and Canada are especially affected by acidic deposition[12,13,14].

Acid precipitation has been recognized as a hazard for many years. The European Atmospheric Network , established in the 1950's, first produced data on the acidification of Europe's precipitation. This documentation lead to the initiation of research by the late 1950's. Wide-scale monitoring and research did not commence in the United States and Canada until the mid 1970's. Canada formed the Canada Network for sampling precipitation in 1976, and in 1978 the United States established a similar approach by creating the National Atmospheric Deposition Program[15].

This environmental phenomena, resulting from the combustion of fossil fuels, has become a local, regional, and international problem. The consequences of acidic precipitation are still the subject of considerable research efforts, but some conclusions are starting to be drawn. Besides directly decreasing the pH of lakes and streams, the acid rain causes leaching of aluminum in soils. The aluminum clogs the gills of fish, leading to suffocation. It disrupts food webs, altering reproduction, growth, and indirectly causing death; causing the most severe alterations in aquatic ecosystems[16].

Highly complex industrialized societies produce energy from the combustion of fossil fuels; this process results in several forms of pollution, including acid rain. The resolution of this problem lies not only in scientific research and technology, but also in economics and politics. The multidisciplinary aspect of acidic precipitation mandates knowledge in several areas for any viable solution. It is also a local, real-life event for most students. As part of a curriculum the acid rain concept encompasses several inclusive concepts such as utilization of natural resources, resource use and management, pollution, technology, economics, and local, regional, and global politics. Consideration of this problem will help to educate students about the inter-relationship of knowledge and society and the necessity of becoming knowledgeable about environmental issues.

METHODOLOGY

The topic of acidic precipitation and specifically, student conceptions about acidic precipitation, was selected as a relevant environmental issue in the state of Maine. Primary sources and popular periodicals were researched to compile the content pertinent to the topic of study. The content was analyzed and separated into five subsuming concept areas pertaining to the topic of acidic precipitation; geologic processes, meteorological processes, ecosystems, economic concerns, and political systems. Concept maps were constructed for the five major concept areas[17]. The concept maps took their final form after a concensus of the entire team was reached. From the five finalized concept maps twelve content principles concerning acidic precipitation were compiled as a guideline for the interviews and for the analyses of the interviews.

insert table 1.

INTERVIEWS

The five concept maps and twelve content principles were used as interview guides. The twelve content principles were then subdivided into 56 specific concepts to rate student knowledge. These 56 concepts are the least inclusive ideas relating to acidic precipitation. In order to maintain consistency, each interviewer worked within one particular grade level. The interviewers for each grade worked as a group to plan and discuss their interviews. Charts, pictures, and materials to be used as props where appropriate were decided upon. The modified clinical interview was discussed and a videotape of a representative interview was analyzed. For further training, the interviewers watched and critiqued audio tapes of similar interviews, and used their first interviews as practice sessions.

One hundred and seventy five students from eighteen schools in Maine were interviewed: fifty three 4th graders, fifty three 8th graders, and sixty nine 11th graders. Schools were selected based upon interviewer proximity and convenience. Where possible, interviewers were assigned to interview a grade level close to the level that they had teaching experience with. Interviewers were University of Maine College of Education graduate students. Rural and urban areas were both well represented. In each school, students interviewed were selected from a particular class based on the willingness of the teacher and the students to participate. The students were not preselected for their level of achievement in science, and were believed to be representative of a fairly heterogeneous population. Approximately half of the sample were females and half were males.

The twelve content principles and associated concept maps from which they were derived helped the interviewers to develop several groups of lead-in questions to guide the interview format. Student response to the lead-in questions guided the interviewer to more specific probing questions to determine the presence or absence of concepts and misconceptions as well as the students' overall level of understanding of the major content principles. Interview props were used to maintain interest and focus attention; each interview was audio-taped and lasted approximately 20 minutes.

Each interview began with a few broad questions to determine the students' general understanding of acidic precipitation. These were followed by more specific quesions from the geologic processes concept map in figure 1. This first map summarized the first three major content principles and their conceptual relationship, including; rock and soil formation;

weathering, buffering and leaching; and fossil fuels and combustion. Props included rock samples (granite, limestone, and coal), photographs and drawings.

insert figure 1.

The second concept map, concerned with meteorological processes, is shown in figure 2 and summarized content principles 4 and 5. Concepts include transportation of pollutants, solar energy, and wind and weather patterns. Interview props included a weather map.

insert figure 2.

The next set of questions dealt with ecosystems and was derived from the content map shown in figure 3. Content principles 6, 7 and 8 are represented in this map which included concepts related to ecosystems and their components, food webs and the effect of altering ecosystems. Pictures of various types of ecological systems were shown to the students.

insert figure 3.

Principles 9 and 10 were derived from the map that describes relationships between economic concepts as they pertain to acidic precipitation. The map is shown in figure 4 . Pictures of industrial activity and natural settings were used to illustrate the concepts of utilization and consumption of natural resources, and the production of goods for profit.

insert figure 4.

The last group of questions dealt with the political issues surrounding acidic precipitation as outlined in principles 11 and 12. The content map is shown in figure 5 . Concepts are related to conflicts and their possible solutions at local, regional, and global levels. Maps and pictures were used to focus the students from local to regional to global .

insert figure 5.

RATING SCALE

After completion of the interviews, each interviewer scored each of their taped interviews. For standardization of the scoring, the principle investigator provided a form which listed all 56 specific concepts organized under each of the 12 major content principles. The following rating system was used to rate student knowledge for each of the 56 concepts:

0 - **Concept not asked** by the interviewer or not covered well enough to be rated.
1 - **No understanding of the concept.** Student either had no knowledge or had only misconceptions of the concept.
2 - **Low partial conception.** Student recognized or understood part of the concept.
3 - **High partial conception.** Student recognized and understood most of the concept.
4 - **Complete understanding.** Student recognized and understood the entire meaing of the concept.

Misconceptions were also identified and tabulated as they occurred. Each interview tape was analyzed and rated with the above scale.

INTER-RATER RELIABILITY

In this study, there were 18 cooperating researchers, each of whom conducted interviews with approximately 12 students from one of three grade levels in 15 different public schools in Maine. Each researcher then evaluated each of his or her own interviews to rate the student's knowledge relating to acidic precipitation. One obvious concern in a study of this magnitude and complexity, as with all qualitative research, is that of inter-rater reliability, or the degree of consistency with which the researchers rated the knowledge of the students. To partially alleviate this concern, each researcher interviewed students from one same grade level, and all researchers used the same set of concept maps to evaluate their interviews. As a final check of inter-rater reliability, each rater evaluated a single set of three interviews; one from each grade selected as being representative of that level of knowledge. The inter-rater reliability was then computed as a function of all researchers rating a single interview from each grade level and as a function of reseachers rating a single interview from the grade level which they had interviewed. Intra-rater reliability, or the relative stability of an individual researcher in rating a series of

interviews, was not considered to be a problem based on a random sampling of interviewers who had checked their reliability by re-evaluating their interviews to determine their rating consistency.

Inter-rater reliability was calculated for each of the 56 concepts and for the 12 content principles, for each grade level. To calculate the reliability level for each concept, a stroke tally of ratings for all interviewers for each interview was compiled. The highest agreement in a given concept was divided by 18, the total number of interviewers, to get a percentage. This was used as the inter-rater reliability. Based on all interviewers scoring the same three interviews; one from 4th grade, 8th, and 11th grade. Reliability was rated as the percentage of agreement on each item. The scores were; 4th =59.3%, 8th=55%, and 11th= 54.7%.

ANALYSIS

Very few interviews covered all 56 concepts, but when analyzed collectively they provided an adequate sample for the entire set of 56 concepts. More importantly, the statistical comparisons between grades were compared on the content principle level, not by comparing individual concept knowledge. Although the knowledge of the individual 56 concepts is desirable, it is the students' understanding of the interrelationships among these concepts that is important. When analyzed at the content principle level, the conceptual framework of or understanding of the student is better able to be studied. Concepts are the building blocks of content principles and these principles represent a more valid measure of the students' understanding.

Means and frequencies were calculated for each content principle. A one-way analysis of variance (Alpha = 0.05) was conducted for each principle by grade level and an F-ratio was calculated to determine if the differences were statistically significant. If a significant F-ratio was found a Tukey HSD Post-Hoc Test was performed to determine between which grades the differences were found.

insert table 2.

Statistically significant differences were found on all of the principles except for principle 10, but only in the comparisons of principles 3, 4, 8 and 11 were these differences found between all three grade levels. On all of the other principles (1, 2, 5, 6, 7, 9, & 12) the differences were only significant between fourth and eleventh grade, and between eight and eleventh grade, but

not between fourth and eighth grades. See Table 2. and Figure 6. It is apparent that students understand only a small fraction of what we consider necessary for a full understanding of the acid deposition phenomena.

insert figure 6.

RESULTS

Interviewers for each grade level came up with a statement of student knowledge at their grade level for each content principle. These statements were then collected and analyzed by the entire research group. This led us to generalized knowledge statements related to the content principles used in the analysis of the interviews.

insert table 3.

insert table 4.

A third significant result of this study is that the knowledge difference between grade levels was most noticeable between the fourth and eleventh grades and the eighth and eleventh grades, but not between the fourth and eighth grades (see figure 6.). This compares favorably with similar conclusions based on standardized assessments of educational progress in Maine which showed no increase in knowledge on several concepts from the fourth through the eleventh grade[18] .

CONCLUSION

A viable environmental curriculum should include a set of organized experiences, which will aid students in developing knowledge and awareness concerning the environment -- in this case acidic precipitation. If the curriculum takes into consideration the existing knowledge of students based upon the 4th, 8th and 11th grade generalized statements which encompass the 12 content principles and directly addresses student misconceptions, the acidic precipitation curriculum can be a meaningful learning experience for the student.

This study can lead to the production of a multidisciplinary curriculum built upon current knowledge that addresses student misconceptions, resulting in an acidic precipitation curriculum,

involving students in analysis and synthesis leading to reconceptualization and contributing to the logical thinking process. Acidic precipitation also involves students with real-life issues and reinforces that notion that scientific facts must be accumulated and analyzed in order to make valid value judgements; that science is everyday life and not the rote memorization of meaningless facts from a textbook. It stresses the inter-relationship of all life and the factors which affect life on the planet earth, and that to preserve this very complex and fragile system we need a general populace knowledgeable in the area of science and natural resources.

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This kind of descriptive research which provides us with such rich data could only be accomplished in the context of a programmatic research effort and with the help of many people. I would like to thank all those teachers, principals and school systems which allowed us to interview their students. In particular, I would like to thank those graduate students who contributed to this effort. These people include. Peggy Brosnan, Dick Derrah, Bob Gaboury, Simon Hassis, Elaine Jones, Greg Marco, Lori Matthews, George Mayo, Stephen McCoy, Rob Mosely, Vicki Nichols, Atheline Nixon, Lorraine Nolet, Donna Read, George Scott, and Mark Turski.

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TABLE 1. CONTENT PRINCIPLES USED IN THE ANALYSIS OF THE INTERVIEWS

1.Geologic processes include sedimentary and igneous processes which produce, among other things, sedimentary rocks such as limestone, fossil fuel beds as coal and petroleum, volcanoes, and intrusive igneous rocks such as granite.

2.Acidic precipitation affects the way various rock types are weathered. Soil produced from sedimentary rocks tend to act as buffers against the effects of acidic precipitation; soils produced from igneous rocks have little buffering capacity, allowing acidic waters to leach essential plant nutrients from the soil and also to liberate metals and other toxins from the soils.

3.The products of combustion of fossil fuels, and to some extent volcanism, contribute sulphuric and nitric oxides and dust to the atmosphere. These elements contribute to the production of acidic precipitation.

4.Chemical pollutants and water combine in the atmosphere as a result of reaction triggered by the sun.

5.Weather patterns and wind currents result from differences in heat in the atmosphere and the earth's rotation and result in the transportation of chemical pollutants.

6.Ecology is the study of aquatic and terrestrial ecosystems including living and nonliving components.

7.Living components include producers, consumers, and decomposers combining to create a food web.

8.The system can be altered by increased acidity affecting growth, reproduction and respiration, and may indirectly cause death.

9.Industry based on consumption of natural resources for the production of materials for profit can lead to acid deposition.

10.Acid deposition affects natural resource utilization in recreation and agriculture.

11.Acid deposition occurs within a political system based on local, regional, and global concerns.

12.Conflicts may arise over acid deposition possibly leading to confrontation, negotiation and/or arbitration resulting in treaties, regulation, and/or legislation to solve conflicts.

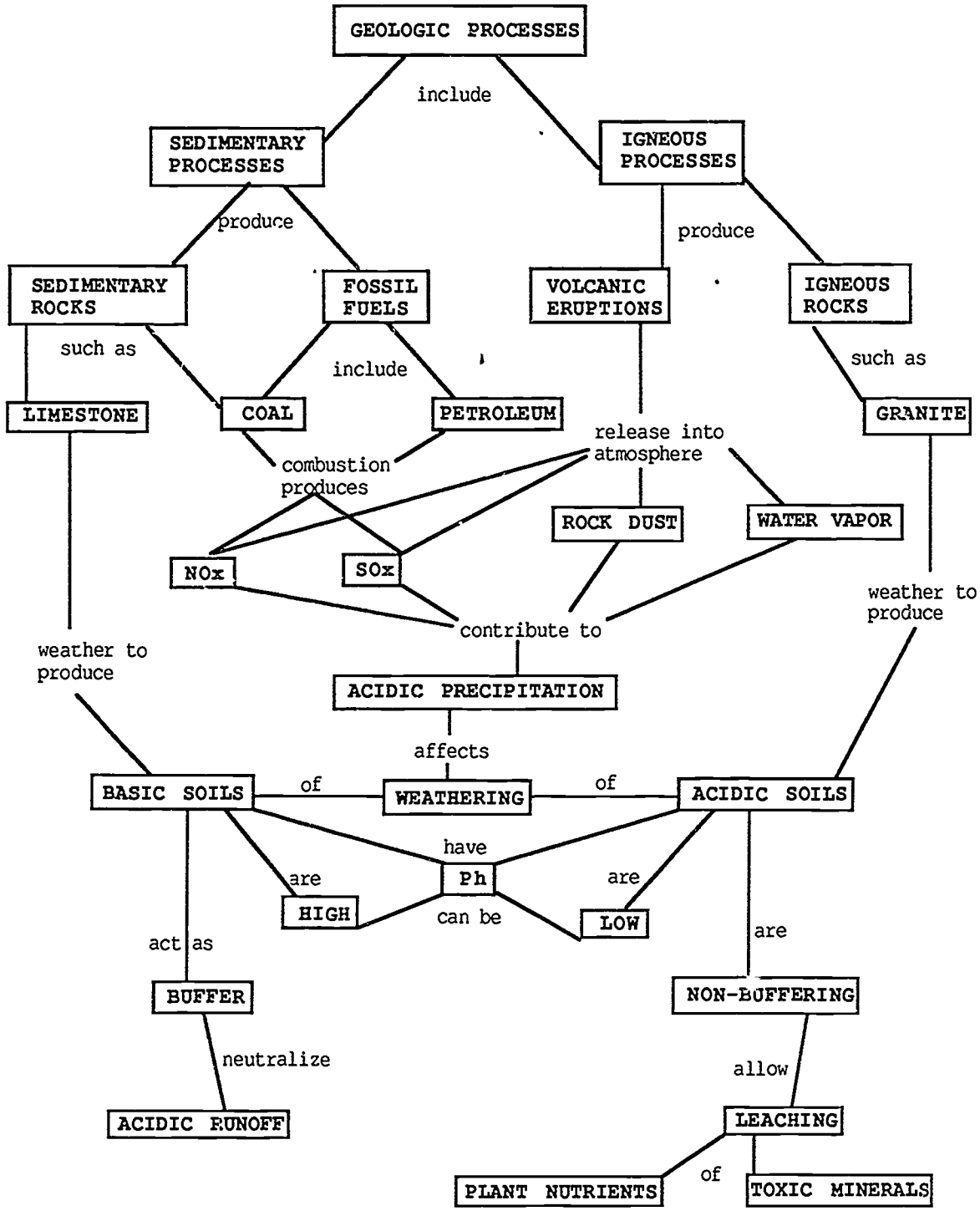

Figure 1. This concept map summarizes content principles 1,2 and 3. The major ideas include those related to geology and geologic processes

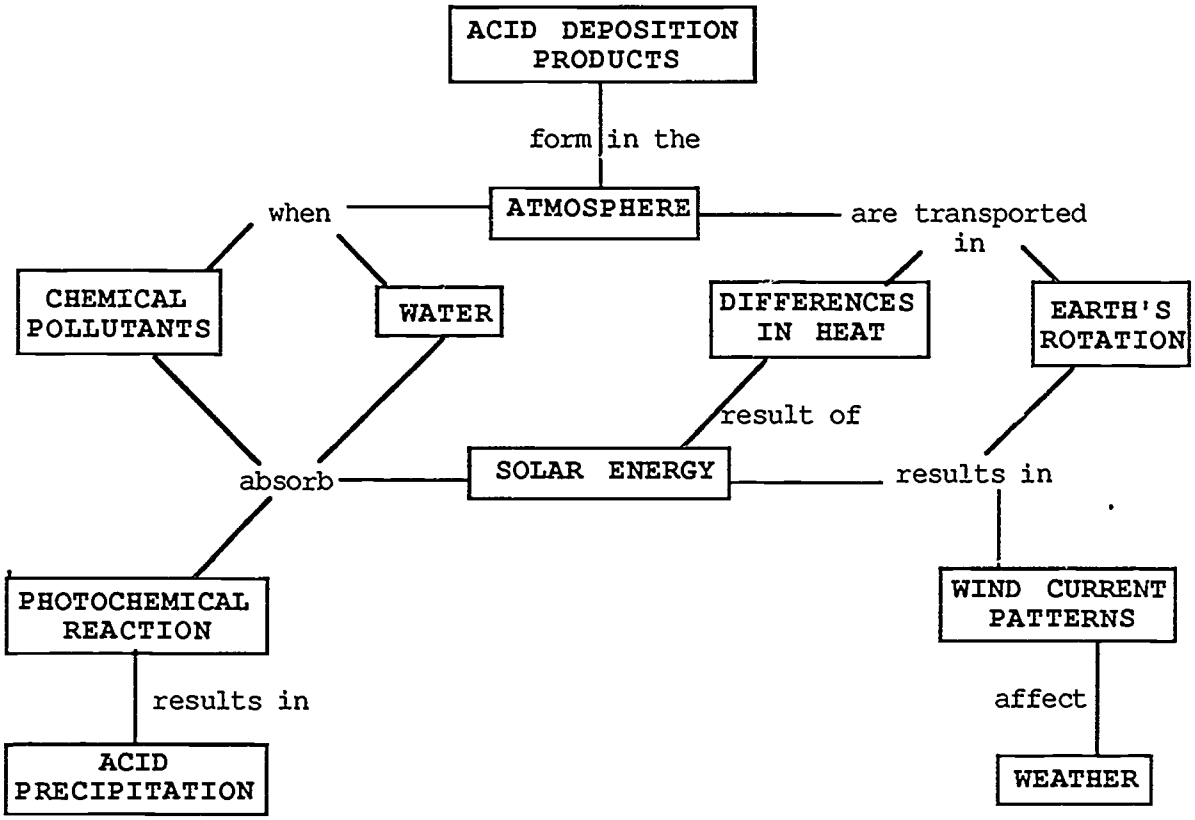

Figure 2. This figure is a concept map of content principles 4 and 5. These include the major ideas related to the atmosphere and atmospheric processes.

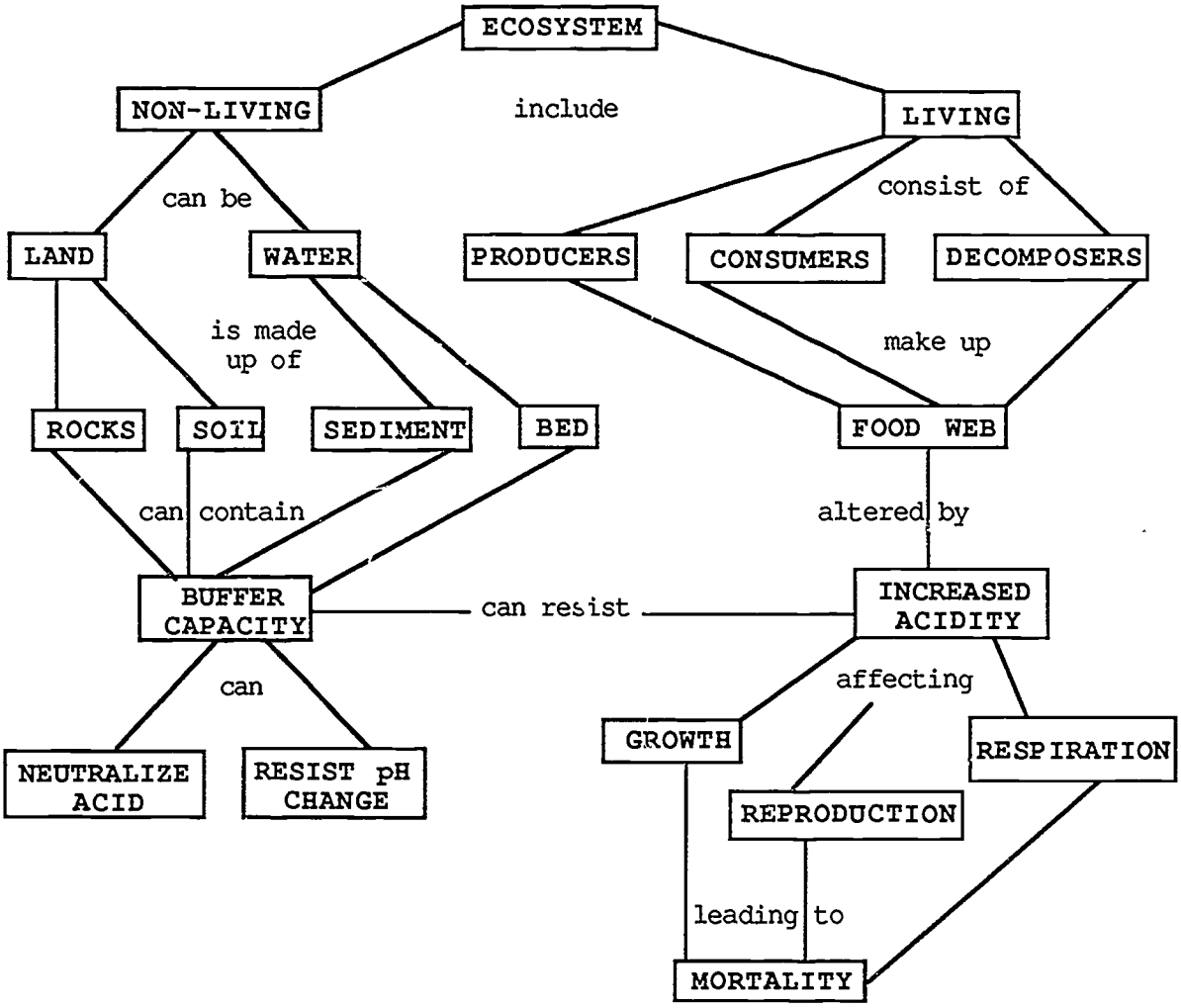

Figure 3. This figure is a concept map of content principles 6, 7 and 8 which summarize the ecological concepts related to acidic deposition.

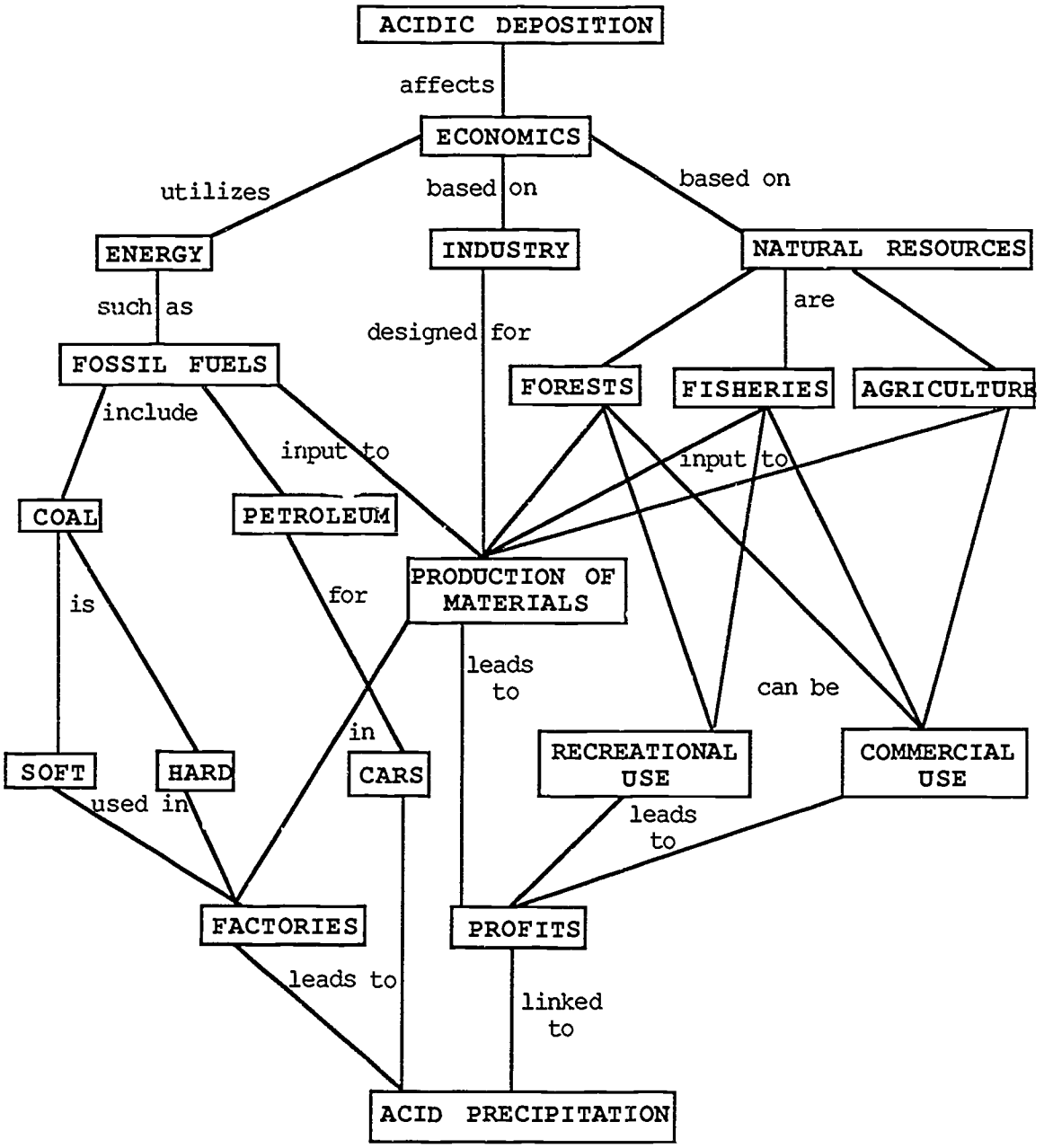

Figure 4. This concept map summarizes those concepts related to economics found in content principles 9 and 10.

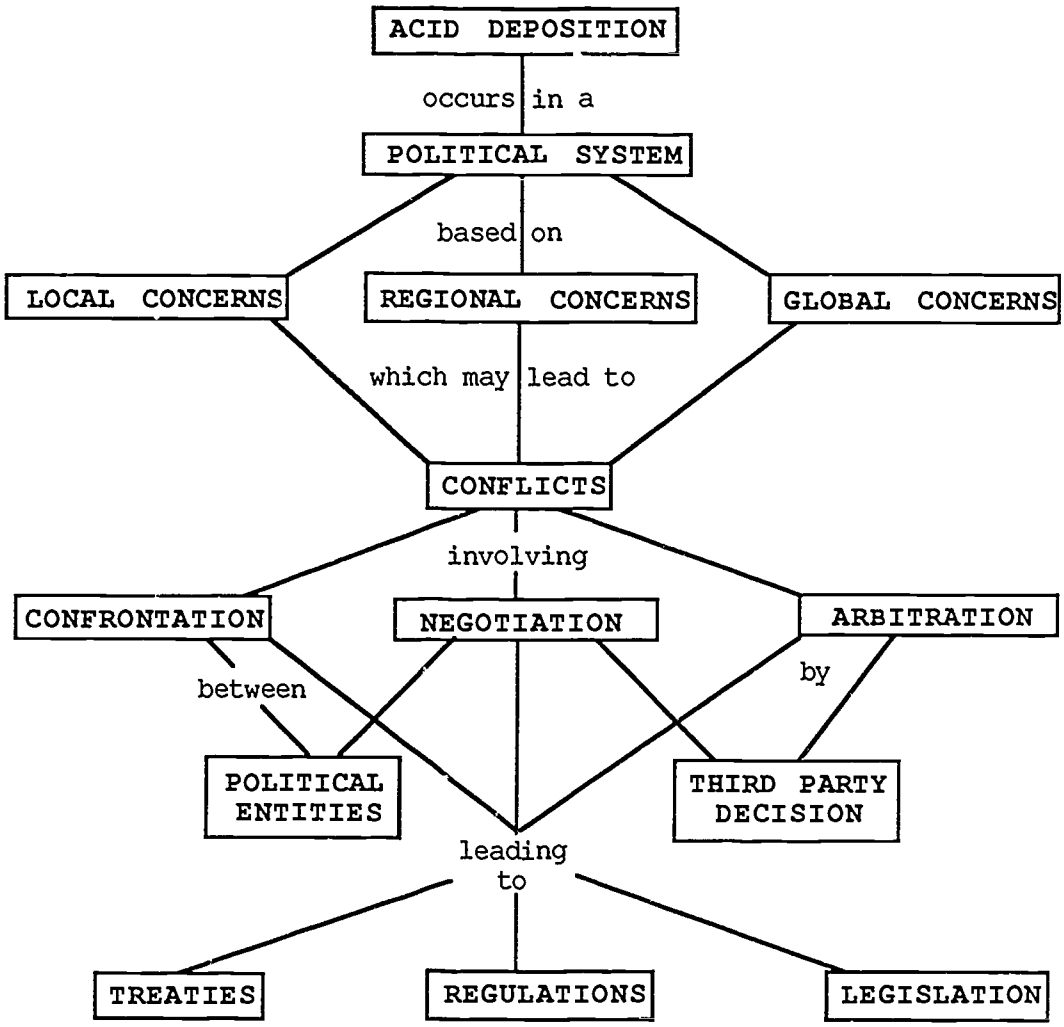

Figure 5. This concept map summarizes concepts found in content principles 11 and 12 related to political aspects of acidic deposition.

Table 2. Mean scores and standard deviations for content principles 1-12 by grade level and ANOVA summary. ANOVAs were performed to compare the mean principle scores among all three grade levels. Alpha =0.05, Tukey HSD post-hoc test. *=Significant differences, NSD = no significant difference.

Content Principle	Mean Score (± S.D.) by grade. 4th	8th	11th	ANOVA Summary: Grade level comparisons 4th&8th	4th&11th	8th&11th
1	1.66(.48)	1.61(.62)	1.88(.70)	NSD	NSD	NSD
2	1.50(.46)	1.63(.47)	1.76(.49)	NSD	*	NSD
3	1.36(.31)	1.66(.52)	1.85(.65)	*	*	NSD
4	1.66(.39)	1.87(.50)	2.43(.65)	NSD	*	*
5	1.64(.41)	1.80(.57)	2.42(.80)	NSD	*	*
6	1.84(.57)	1.93(.63)	2.89(.69)	NSD	*	*
7	1.94(.56)	1.87(.60)	2.75(.76)	NSD	*	*
8	1.51(.35)	2.10(.54)	2.29(.73)	*	*	NSD
9	2.10(.69)	2.12(.61)	2.88(.82)	NSD	*	*
10	1.78(.56)	1.86(.69)	2.15(.69)	NSD	*	NSD
11	1.45(.46)	1.80(.53)	2.15(.69)	*	*	*
12	1.45(.46)	1.80(.53)	2.61(.82)	*	*	*

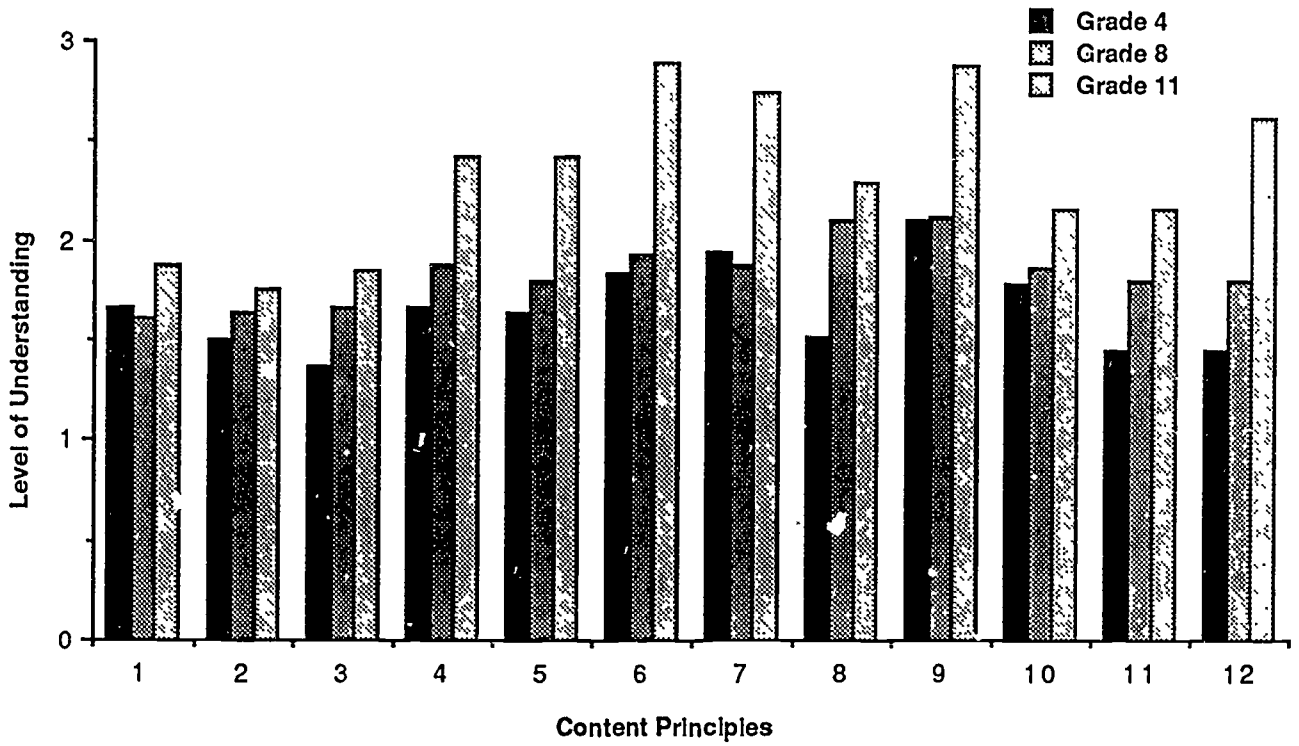

Figure 6. Mean interview scores of fourth, eighth and eleventh grade students on science and natural resource concepts related to acidic deposition

Table 3 .

Generalized student correct conceptions for content principles related to Acidic Deposition

CONTENT PRINCIPLE	CORRECT CONCEPT
1.	Different types of rocks can be recognized. Fossil fuels include coal and petroleum.
2.	Acidic precipitation affects how rocks are weathered. Water can carry materials out of the soil.
3.	Burning fossil fuels contributes to atmospheric pollution, which contributes to the production of acidic precipitation.
4.	Chemical pollutants and water are in the atmosphere.
5.	Weather and wind patterns, moving west to east, carrries pollutants.
6.	Ecology is the study of aquatic and terrestrial ecosystems, including living and non-living things.
7.	Food webs are composed of series of interrelationships.
8.	Systems can gradually be altered by increased acidity caused by acid rain.
9.	Factories produce things for profit, which can lead to acidic precipitation.
10.	Acid rain has a negative effect on certain recreational and agricultural activities.
11.	Within local political systems there are concerns related to acid deposition.
12.	Acid deposition can lead to conflicts with a variety of mechanisms for resolution.

TABLE 8.
Missing concepts for each content principle related to
Acidic Deposition

Principle	Content Missing Concepts
1.	Sedimentary and igneous processes produce, sedimentary rocks such as limestone and intrusive igneous rocks such as granite.
2.	Soil produced from sedimentary rocks tend to act as buffers against the effects of acidic precipitation; soils produced from igneous rocks have little buffering capacity, allowing acidic waters to leach essential plant nutrients from the soil and also to liberate metals and other toxins from the soils.
3.	Sulphuric and nitric oxides contribute to the production of acidic precipitation.
4.	Chemical pollutants and water combine in the atmosphere as a result of reaction triggered by the sun.
5.	Weather patterns and wind currents result from differences in heat in the atmosphere and the earth's rotation.
7.	Living components include producers, consumers, and decomposers.
8.	Altered systems affect growth, reproduction and respiration, and may indirectly cause death.
9.	Industry is based on consumption of natural resources.
10.	Acid deposition affects natural resource utilization.
11.	Political systems are based on local, regional, and global concerns.
12.	Conflicts lead to confrontation, negotiation and/or arbitration resulting in treaties, regulation, and/or legislation.