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ABSTRACT

In an effort to contribute information for science teachers and curriculum developers in Maine, this study generated base line data on 4th, 8th, and 11th grade students' knowledge of marine science and natural resources principles in relation to the Gulf of Maine. Five concept maps representing 15 major content principles were developed. Two hundred twenty-six students from 12 schools in Maine were interviewed on marine science, natural resources and decision-making concepts and principles. Student knowledge was then classified according to correct concepts, missing concepts and misconceptions. Similarities and differences between the three grade levels were analyzed and compared to results of the Maine Assessment of Educational Progress in Science. The results indicated that the students in the sample did learn a few basic marine and natural resource concepts in the elementary grades, but that there was little further assimilation of new concepts or differentiation of existing concepts as students progressed through the grades. The results are discussed with regard to possible implications for future marine science curricula. (TW)

An Assessment of 4th, 8th and 11th Grade Students' Knowledge Related to Marine Science and Natural Resource Issues

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Abstract

This study generated base line data on Maine's 4th, 8th and 11th grade students' knowledge of marine science and natural resource principles in relation to the Gulf of Maine. A representative sample of public school students (n=226) was interviewed on marine science, natural resource and decision-making concepts and principles. Student knowledge was classified according to correct concepts, missing concepts and misconceptions. Similarities and differences between grade levels were analyzed and compared to results of the Maine Assessment of Educational Progress in Science (1984). The results of this research have implications for the development of more comprehensive and effective curricula for educating students and teachers about marine science and resources.

Background

Science and environmental education are an important part of the school curriculum. Decreasing resources, increased utilization, pollution and advanced technology demand a society that is knowledgeable about basic science concepts related to resource use and management. The Gulf of Maine is a uniquely productive and valuable resource which is shared by the U.S. and Canada, and which has significant impact on Maine's social and economic fabric. The recent World Court proceedings concerning the United States and Canada maritime boundary in the Gulf of Maine brought together fundamental information on numerous marine science and natural resource issues from such fields as geology, physical and chemical oceanography, ecology, resource utilization and management, and decision-making. In the interests of creating a Maine public educated in basic marine science concepts and aware of related resource and environmental issues, we used the World Court information and other relevant research related to the Gulf of Maine as a framework for establishing the extent of student knowledge of students' knowledge about marine "systems" and resources.

Rationale

The problems facing science educators in Maine are numerous. There are no statewide curricula, and teachers must select/design their own educational materials and teach students who will subsequently take recently mandated state-wide, standardized, science competency tests in 4th, 8th and 11th grades. In addition, teachers are faced with the task of making subject content and lessons meaningful and relevant. One step towards solving these problems is to design science curricula based on real events, up-to-date scientific information and students' existing relevant knowledge. Today's environmental problems and issues are front page material and have the potential of making science real and adding meaning to teaching and learning. If we fail to design meaningful educative materials, students may acquire new information by rote, and arbitrarily incorporate this information into their knowledge structures (Ausubel, Novak and Hanesian, 1978). Such information tends to be soon forgotten. Identifying major organizing science concepts and principles and assessing students' pre-instructional knowledge of these concepts and principles is a prerequisite for sound curriculum development (Champagne & Klopfer, 1984).

Our research indirectly addresses basic issues in marine science curriculum design by asking the following questions: (1) What marine science and resource concepts do 4th, 8th and 11th grade Maine students possess concerning the Gulf of Maine as a marine ecosystem and shared resource? (2) Does the students' comprehension of these concepts change between 4th and 11th grade?, and (3) How do the results of our research compare with those of the recent Maine Assessment of Educational Progress in Science (MAEPS, 1984).

Methods

The topic was selected by the principal investigator following a statewide news media survey of current events related to marine science and environmental education. Primary research and secondary sources related to marine science and resource issues concerning the Gulf of Maine were identified. Twelve students in science education at the University of Maine analyzed these scientific reports, including detailed legal briefs prepared by Canada and the U.S. for presentation before the World Court at the Hague, Netherlands (1984). Summary papers and concept maps (Novak and Gowin, 1984) were constructed from the contents of these reports. The maps were analyzed, discussed and refined. This subsequently yielded 5 maps representing 15 major content principles which the research group considered to be essential for an understanding of the marine science and natural resource issues identified (Table 1).

Two hundred twenty-six students (226) from twelve (12) schools in Maine were interviewed; seventy-four (74) 4th graders, sixty-nine (69) 8th graders and eighty-three (83) 11th graders. In each school, an entire class was interviewed. The students were not preselected for level of achievement in science. Coastal and inland areas were both well represented. Interviewers were the same students who previously analyzed the primary research documents. Each student on the research team was assigned to one school system. Interview techniques were standardized during practice sessions using audio tapes and video tape viewing.

The previously constructed concept maps, each with several general lead-in focus questions, guided the interview format. Lead-in questions were followed by more specific probing questions to determine the presence (or absence) of concepts and misconceptions, and the students' level of understanding of the major principles. Interview props were used to sustain student interest and to focus their attention. Each interview was audiotape recorded and lasted approximately 20 minutes. The tapes were subsequently evaluated to determine the presence or absence of concepts and misconceptions in relation to each major content principle.

Table 1

Content Principles Based on Primary Research Used in Design and Analysis of Interviews

Number	Major Content Principle
1.	The Gulf of Maine is separated from the Atlantic Ocean by Georges Bank and is bordered by the coastlines of the U.S. and Canada.
2.	The ocean bottom is continuous with the continent, has a slope, gets progressively deeper, and is interrupted by bottom features such as channels, banks and shoals.
3.	Ocean water in the Gulf of Maine is characterized by low temperatures and salinity, which is primarily the result of freshwater inputs from the continent.
4.	Ocean water in the Gulf of Maine is nutrient rich.
5.	Water in the Gulf of Maine moves because of wind-driven currents, river inputs and tides, which collectively result in upwelling and uniformally mixed waters.
6.	Energy flows through this system from the sun to plants to animals.
7.	Within the system, plants capture light energy and convert it to food.
8.	Within the system, plants and animals interact in a complex food chain and web.
9.	The Gulf of Maine contains valuable living and nonliving resources that man has exploited over several generations.
10.	Renewable resources in the Gulf of Maine (fish, seals, lobsters, seaweed) have been harvested using a variety of traditional techniques (drags, traps, nets).
11.	Non-renewable resources, such as hydrocarbons and gravel, are being considered for exploitation.
12.	The Gulf of Maine is also considered valuable for recreation, research, tourism, and other non-consumptive resource users.
13.	The Gulf of Maine has traditionally been utilized as a common resource by many nations, and currently there is a conflict over the future utilization of these resources.
14.	Disputes over resources can be negotiated by concerned parties through mutually agreed upon decision-making (negotiation).
15.	In order to insure a balanced system, management strategies based on conservation and utilization must be practiced.

Interview Details: Each interview began by showing the student a map of the Gulf of Maine region and asking several general lead-in questions on geography and ocean bottom topography: Do you recognize this area? What can you tell me about it? What do you think the ocean bottom looks like?

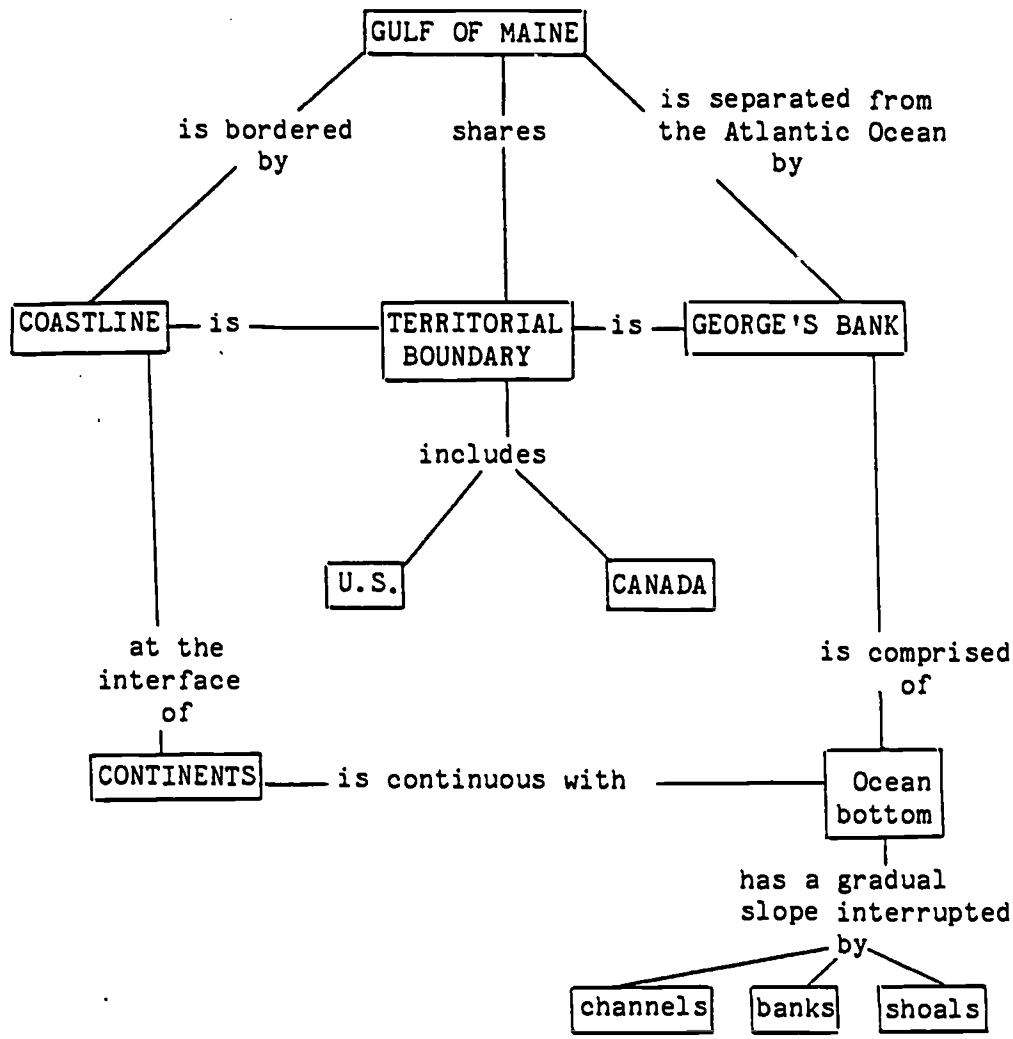

Figure 1. Concept map concerning geography and ocean bottom topography of Gulf of Maine.

The concept map in figure 1 summarizes the first two major content principles and their conceptual relationships. The two principles include geographical and geological concepts related to the Gulf of Maine.

The second set of interview questions covered principles 3, 4 and 5 concerning physical and chemical oceanography. Figure 2 shows the concept map constructed from these principals. The general lead-in questions were: Does ocean water move? How? Where does it come from? What are some characteristics of ocean water, particularly in the Gulf of Maine? A basin of water was used as a prop to promote discussion on water movement.

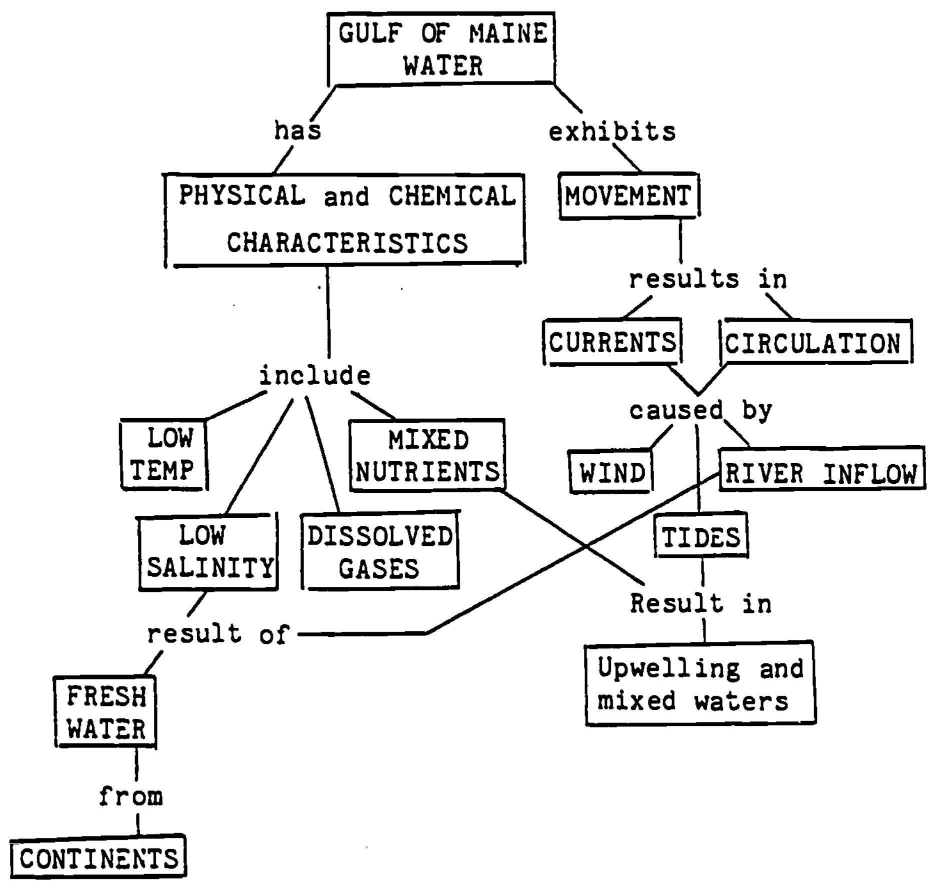

Figure 2. Physical and chemical Oceanography Concept Map concerning the Gulf of Maine.

The next set of questions dealt with marine ecology (principles 6, 7 and 8). An aquarium with plants, fish and invertebrates, or a picture of such an aquarium, was used to stimulate student responses. Lead-in questions were: What are some living things in this aquarium or in the ocean? In what ways are plants and animals related and how do they differ? Do plants and animals depend on each other in any way(s)? How do plants and animals get food and energy? Figure 3 is a concept map of principles 6, 7 and 8.

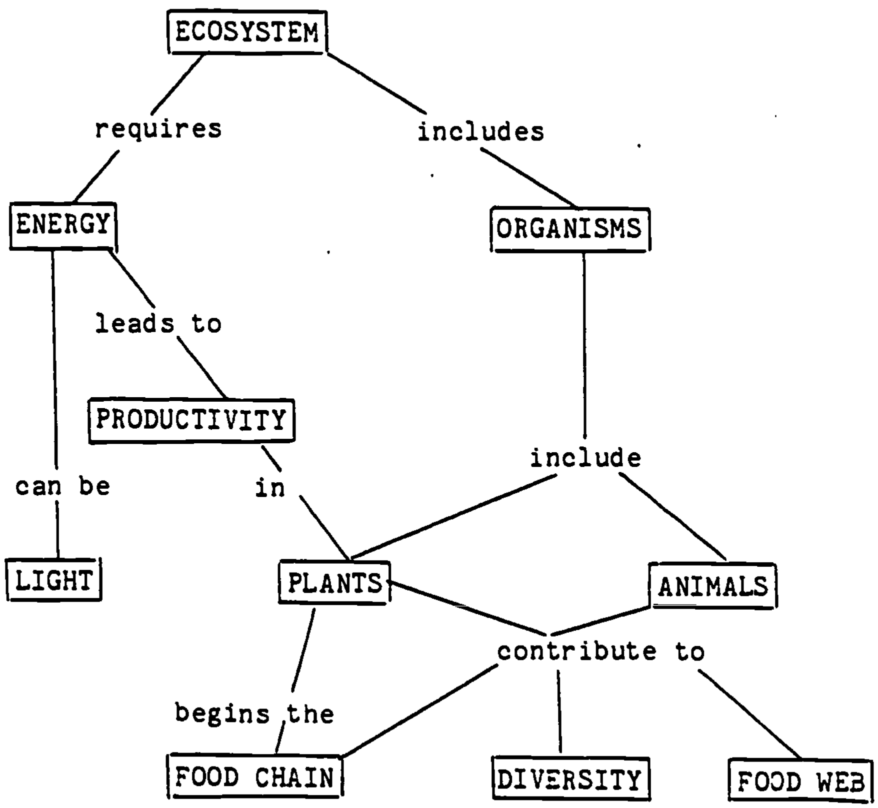

Figure 3. Ecology Concept Map to guide student interviews.

The next set of questions and props (a model or picture of a boat, a can of fish product, such as tuna; a model or picture of a fish) were designed to probe student knowledge of natural resources (principles 9-11; figure 4). Lead-in questions were: What things do people use from the ocean? What are they? Where do they come from? How do we get them?

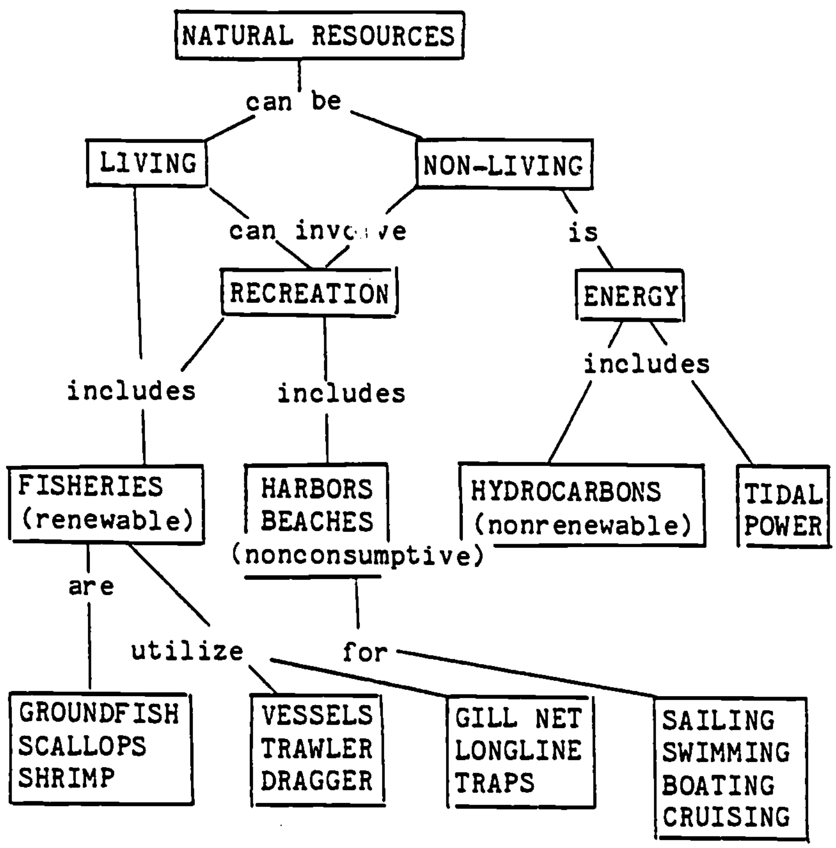

Figure 4. Gulf of Maine natural resource concept map.

The last set of questions dealt with concepts and propositions on resource use, management and decision-making (principles 13, 14 and 15; figure 5). Lead-in questions were: How do we reach mutually agreed upon decisions concerning use and management of natural resources? How do we take care of a resource if two interests can't agree on a decision? A map of a small pond with a scenario of a fishery shared between neighbors was used as a prop to probe student concepts about resource management.

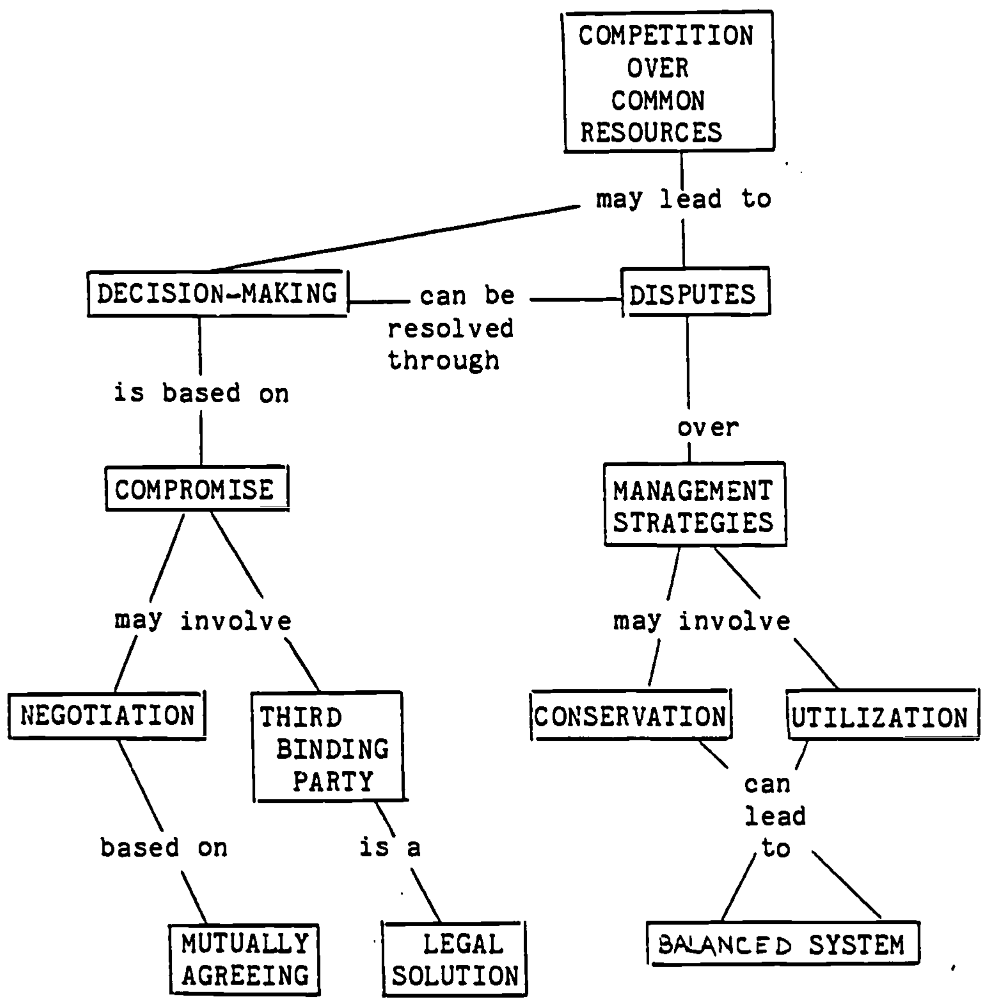

Figure 5. Natural Resource Decision-Making Concept Map.

Data Analysis

Prior to scoring the interviews, investigators jointly scored several audiotaped interviews to ensure consistency of scoring. Student knowledge of content principles was scored on the following scale:

3 - Fully complete conception: Student recognized and understood the meaning of the entire major content principle.

2 - Partially correct conception: Student recognized and understood most concepts (and proposition) in content principle; (individual concepts within the principle were identified and tabulated).

1 - Little conception: Student recognized or understood some concepts and propositions from content principles; (again, individual concepts were identified and tabulated).

0 - Completely missing concept: Student was unable to give a clear or meaningful explanation of any concepts within the major content principle.

M - Misconception: Student drew conclusions or gave explanation based on concepts unrelated to the given set of events.

The mean interview score for each principle and the grand mean interview score on all 15 principles were calculated for each grade level. For this purpose, misconceptions were given the same rating as completely missing concepts (0). One-way analysis of variance and Duncan's multiple range test were used to determine whether the mean scores of 4th, 8th and 11th graders on each content principle were significantly different from one another. Similar analyses were done to determine significant differences between the grand mean scores of each grade level.

Results

Figure 6 shows that mean interview scores for each principle at each grade level were all relatively low. The highest mean score on any single principle was obtained by 11th graders on principle 10 (marine renewable resources and harvesting techniques). Yet even this score reflects only a partial understanding of the principle (mean score = 1.7). Students at all grade levels had virtually no understanding of principle 4, concerning the concept of "nutrient". Comprehension of ecological concepts involving energy flow through ecosystems (principles 6 and 7) improved somewhat at the higher grades. Older students also showed greater comprehension of natural resources and related decision-making concepts and processes. The grand means indicate that, overall, students at each grade level understood only a few basic science and natural resource concepts related to the Gulf of Maine.

With the exception of principles 6, 7, 11, 14 and 15 (figure 6), the statistically significant mean score differences between grades shown in table 2 do not represent substantial differences in the degree of concept differentiation and overall comprehension of the principles involved. Although the grade-level grand means were significantly different, figure 6 shows that the largest difference between these means (4th and 11th grade) was only about 0.4. For all practical purposes, this difference represents relatively minor gains in general knowledge and comprehension of marine-related concepts and principles between 4th and 11th grade.

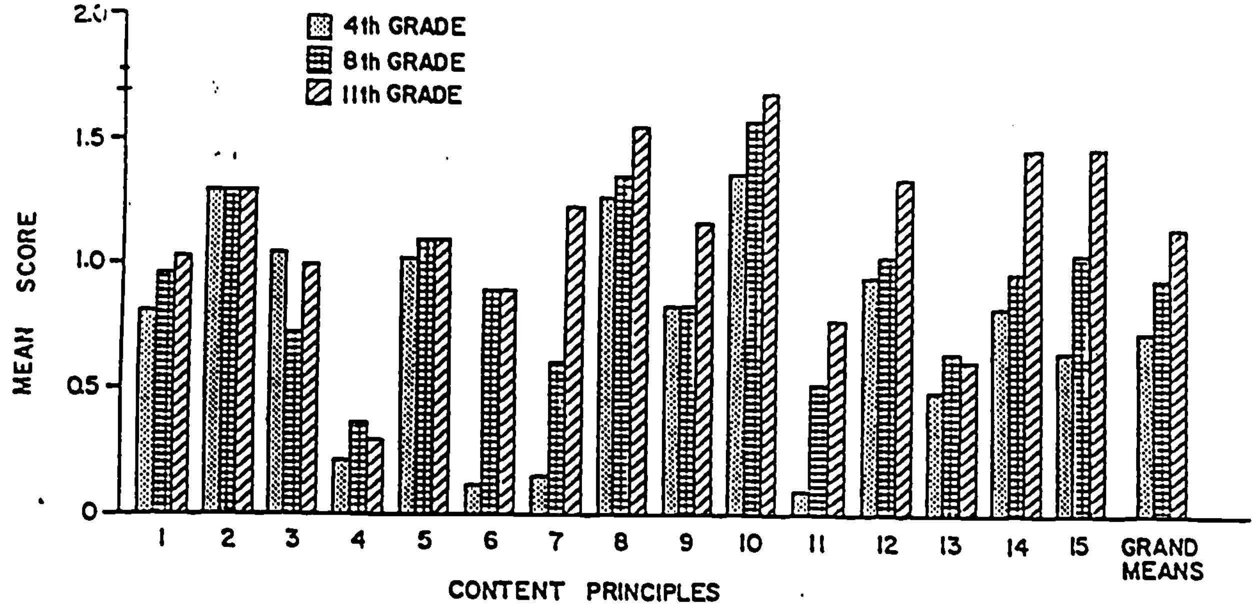

Figure 6. Mean interview scores of 4th, 8th and 11th grade students on marine science and natural resource principles.

Table 2

Significant differences between mean scores on content principles and between grand mean scores of 4th, 8th and 11th grade students. Asterisks indicate significant difference, p<0.05 (ANOVA, Duncan's multiple range test). No significant differences occurred between any grade-level mean scores for principles 1, 2, 5, 8 and 13.

	Principle									
	3, 4		6	7, 11, 15		9, 12, 14		10	Grand Means	
Grade	4	8	4	4	8	4	8	4	4	8
8	*		*	*					*	
11		*	*	*	*	*	*	*	*	*

Table 3 shows generalized student statements of correct concepts for each content principle. Each statement represents the majority of student responses across the three grade levels for each principle.

Table 3

Generalized Student Correct Concepts for Each Content Principle

Content Principle	Correct Concept
1	The Atlantic Ocean is bordered by the coastlines of U.S. and Canada.
2	The Ocean bottom is continuous with continent, has a slope, gets progressively deeper and is interrupted by bottom features.
3	Ocean water is characterized by low temperature, has salinity and rivers and streams run into the ocean.
5	Ocean water mixes, movement is wind driven, there are tides and waves and materials move around.
6	Plants need light for something and some animals feed on plants.
7	Plants need light for something and some animals feed on plants.
8	Plants and animals interact in food chains and webs.
9	We have been fishing in the ocean for a long time and there are resources in nature we use.
10	We fish for shellfish and fish with nets and traps.
11	There is a possibility there are other resources off our coast (oil).
12	We use the ocean around Maine for swimming, boating and beauty.
13	Conflicts over resources exist.
14	Disputes over resources might be solved by people.
15	Resources can be conserved and utilized if you are careful.

Since the mean score for each content principle at each grade level was below two, a partially correct response, there were important concepts in each principle which the students were missing. Table 4 summarizes these missing concepts for each principle. Each missing concept reflects a gap in student knowledge across all grade levels.

Table 4

Missing Concepts for Each Content Principle

Content Principle	Missing Concepts
1	Gulf of Maine separated from Atlantic by Georges Bank.
2	Channels, banks, shoals; distribution and size of bottom features.
3	Source of salinity, concentration and dissolved gases.
4	Nutrients.
5	Currents, upwelling, uniform mixing.
6	Energy flow.
7	Microscopic algae are very important for primary productivity. Plants convert energy to food.
8	Marine species and distribution, complexity of relationships.
9	Non-living resources/exploitation over time.
10	Renewable natural resources.
11	Future exploitation of other resources.
12	Oceanographic research.
13	Future exploitation of resources.
13	Common resources, exploited by many nations, knowledge of conflict and utilization process.
14	Mutually agreed upon decision-making.
15	Balanced system, management; conservation utilization.

Table 5 shows misconceptions which were held by a majority of the students interviewed.

Table 5

Content Principle	Common Misconception
2	Coral reefs exist throughout the North Atlantic Ocean.
7	Some deep aquatic plants don't need light (dark on bottom).
13	The oceans are a limitless resource.
14	There are no political boundaries in the oceans.

Comparison To Maine Assessment of Educational Progress in Science (1984)

The Maine Educational Reform Act of 1984 mandated a yearly Maine Assessment of Educational Progress in Science (MAEPS). The MAEPS is designed to test fourth, eighth and eleventh grade student performance throughout the state of Maine. The results are intended to serve as a basis for curriculum planning to improve schools. The 1983-1984 assessment was conducted by the RMC Research Corporation of Hampton, New Hampshire and sampled approximately four thousand students. The research design permits "the performance of the sampled students at each level to represent reliable estimates of the performance of all Maine students at that grade level" (Dept. of Education and Cultural Services, p. 44). Although we make no claims about the generalizability of our results to all students of the three grade levels investigated, it is possible to make general comparisons between some of our results and those of the MAEPS.

Four areas that overlap conceptually are tides, waves, photosynthesis and ecology. Within these four areas several questions were presented on MAEPS and in our study across the three grade levels. On the MAEPS, sixty percent of eighth grade students correctly answered the multiple choice question related to the cause of tides (table 6). The majority of 8th graders understood that tides are primarily caused by the effect of the moon's gravitational pull on the earth. However, only fifty percent of eleventh grade students correctly identified the correct cause of the tides on a similar but more difficult open ended version of the question in table 6.

Table 6

MAEPS Test Item on Tides and 8th Grade Percent Response

Percent of Students Selecting Each Item		MAEPS Test Item
Gr. 8		Of the following which is the most direct cause of the tides on Earth?
5	A.	the tilt of the Earth's poles
8	B.	the magnetic field of the Earth
6	C.	the slope of land near the shoreline
9	D.	the revolution of the Earth about the Sun
60	*E.	the effect of the Moon's gravitational pull on the Earth
11	F.	I don't know.

The results of our study related to the Gulf of Maine indicated that students do recognize the word tides and relate it to the moon's gravity. However, our study concentrated on the more inclusive concept of water movement. A related MAEPS test item (table 7) tested the concept of ocean waves and their causes across all three grade levels.

Table 7

MAEPS Test Item on Waves and 4, 8 and 11 Grade Percent Response

Percentage of Students Selecting Each Item				MAEPS Test Item
Gr. 4	Gr. 8	Gr. 11		Most waves on the ocean's surfaces are caused by
52	40	34	*A.	the wind
9	6	8	B.	water temperature differences
20	35	40	C.	the moon's gravity
19	19	18	D.	shifts in the ocean floor
1	0	0	E.	NA

Table 7 shows that fifty-two percent of the fourth graders, 40 percent of the eighth graders, and only 34 percent of the eleventh graders correctly selected "the wind" as an answer. Fewer than 10 percent at each grade level answered "water temperature differences", and just under 20 percent answered "shifts in the ocean floor" at each grade level. It was "the moon's gravity" which was the increasingly popular wrong response, attracting 20 percent of the fourth graders, 35 of the eighth graders, and 40 percent of the eleventh graders.

The MAEPS test item results related to tides and waves can be more fully explained through the analyses of our interviews. We found that the concepts of tide and the moon's gravity are present in students' understanding of water movement (see table 3). However, the interviews revealed that most students at all grade levels associate water movement with wind. Responses relating storms, winds and waves emphasize this relationship and it seems experience and media coverage of coastal storms and hurricanes may be the source of this information. Comparisons of interviews for content principle 5 across the grade levels (table 2) revealed no significant differences between the grades (figure 6, table 2). Thus it appears students learn about ocean water movement early, and there is little or no subsequent differentiation of those concepts.

In relation to content principles 6 and 7 which involve energy, sunlight, plants, food and animals, there were three similar MAEPS question relating plants, photosynthesis and animals. These questions and their results are shown in table 8.

Table 8

MAEPS Test Items Relating Plants, Photosynthesis and Animals and 4, 8 and 11 Grade Percent Response

Percentage of Students Selecting Each Option			MAEPS Test Item
Gr. 4	Gr. 8	Gr. 11	Green plants are important to animals because the plants
20	14	6	A. consume both food and oxygen
17	17	13	B. consume food and give off oxygen
8	7	4	C. consume food and give off carbon dioxide
26	50	62	*D. produce food and give off oxygen
7	10	12	E. produce food and give off carbon dioxide
22	4	2	F. I don't know.
			What products do plants produce during photosynthesis?
	9		A = (correct response) sugar for one of the "oses")
	3		B = (correct response) carbohydrate
	0		C = protein
	0		D = fats
	0		E = starch
	0		F = minerals
	1		G = water
	40		H = other (incorrect response)
	21		I = oxygen
	23		NR
			What two products do plants produce during photosynthesis?
		25	A = (correct answer) sugar and oxygen (could give one of the "oses", carbohydrates, or simply food instead of sugar)
		6	B = sugar/food and carbon dioxide or water
		6	C = sugar/food and a "wrong product" other than carbon dioxide or water
		15	D = oxygen and carbon dioxide or water
		23	E = oxygen and "wrong product" other than carbon dioxide or water
		11	F = neither oxygen nor sugar/food given
		13	NR

According to the MAEPS Science Advisory Committee,

> It is not surprising that only one-fourth of the fourth graders knew that green plants are important to animals because they make food and give off oxygen. However, on the parallel item for Grade 8 and Grade 11 students only 50 percent of the eighth graders and 62 percent of the eleventh graders demonstrated that knowledge. (Dept. of Ed., 1985, p. 19).

Based on the results of our study, we agree that fourth graders do not understand the complex role of plants. In fact, content principles 6 and 7 were among the lowest 4th grade scores, indicating almost no understanding. Although there was a significant increase in comprehension of these principles in grades eight and eleven (figure 6, table 2), the level of understanding was still relatively low. A typical student explanation of the relationships in principles 6 and 7 was not much more complex than "plants need light (for something) and animals eat plants". In fact, the common misconception in this area that "some plants deep in the ocean do not need light" throws into question student understanding of the concept of photosynthesis. This is substantiated by the MAEPS summary which states:

> Regarding the photosynthetic process, it is likely that most students would recognize the term "photosynthesis"; however, the results on two MAEP exercises suggest that students' understanding of the process is lacking as most students at Grades 8 and 11 had difficulty in identifying products of photosynthesis." (Dept. of Ed., 1985, p. 19).

Finally, in the MAEPS general test-item area of Ecology and the Environment (N=15), the science advisory committee concluded,

> On a variety of MAEPS ecology items, there was little grade 8 to 11 growth evidenced (Dept. of Ed., 1985, p. 20).

Among the ecology items was an open ended fourth grade food chain question (table 9) which corresponds to our content principle eight (table 1).

Table 9

MAEPS Test Item on Food Chain and 4th Grade Percent Response

Percentage of Students Selecting Each Option	MAEPS Test Item
Gr. 4	Give an example of a food chain with at least three links in it.
16	A = (correct answer) any reasonable chain with living thing, eating living thing, eating living thing
2	B = a reasonable 2-linked chain
4	C = an unreasonable chain
43	D = other incorrect response
35	E = NR

The results of our study indicate that fourth graders do understand the basic concept of food chains and webs (table 3, figure 6). Fourth grade students understood that "plants and animals interact in food chains and webs" although they could not give examples of specific marine organisms and their relationships. There was very little increase in knowledge of food chain dynamics in grades 8 and 11 (figure 6), and no two grades were significantly different. We concur with the MAEPS conclusion concerning no growth between 8th and 11th grade and would extend it to include fourth grade as well.

Conclusions

It appears that the students in our sample did learn a few basic marine science and resource concepts in the elementary grades, relevant to current marine natural resource issues. However, there was little further assimilation of new concepts or differentiation of existing concepts as students progressed through the grades. These results have important implications for design and development of future marine science curricula. In order to better educate students, we must first determine the concepts and principles they already know. The data in Table 3 shows marine science and natural resource concepts with which the students in our survey generally were familiar, whereas table 4 indicates critical missing concepts. Educators can use this kind of information to introduce new concepts and principles in ways that relate meaningfully to the students' existing knowledge. Furthermore, student misconceptions (Table 5) must be determined and taken into consideration since they have been shown to interfere with or inhibit new learning.

We believe this type of study, which concentrates on student knowledge in a qualitative or semi-quantitative manner, can contribute significant information for teachers and curriculum developers. Information derived from student interviews often reveals critical gaps in conceptual relationships, and their potential causes, which multiple choice questions frequently fail to assess. The agreement of our results with those of the statewide science assessment in Maine indicates that our techniques have value for small scale programmatic research in assessment of student knowledge and its implications for curriculum needs, design and development.

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