“Mapping the Oceans” – Helping Students Make Connections

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Since the initiation of state and national science standards and application of high stakes accountability testing, research has shown educators have focused more on the factual parts of science, often neglecting the concepts of science and – in many cases – the context of science. As stated by Munby et al (2000): "when science is separated from its original contexts of investigations and questioning and becomes transplanted in secondary school culture, it becomes inauthentic[1]." As a thematic center designed to complement existing COSEE Network efforts, COSEE-Ocean Systems (OS) is moving forward in its development of effective tools and techniques to aid learners in better understanding the context of the oceans in both the earth and solar systems. Acting upon recent national efforts to "map" ocean topics into the educational standards, we are piloting effective ways to bring the relevance of the oceans to classrooms, particularly rural and inland audiences.

Novice to Expert

We know from a number of national reports on science education including *Project 2061*[2], the *National Science Education Standards*[3], and the National Research Council’s *How People Learn*[4] that we need to move science education from a memorizing and repetitive system to a dynamic and engaging system. An individual’s understanding develops as new elements are added and connected with existing knowledge. In order to develop competence in an area, students need three things[4]:

1. A deep foundation of factual knowledge;
2. An understanding of facts and ideas in the context of a conceptual framework, and
3. The ability to organize knowledge in ways that facilitate retrieval and application.

From *How People Learn* (2000): "Research shows that it is not simply general abilities, such as memory or intelligence, nor the use of general strategies that differentiate experts from novices. Instead, experts have acquired extensive knowledge that affects what they notice and how they organize, represent, and interpret information in their environment. This, in turn, affects their abilities to remember, reason, and solve problems." Conversely, novices have knowledge parsed into discrete, "hard to retrieve" packets. While there is no expectation for students to become experts in ocean science, the study of expertise does reveal what effective learning looks like.

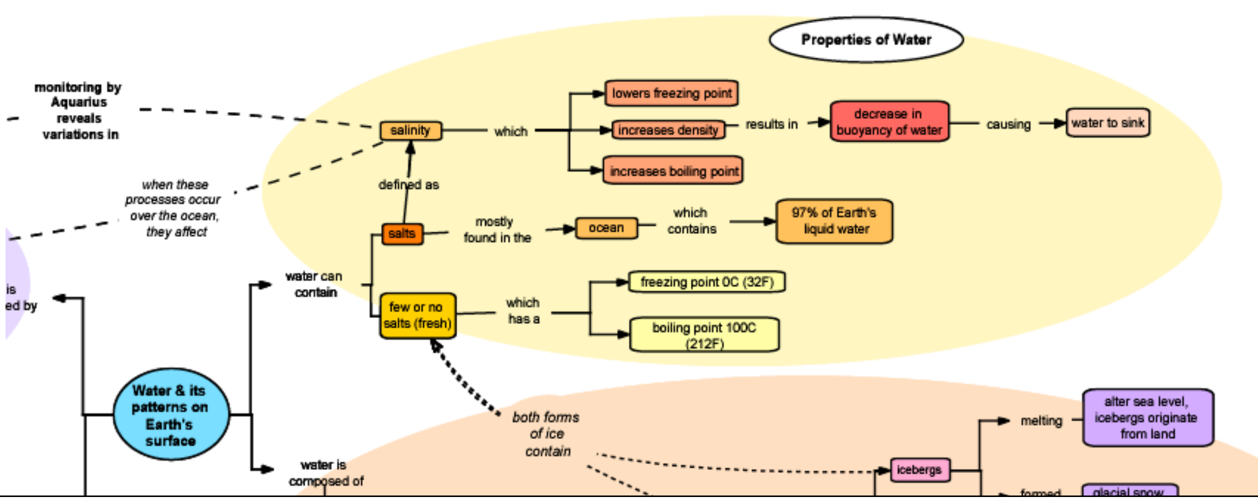

Figure 1. This excerpt from the concept map “*Water and its patterns on Earth’s Surface*” was developed for the NASA mission *Aquarius*. It highlights the effects of salinity on water properties. See the *Aquarius* website for more information - http://www.bigelow.org/aquarius/

So how can we help students better organize both new and existing knowledge? COSEE-OS is implementing tools and methodologies to promote effective learning, such as concept mapping, with an ocean science context. Concept maps are well suited for understanding parts of a complex discipline, such as oceanography. The value of concept mapping lies in both the process of construction and in the final product, the map - a visualization of the journey to understanding. Information organized as a concept map, reveals how a student sees the links between concepts or ideas, identifies gaps in knowledge, and exposes misconceptions. Through this process, a teacher can observe and evaluate students in two ways: understanding between topic concepts, and the students' perception of the whole topic[5].

Ocean science can be used to demonstrate many fundamental principles of science, including those outlined in our national education standards. By building model concept maps around ocean sciences, COSEE-OS anticipates assisting both teachers and students in constructing science knowledge rather than just consuming interesting facts and vocabulary. These model maps are not intended to be "answer keys," but will serve as a point of reference. Constructed by consensus among ocean scientists and K-12 educators, the maps suggest science content with appropriate and accurate connections between concepts.

Concept Mapping Basics

Concept mapping can multi-task throughout a curriculum unit, serving a variety of functions for both teachers and students. Concept maps can be used to assess student knowledge, encourage thinking and problem solving as a student assignment, along with organizing information and learning goals. It helps the learner see what they've learned and the steps that were taken to gain deeper understanding.

It was Joseph Novak who mainstreamed concept maps in the early 1970s. Novak defines concept maps as "graphical tools for organizing and representing knowledge. They include concepts, usually enclosed in circles or boxes and relationships between concepts indicated by a connecting line linking two concepts. Words on the line, referred to as linking words or linking phrases, specify the relationship between the two concepts[6]." Figure 1 is an illustration of a concept map in an ocean science context. The power of a concept map is its ability to show the learning process by[7]:

- seeing conceptually
- identifying patterns and relationships
- matching words with concepts
- elaborating concepts with details
- realizing hierarchy of main ideas with details
- eliciting synthesis, conclusions, interpretations, and inferences from details
- constructing meaning
- experiencing critical and creative thinking
- moving from small amounts of information to large quantities of data

However valuable this approach may be, learning is not built on concept maps alone. Concept maps can fail to help educators and students in these ways:

1. get to the big idea; "Why am I learning this?"
2. go in reverse; i.e., get to the specific ideas ("At what level should I teach this?")

By placing factual knowledge in a conceptual framework, the sum becomes greater than its parts because applying concepts within a context helps the learner to create new meaning for how the world works. Knowledge of facts and knowledge of organizing ideas are mutually supportive. This essential link between factual knowledge and conceptual framework defines the difference between emphasizing "big ideas" and producing graduates with a knowledge base that is superficial[9].

Secrets Revealed

There are some organizational patterns that will appear in the construction of concept maps. These include:

- *Branches* - An idea may branch many times to include both closely and distantly related ideas.
- *Arrows* - Arrows can be used to join ideas from different branches.
- *Groupings* - If a number of branches contain related ideas, a circle can be drawn around the whole area.
- *Lists*
- *Explanatory/Exploratory notes* - A few sentences may be necessary to explain, question, or comment on the relationship between linked concepts.

Adapted from University of Victoria Learning Skills Program Handout[8]

Seeing is Believing

In December 2005, COSEE-OS brought a group of ocean science researchers together to produce a concept map(s) around oceans. The goal of the day was to ask, discuss, and capture the essential pieces of information students need to know related to the "Ocean Literacy" topic "*The ocean is major influence on climate*[10]." Led by Educational Researchers Drs. Ann Taylor and Margaret Powell the scientists embarked on a concept mapping experience. The COSEE-OS planning team proposed that this method would be an innovative and effective method to gather vital information from scientists while providing academic background about this educational tool and process. Once briefed on the background of concept mapping, scientists worked in pairs to answer a set of questions. These questions were meant to help scientists think about what a 6-year-old in Iowa knows - compared to a 4th grader in California or a 17-year-old in Maine - about the ocean. Through this process, the participants learned that everyone is influenced by their environment and operates in the world based on their own set of preconceived ideas or misconceptions about a subject, whether or not they realize it. These preconceptions (right or wrong) can be powerful tools for a teacher to use in exposing and clarifying topics in the classroom. If students' preconceptions are not addressed directly, then they default to memorization strategies rather than trying to "think through the problem."

Errors and Myths

Student (and sometimes teacher) misconceptions are not remediated simply by telling the individual the correct ideas. The learner must actively and deliberately seek to reconstruct the relevant knowledge in their long-term memory in order to correct the misconception. The concept map approach is ideal for helping students clarify their misconceptions and build powerful, valid knowledge structures. From *Teaching Science for Understanding*[11]

This activity reminded scientists that students' knowledge depends not only on their prior experience with ocean sciences education, but also on their geographic proximity with the ocean. In addition, there was extensive discussion about the wide range of science backgrounds teachers have based on the grade level they teach. The scientists were surprised by the following information on today's graduates[7]:

- 70 – 80% of U.S. students read at an 8th grade level
- Most students do their research using the Internet; they often don't use traditional sources such as textbooks, literature, current research etc.
- Teachers have less time to dig deeper in a subject as the result of the amount of other administrative paperwork that is asked of them.

It is important to consider the realities of the education system and potential "roadblocks" when developing materials and methods for teachers and students.

The scientists were then broken into groups to begin the formal concept mapping process. The group was asked to reflect on what they were thinking while constructing their maps. Some of the scientists explained they were thinking about relationships, that the process was causing them to "stretch" their thinking in new ways. Others wondered about scale and how to represent going from "large-scale to small-scale processes" or vice versa. All in all, the scientists quickly transitioned from being "concept mapping novices" to making insightful decisions on how to best represent ties between oceans and climate. Since concept maps are based on discussion, collaboration, visualization and connection, the scientists – through creation of their own concept maps – were able to see how difficult it can be to describe what you understand about a subject.

The group produced two consensus maps, which provided a solid foundation for continuation of the concept mapping process with educators. In preparation for this important next step, COSEE-OS multimedia designers are creating "storyboards" and interim products based on the maps created by the initial scientist/educator teams. Ultimately, COSEE-OS concept maps will be integrated into a web-based interface that provides access to a "virtual journey" through the ocean-climate system. The "journey" will be linked to relevant visualizations, reviewed educational resources, Oceans in the News articles, and more. A review by scientists, educators (formal and informal), and other discipline experts will be conducted before this online tool is field tested with teachers.

Concept Mapping Technology

Now that the COSEE-OS team has worked through several phases of the concept mapping process, we are learning about the benefits of using technology to construct concept maps. A new world of learning opportunities has opened with the advent of concept mapping computer software. Table 1 summarizes some of the software available. This is not an exhaustive list, just the software that the COSEE-OS team has directly experienced. Most have the ability to click and add concept nodes, branches, connecting lines, and add text to each of these elements. Using this technology, maps can be saved, stored, and projected to facilitate construction, brainstorming, and organizing of new and old ideas. The versatility of the software makes it a powerful tool for use by various working groups.

If you want to begin using concept maps but would prefer something low-tech, consider using sticky notes. Write the relevant concepts on the sticky notes and rearrange them as necessary. Marker boards, white boards, or large sheets of paper are great for this activity allowing students to draw connecting lines between concepts and revise as needed.

Table 1. Concept mapping software used by the COSEE-OS team

Software name *Click to visit website*	**Operating System**	**Free Trial duration**	**Cost** (As of June '06)	**Export file type**	**Comments from COSEE-OS software trials**
Freemind	Mac / PC	n/a	free	svg, png, pdf, jpg, html	Easy to use, but not as powerful as other programs; limited formatting; the larger the map the smaller the print on export; more mind-mapping (organizer) than concept mapping; not suited for a lot of text; capable of storing web-links in concept nodes
Inspiration / Kidspiration	Mac / PC	30 days	$64	gif, jpeg, pict, Powerpoint, MS Word	Familiar to teachers & students, user-friendly; allows use of graphics within map; allows user to move between outline form and diagram; use suggested templates, create templates or start from scratch; intended for education/classroom use
Smart Ideas by Smart Technologies	Mac / PC	30 days (unlimited access)	$59	MS Word, text, png, jpeg, svg, html	View and construct in diagram or outline form; add levels and move between levels; add text to connecting lines; many formatting options; good export quality for reproduction / publication of maps; the current COSEE-OS favorite and most thoroughly trialed; intended for education/classroom use
Novak's IHMC CMap tool	Mac / PC	n/a	free	jpeg, bmp, eps, png, pdf, svg, emf, html	Straightforward to use; built-in icons for attaching/storing links; web-ready application; better suited for lots of text; good option for sharing among working groups; intended for education use and more
Mindjet's MindManager Basic 6	Mac / PC	21 days	$229	bmp, pdf, jpg, png, tiff	Better suited as an organizer or mind mapping; intended as a business tool; the fastest way to organize many different complex concepts for a group of people; intuitive to use; can integrate a variety of software programs

Encouraging Meaningful Learning

Concept mapping is not the magic bullet, but as we engage scientists and educators together the benefits are emerging. This approach has provided a forum for scientists and teachers to get "on the same page." Scientists who have participated in the concept mapping are realizing how others view their "science" and redefining how they share their knowledge and experience. Teachers are seeing how scientists think and getting assistance in translating those thoughts into a common language through concept maps. Preliminary evidence tells us that the use of concept mapping to encourage meaningful learning is: practical and familiar for teachers, grounding for scientists, and will lead, in time, to enhanced student motivation and interest in learning science.

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