Organizing the essential components of effective professional development for educators at a pre-conference workshop, Designing Professional Development to Support Ocean Literacy. June 29, 2009 (Photo credit: Craig Strang)

Developing the Ideas of Ocean Literacy Using Conceptual Flow Diagrams

By Craig Strang, Kathy DiRanna, Jo Topps

Upon publication of *Ocean Literacy: The Essential Principles of Ocean Sciences K–12*,[1] there was broad recognition of the potential power of a consensus document describing what every person should know about the ocean to be considered science literate. There was also recognition of the limitations of such a document that describes the ideal end state, yet provides no road map for how to get there. We knew that ultimately we would need to craft a road map to provide an answer to the question, "If students are to understand the Ocean Literacy Principles by the end of grade 12, what would we need to teach them in grades K through 2, in grades 3 through 5, in grades 6 through 8, and in grades 9 through 12 to help them reach that goal?" The answer to that question—a scope and sequence—would be of great interest to teachers and informal science educators, but also to national and state standards committees, curriculum developers, textbook writers, and assessment specialists. But what would be an effective way to represent this complex information so that it would be comprehensive, understandable and accessible for these different end users? For this answer, we turned to literature in learning, teaching, and teacher professional development.

Research in the learning sciences (National Academies, 2018) reveal that to develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application. Thus to facilitate the development of students' conceptual understanding and organization of ocean sciences ideas, the scope and sequence should have a logical and coherent approach to building the complex ideas of the Ocean Literacy Principles from one grade band to the

1 Since the publication of *Ocean Literacy: The Essential Principles of Ocean Sciences for Grades K–12* in 2005, there have been two major updates to the Ocean Literacy Guide, one in 2013 and one in 2020. The title changed to *Ocean Literacy: The Essential Principles of Ocean Sciences for Learners of All Ages* in recognition that the concepts contained in the guide were important for informal as well as formal K through 12 education.

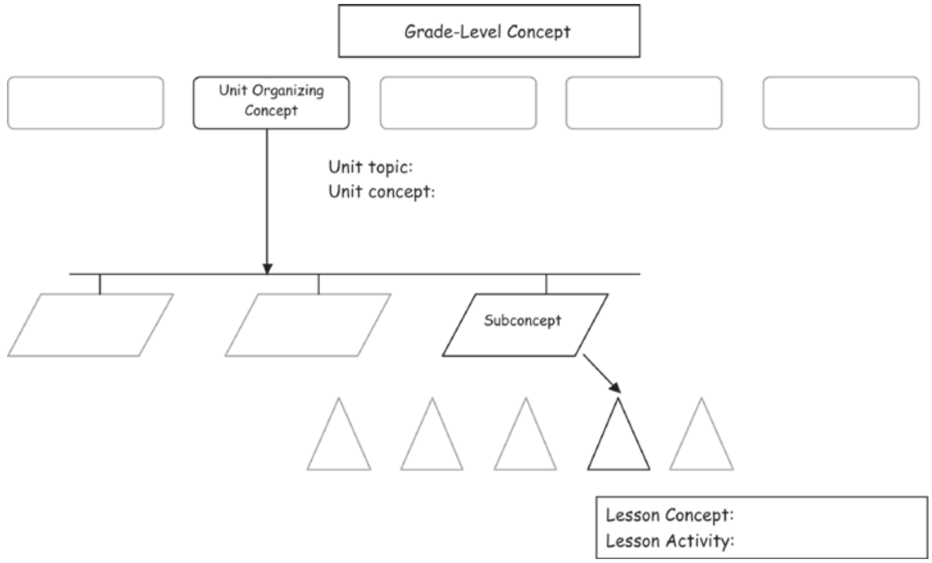
next. Conceptual flow diagrams (as shown on pages 16 to 74) offer a way to present and organize such a progression of ideas, and can be a versatile tool for several reasons: they describe the developmentally appropriate concepts at each grade band, as well as the relationships among the concepts, in a graphical format; they provide a research-based example of a sequence in which the concepts can be taught, beginning at the earliest grades; and the diagrams balance the need for clarity and utility with fidelity to learning theory and cognitive science. Additionally, we have developed a way to organize these concepts in a tabular format. This helps convey the connections and relationships between concepts, without relying on visual cues. As in the conceptual flow diagrams, strands of connected ideas are organized under a topic title and brief description. Instead of using arrows to convey connections between individual concepts, the tabular format stacks the concepts and subconcepts in rows and columns in the order in which they should be presented (i.e., top row to bottom row within a column, then left to right). This means some concepts are repeated under each higher-level concept to convey the connections among them.

Figure 1

Shows the generic layout of conceptual flow diagrams developed by teachers to describe an instructional sequence.

Concept Maps versus Conceptual Flows

Conceptual flow diagrams (using arrows or a tabular format) are a specialized and distinct form of concept maps. Concept maps are graphical tools for organizing and representing knowledge that were developed in 1972 in the course of Joseph Novak's research program at Cornell University where he sought to follow and understand changes in children's knowledge and understanding of science (Novak & Musonda, 1991). The data from Novak's study indicated "the lasting impact of early instruction in science and the value of concept maps as a representational tool for cognitive developmental changes." Novak's concept maps include concepts, usually enclosed in circles or boxes, and relationships between concepts indicated by a connecting line linking two concepts. Text on the connecting line, referred to as linking words or linking phrases, specify the relationship between the two concepts. Concepts are generally represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map, and more specific concepts arranged below. The hierarchical structure for a domain of knowledge may be somewhat relative as it often depends on the context in which that knowledge is being applied or considered (Novak & Cañas, 2008; Novak & Gowin, 1984). The use of concept maps generally represents a constructivist approach to learning and teaching, as it assists the learner in developing and displaying the trajectory of their understanding of new concepts and ideas.



Conceptual flow diagrams were first developed by the K–12 Alliance/WestEd in California in 1989, for use with teachers during professional development institutes conducted for an NSF-funded statewide systemic initiative.[2] Hundreds of teachers have used this model to develop conceptual flow diagrams to improve their content knowledge, their curriculum planning, and their instruction of complex science concepts. As a product, a conceptual flow diagram resembles a map of nested concepts. The biggest ideas are supported by small ideas, and those small ideas are maintained by even smaller ideas that become learning sequence concepts (**see Figure 1**). The conceptual flow diagram differs from a concept map in that it addresses concepts in a unit of instruction, and has both a hierarchy of ideas (indicating the relationship between and among the ideas) and a direction, i.e., the sequence for instruction of the unit. Conceptual flow diagrams are intended to be read and taught from top to bottom and from left to right. Concepts nested beneath other concepts, either connected by arrows or in an individual column in the tabular format, serve to elucidate and support the concepts above. Concepts to the right, i.e., in another strand, or in the next column, build on those to the left, and often move in a developmental sequence, especially in the early grades, from more concrete to more abstract.

The process of guiding teachers through the development of conceptual flow diagrams is described at length in the book, *Assessment Centered Teaching: A Reflective Practice* (DiRanna *et al*., 2008). The process of making conceptual flow diagrams has also been adapted for a variety of purposes, including planning for classroom instruction and assessment simultaneously, assisting in school district analysis, selection and adoption of instructional materials, and helping curriculum developers to design instructional materials. Given these versatile uses of conceptual flow diagrams to display and organize big ideas and concepts in a well-thought-out progression of learning and teaching for different educational purposes, we decided to use conceptual flow diagrams to represent the scope and sequence.

Purpose of Conceptual Flow Diagrams

The conceptual flow diagram is a “backward-planning” tool. Starting with the end in mind and planning backwards (Wiggins & McTighe, 2005) is a means for setting comprehensible goals and designing better instruction. Teachers can array the big ideas that are important for students to know, the standards they are responsible for teaching, and the content presented in the instructional materials into one comprehensive, sequential chart. As teachers identify and integrate these three elements, the process of constructing a conceptual flow diagram enables teachers to clearly identify specific goals for student learning and progress. The conceptual flow diagram assists learners by making them aware of the links in the concepts they are addressing. Too often it is a mystery to students why they are learning what they are learning. As one teacher put it,

> *The conceptual flow diagram is a determination of where you are going in your teaching and what you’re going to reflect on. You have to know what concepts are important and the order in which they go to conceptualize the whole learning. I put my conceptual flow on the wall for the kids so they learn where they’re going, too.*
>
> —Teacher Leader 1, NSF Center for Assessment & Evaluation of Student Learning

Developing conceptual flow diagrams helps teachers build foundational knowledge about the importance of helping students to construct conceptual frameworks rather than “learn” factual information. When a conceptual flow is displayed in the classroom, it allows both teachers and students to connect new ideas and information, providing opportunities to learn with deeper understanding.

2 Since the time that the Ocean Literacy Scope and Sequence was developed, conceptual flow diagrams have evolved to include an emphasis on 3-dimensional instruction articulated in *A Framework for K–12 Science Education*, i.e., Scientific and Engineering Practices (SEPs), Disciplinary Core Ideas (DCIs), and Crosscutting Concepts (CCCs) (National Research Council, 2012).

A completed conceptual flow diagram serves the following four purposes:

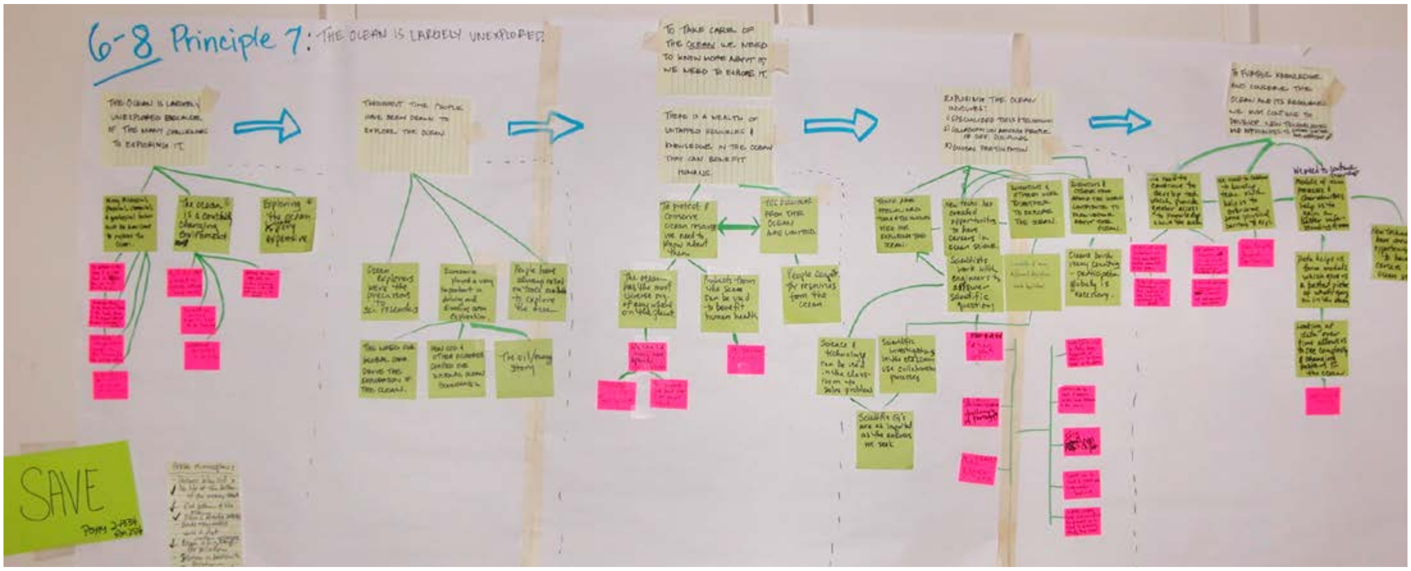
1. Details the important concepts and linkages to other ideas;
2. Identifies an instructional sequence for which resources (e.g., textbooks, instructional materials) can be used to support teaching;
3. Identifies important concepts for assessment of student understanding; and
4. Eventually serves as the foundation of an assessment plan for the unit of instruction.

Construction of Conceptual Flow Diagrams

Conceptual flow diagrams are designed by a team, often led by a facilitator knowledgeable of the process. The process for a team of 2 to 5 people to build a conceptual flow diagram for a unit of instruction includes these five steps:

1. Individuals write a narrative response to the question, “What should students be able to demonstrate their understanding about by the time they leave grade (blank)?
2. Individuals re-write and transfer each concept statement in complete sentences from their narrative responses onto separate post-it notes of three different sizes using the larger size for the larger, more important concepts.
3. Team members share their concepts on post-it notes with one another. They arrange the notes into a collaborative draft conceptual flow diagram with larger concepts at the top, and smaller, nested, supporting concepts below. This step can take several hours.
4. Team members match their collaborative, draft conceptual flow diagram to the concepts addressed in the instructional materials and to the science content standards and pedagogy used by team members.
5. Team members review the progression of concept clusters (each cluster is comprised of a large concept and the nested, smaller concepts below it) and place them in an instructional sequence that provides strong links for student understanding (see Figure 2).

Figure 2



Sample of a first draft of the conceptual flow diagram for Principle 7 grades 6 through 8 developed at the first Ocean Literacy Scope and Sequence working meeting in 2006.

Conceptual Flow and Teacher Change

In addition to aiding teachers in curriculum development, conceptual flow diagrams have been used as a foundational process for developing classroom assessment plans. A research study of teachers who received professional development on the building of conceptual flow diagrams found that most grade level teams shifted over time toward a *greater focus on big ideas* by removing, adding or reorganizing learning goals to focus on what was most important for students to learn. Another common shift was toward *more coordinated relationships among big ideas and smaller supporting concepts*. Most teams increasingly represented conceptual relationships among unit goals rather than as a list of sequential lesson topics. Paralleling organizational shifts in the conceptual flow diagrams, all of the teachers' assessment plans were more coherently organized in later portfolios. Assessment plans shifted from long lists of possible assessments toward judicious selection of a few key assessments for tracking student progress. Teachers indicated generally strong understandings of how to use conceptual flow diagrams to guide assessment decisions and to select their "juncture" assessments (Gearhart & Osmundson, 2009).

I think teachers need to understand the conceptual flow of their curriculum…what concepts they want students to learn; what concepts to assess with their students… then they can plan for teaching.

[Developing the Conceptual Flow] moved us from a list of topics to…nesting of important ideas. Identifying what really matters for student understanding drives decisions about…questions in the assessment.

—Teacher Leader 2, NSF Center for Assessment & Evaluation of Student Learning

In a political climate that often stresses coverage of material in preparation for state testing, teachers appreciate the process that building conceptual flow diagrams provides because it focuses on conceptual understanding of big ideas. One teacher explained,

My district is into curriculum mapping and… I'm trying to cover the standards, but (by using conceptual flow diagrams) you have to go deeper into the standards to assess the concepts that are actually behind the understanding, instead of just checking off standards.

—Teacher Leader 3, NSF Center for Assessment & Evaluation of Student Learning

Based on the findings of Gearhart and Osmundson, the benefits of conceptual flow diagrams appear to go beyond assessment planning: teachers *take ownership* of their instruction by becoming better consumers of instructional materials. As they grapple with important concepts and how they should be arranged in a meaningful sequence, teachers gain insight into how instructional materials are organized, which materials are designed to support students' understanding of the big ideas, and which lessons, resources, and assessments need to be revised. Teachers can then modify their instruction and assessment practice to address any gaps or weaknesses.

With a new focus on the concepts in the conceptual flow diagram, I was able to really see my instructional materials. I mean, I knew that our instructional materials were not often perfect, but this really brought out where the holes are, where I need to revise and what I need to put in there to make sure the students understand the concept that I'm trying to teach.

—Teacher Leader 4, NSF Center for Assessment & Evaluation of Student Learning

I always look at a unit now and make sure that it does flow conceptually. If not, then I rearrange to make sure I include ideas that build upon one another. I always make that a part of my science teaching and I want to incorporate conceptual flow diagrams into other content areas.

—Teacher Leader 5, NSF Center for Assessment & Evaluation of Student Learning

While collaborative development of working versions of conceptual flow diagrams has been demonstrated as an effective teacher professional development activity, involving hundreds of people in the development of a set of 28 completed conceptual flow diagrams has, to say the least, never been accomplished before. *The Ocean Literacy Scope and Sequence for Grades K–12* represents a new use of conceptual flow diagrams. In 2006, the authors and several other colleagues led a group of 46 ocean scientists and educators through the development of the first Ocean Literacy conceptual flow diagrams. The process was uplifting and invaluable. Achieving a final product, however, took considerable revision, iteration, and review before consensus was reached on all 28 diagrams. In 2015, the *Alignment of Ocean Literacy to the Next Generation Science Standards* was completed to detail the correlations between the Next Generation Science Standards (NGSS)—specifically the Disciplinary Core Ideas (DCI) and Performance Expectations (PE)—and the concepts included in the *Ocean Literacy: The Essential Principles of Ocean Sciences for Learners of All Ages* and the *Ocean Literacy Scope and Sequence for Grades K–12 (Scope and Sequence)*. The alignment documents are organized by grade band and provide a 4-point scale with a description and explanation for each rating. Providing coherence across the Ocean Literacy Framework and NGSS helps to leverage our community's work and make it more valuable and useful. (**See page 75 for the Alignment documents.**) The Scope and Sequence has become a catalyst for research about how students form and revise their understanding of complex ocean sciences concepts. Further, the Scope and Sequence is a driving force in defining the content that students will encounter in textbooks, curriculum materials, and assessments.

Editors' Note: This article was updated to reflect changes since the original 2010 publication. Any errors are the responsibility of the editors.

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