

Using

# CONCEPT MAPS

in the

# Science Classroom

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Teaching science in middle school is both rewarding and demanding. Creating an exciting learning environment with a rich science curriculum that engages all students is challenging enough. Monitoring the progress of as many as 150 individual students and knowing that they understand the science concepts we are teaching can be overwhelming. How can we know if students develop a coherent and scientific understanding of the important concepts? Is it possible to produce a snapshot of this understanding? In this article we address these questions by sharing some practical tips for using concept maps as a way to monitor students' understanding.

## What is a concept map?

A concept map is a graphical representation of the relationship among terms (see Figure 3). This will sound familiar if you have used graphic organizers or visual learning tools such as Inspiration software. In our research, we use a type of concept map in which students are provided only the terms (concepts). Students are asked to connect a pair of concepts with a one-way arrow, then label the arrow with a word or short phrase that describes the re-

lationship between the two connected terms. These connected terms can be read as a sentence, such as "Water has density." These sentences—two terms linked by an arrow and phrase—are called *propositions*.

Although there are many variations in the way you can design concept map activities, open-ended activities that allow students to construct their own map structure are the most revealing. For this reason, mapping activities with very few constraints and no pre-defined, fill-in-the-blank map structure are considered the gold standard for learning more about connections students are making between important concepts.

## Concept maps' benefits

As students are introduced to new science concepts, they embark on a cognitive process of constructing meaning

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and making sense by consciously or subconsciously integrating these new ideas with their existing knowledge.

Concept maps provide a unique graphical view of how students organize, connect, and synthesize information. As a result, concept

mapping offers benefits to both students and teachers.

Concept maps give students an opportunity to: (1) think about the connections between the science terms being learned, (2) organize their thoughts and visualize the relationships between key concepts in a systematic way, and (3) reflect on their understanding. In sum, concept maps allow students to think deeply about science by helping them to better understand and organize what they learn, and to store and retrieve information more efficiently. Students also articulate and challenge their thoughts about science when they discuss their maps with each other. Concept mapping naturally integrates literacy and science by providing a starting point for writing about science; this can be particularly helpful for English language learners.

Concept maps are also valuable tools for teachers because they provide information about students' understanding. Teachers can examine how well a student understands science by observing the sophistication of their concept map. When an expert creates a concept map, it is typically an elaborate, highly integrated framework of related concepts (Chi 1988). Highly sophisticated maps show highly integrated knowledge structures, which are important because they facilitate cognitive activities such as problem solving. A closer look at the propositions in a concept map also reveals students' level of understanding. For example, linkages drawn between two unrelated concepts expose students' alternative or naïve conceptions in science. Likewise, the absence of a link between two closely related concepts can reveal that a

student has not yet developed a strong understanding of the relationship between the concepts. When concept maps are used on repeated occasions, they can clearly show how students' understanding improved over time. Providing students with the same concepts on more than one occasion can show how the quality of the students' propositions improves over the course of instruction. Accordingly, teachers can quickly see gaps in learning and modify lesson plans based on the information from students' concept maps.

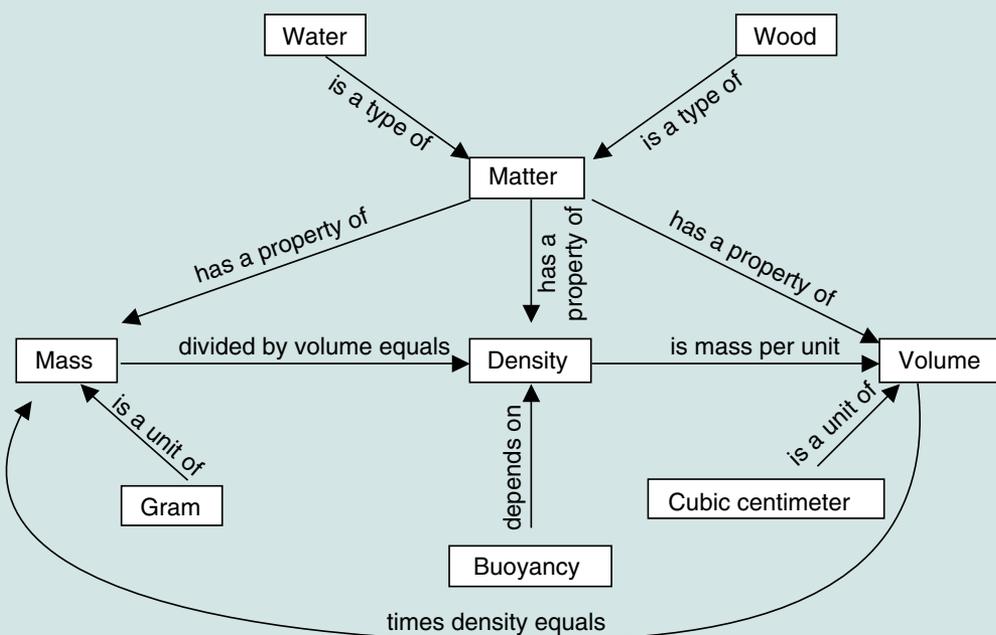
### Designing a concept mapping activity

Concept maps have great potential as both instructional and assessment tools in the classroom, but the design of a concept mapping activity can greatly change what is measured. To effectively use concept maps in your classroom, we offer the following recommendations:

**Step 1—Select key terms.** Scan your curriculum unit and select the most important and critical terms related to the key concepts being taught. Using the terms you have selected, see if you can construct propositions that reflect what students should know and be able to express

**FIGURE 1** Concept map created by teachers for density and buoyancy unit

As an example, for a unit on density and buoyancy, we considered *matter*, *density*, *mass*, *volume*, and *buoyancy* to be the most fundamental terms. To determine if students understood related measurement terms, we also included *gram* and *cubic centimeter*. To add real-life context and allow connections to *matter*, we included *water* and *wood*.



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at the end of the unit. Keep the concept map manageable by selecting a short list of about 8 to 12 terms.

**Step 2—Determine where in the unit or curriculum the maps will be embedded.** Concept maps fit best when alternated with the hands-on science activities in a unit. Most often, concept maps are based on the terms that make up the content of a series of investigations. As such, consider inserting a concept mapping activity at key junctures in the unit. Some criteria to keep in mind in identifying these natural joints are: (1) a sub-goal of the unit is achieved and there is a body of knowledge that can be assessed, (2) a critical point in instruction is reached and it is important to know about students' understanding before proceeding, and (3) a critical shift in student understanding is expected after a particular series of investigations and feedback to students is crucial to help them improve their understanding and to help inform your instruction.

**Step 3—Create the activity.** For maximum insight into student understanding, design the activity to follow the open-ended construct-a-map style, where students are only provided with the key terms (Yin et al. 2005). For students' convenience, you can have them write the science terms on small sticky notes (see Figure 2). This allows students to move and organize their thoughts while creating their rough draft.

We also recommend that the activity include an opportunity for students to redraw and revise their maps. For example, in our study students created their rough draft using sticky notes, but then were asked to draw a final version of their concept map without using sticky notes. By redrawing their maps, students are encouraged to continue reflecting

on the meaning of the science terms. You may be surprised at how many students generate additional details as a result of this redrawing step.

To help visualize the entire activity, you can download a copy of the concept map assessment activity we used for a recent study (see Resources), which includes an introduction to and example of the construct-a-map style of concept mapping, a practice concept-mapping activity, and a concept-mapping activity.

### Implementing a concept map activity in your classroom

**Step 1—Train your students.** If students have never created an open-ended type of concept map, provide them with a practice topic they are quite familiar with (science-related or otherwise, such as bicycles or food). For example, while the concept map activity in our study was for a unit on density, for training purposes it included an example concept map on a nonscience topic (roses), and a practice activity based on the water cycle.

**Step 2—Create individual maps first.** Ask students to create their own individual maps first. This independent reflection step is crucial; it elicits the personal understanding of each student. We have found that creating a concept map as a class activity without completing individual maps is very time consuming and not engaging for all students.

**Step 3—Review the maps in small groups.** After students finish their individual concept map, organize small group discussions. Have students share their concept maps with partners. Ask them to find similarities and differences in their maps and try to reconcile them. Group discussions provide opportunities for students to engage in the social aspect of science, where they can articulate their thoughts and learn from each other. Consider the creation of heterogeneous groups with students at different levels in every group.

**Step 4—Whole class discussion of certain parts of the small group concept maps.** Ask each group to present their important propositions to the whole class and explain their choices. Many propositions can be discussed, but focus on those that are more relevant to what you want to know about the students' level of understanding. A whole-class map can also be created based on these discussions to document class progress, engage students, and provide stimuli for in-depth conversations about science.

### Evaluating concept maps

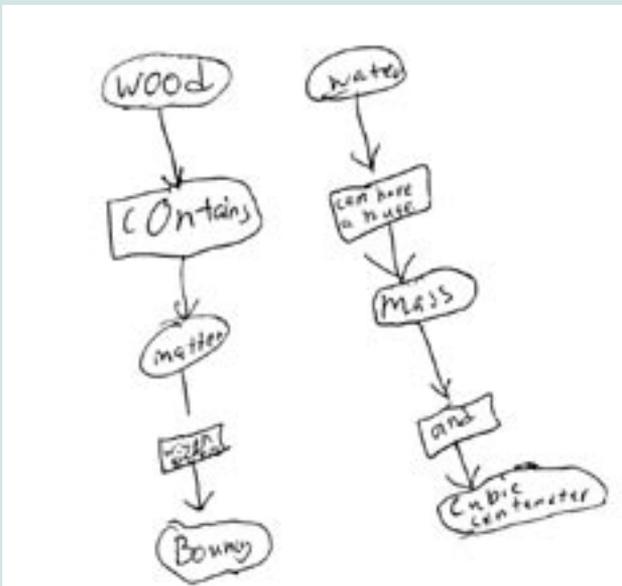
Even without formal grading or scoring, you will find that concept maps are very informative. A quick scan of the maps will show you what your students are

**FIGURE 2** A student using sticky notes to make a concept map

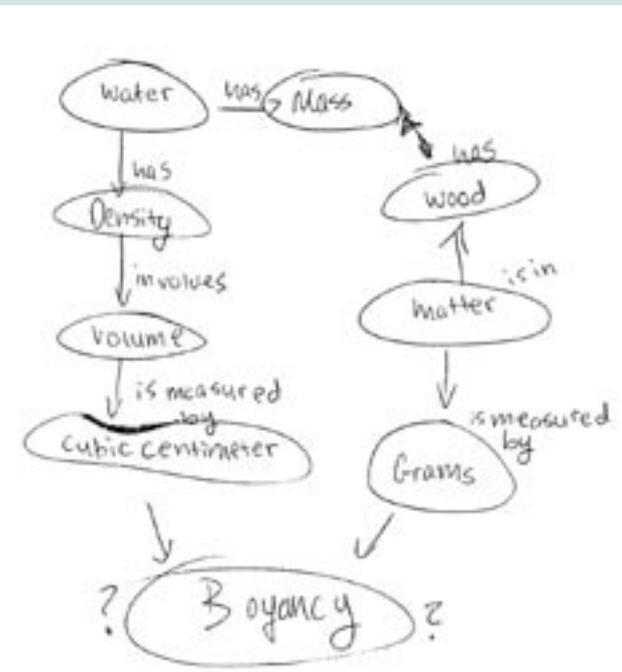


**FIGURE 3** Examples of map structure types

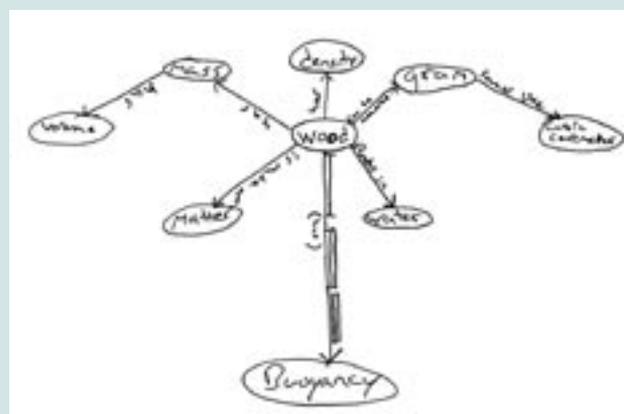
**A: Linear**



**B: Circular**



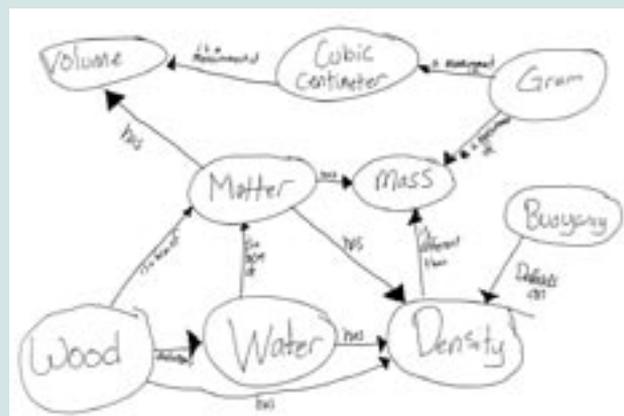
**C: Hub or spoke**



**D: Tree**



**E: Network**



Note: Figures 3A–E were actual concept maps generated by middle school students participating in a SEAL concept map study.

thinking, which in turn will help you generate ideas for improving their understanding. In some cases you may want to formally evaluate or score students' maps. By selecting the most important science terms from your curriculum and creating a consistent scoring process, a concept map activity can be a powerful assessment instrument. We recommend that you focus on the following factors:

### **The complexity of the maps**

Because map complexity is easy to determine and is quite informative, begin by evaluating this feature. This can be as simple as observing whether the maps are complex networks, or if they are simple structures. Experts and highly proficient students tend to create highly interconnected maps, whereas novices tend to create simple structures that are linear, circular, a hub with spokes, or a tree with few branches (see Figure 3).

### **The existence of the most important propositions (pairs of connected terms)**

The most important propositions describe relationships that reflect the main ideas contained in your science unit. They are the important ideas that you expect students to know after completing the curriculum unit. Therefore, the important propositions are what you hope to see on students' maps. For example, in a unit on density and buoyancy, you would hope to see connections among mass, volume, and density, and connections between mass and matter, volume and matter, density and matter, mass and gram, and volume and cubic centimeter (see Figure 1). If a student misses these connections in his or her concept map, the student may not understand the relationships among the key concepts in the unit.

### **The quality of the propositions**

The existence of the important propositions or links on a map indicates whether the student knows that there are relationships among those concepts. However, it is still unclear whether the relationships identified are reasonable, or scientifically meaningful. To examine the quality of propositions, we use a four-level rubric. For example, when connecting mass and matter, actual student responses included:

- 0—Mass is an object equal to matter (wrong or scientifically irrelevant)
- 1—Mass is related to matter (partially incorrect)
- 2—Mass measures matter (correct but scientifically thin)
- 3—Mass is amount of stuff in matter (scientifically correct)

You may prefer to save time by using a three-level scoring system instead: 0 = wrong; 1 = partially correct or correct but scientifically thin; 2 = scientifically correct.

You can score individual propositions and sum them to obtain a total score. You may also consider color-coding the propositions with highlighter pens to match the scores in the rubric (green = 3, blue = 2, yellow = 1, no color = 0), which gives a quick impression of how students are doing by looking at their answer sheets. To simplify this further and save time, you may want to use a green pen to highlight only the key propositions that students include on their maps. This will provide a snapshot of the level of sophistication your students have reached in their thinking.

When you score students' maps, you can also identify common misconceptions for further discussion with the class or with individual students. These may serve as the basis for a follow-up or clarification lesson.

### **Final comments**

Open-ended activities where students create their own phrases and map structure are preferable because they: (1) more accurately reflect differences across students' knowledge structures, (2) provide greater latitude for demonstrating students' partial understanding and misconceptions, (3) supply students with more opportunities to determine their conceptual understanding, and (4) elicit more high-order cognitive processes, such as explaining and planning. In general, concept map assessments provide a different perspective on student understanding that complements selected-response and performance-based instruments. For insights into your students' thinking about science, a carefully designed concept map activity can be a tremendous asset. ■

### **References**

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- Yin, Y., J. Vanides, M. A. Ruiz-Primo, C. C. Ayala, and R. J. Shavelson. 2005. A comparison of two construct-a-concept-map science assessments: Created linking phrases and selected linking phrases. *Journal of Research in Science Teaching* 42 (2): 166–184.

### **Resources**

- Concept map assessment activity example (Word format)—[www.vanides2.com/conceptmaps/conceptmap-example.doc](http://www.vanides2.com/conceptmaps/conceptmap-example.doc)
- Stanford Education Assessment Lab (SEAL) research papers on concept maps—[www.stanford.edu/dept/SUSE/SEAL](http://www.stanford.edu/dept/SUSE/SEAL)