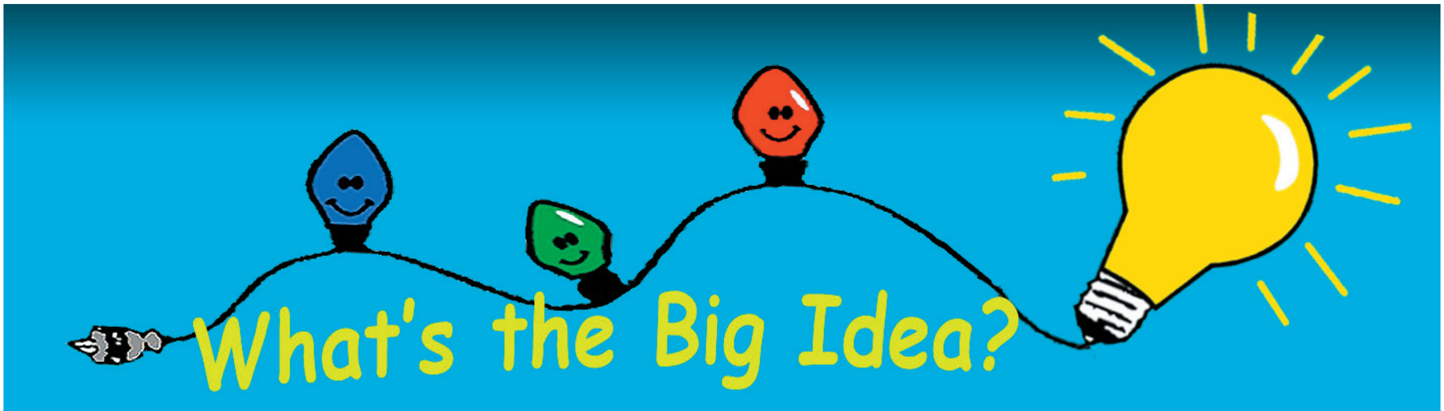

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A Welcome Rain

A perfect storm, in the good sense, is brewing for all of America's children. Critical thinking is coming back to school. So is creativity, collaboration and the ability to communicate.

These four C's of the 21st Century Skills have provided a foundation for the new *Common Core State Standards (CCSS) in English Language Arts and Literacy in History Social Science, Science and Other Technical Subjects*; the new *Common Core State Standards in Mathematics*; and the *Next Generation Science Standards (NGSS).*

While this is a mouthful to say, the intent to educate our youth as problem-solving students rather than robotic, drill and kill learners is welcomed by many, especially the K-12 Alliance.

Yet, as we know, any change – even for the better – takes time, energy, resources and support. The K-12 Alliance is helping educators make sense of these new standards and find ways to help implement them in our classrooms. In this introductory article, we address how literacy in science can be used to meet the CCSS-ELA and incorporate the NGSS.

(To find out more about CCSS-ELA and NGSS, see At A Glance: Standards, Practices and Concepts, page 11.)

Separating myths from reality

There are many myths about the CCSS-ELA Literacy in Science Standards: "I will have to be a reading teacher." "I can't do science anymore." "These are the science content standards." None of these are true!

"I can integrate with my Language Arts teacher." "I can use informative text to deeper student understanding of an experiment." "I can have students use their science notebooks to produce argumentation writing." All of these are true!

So what might this paradise look like? Let's take a look.

Middle school teacher Ms. Marquez is teaching a unit on matter and its properties and she has identified her science learning goal for students to understand density as one such property. She knows that NGSS has performance expectations that involve science and engineering practices (see At a Glance, page 11).

Review of her student work has made her think that students need more experience with analyzing and interpreting data. Density activities could provide a meaningful way to strengthen student understanding in this area.

NGSS also helps teachers think about cross-cutting concepts (see At a Glance, page 11). Ms. Marquez has been working with students on the concept of patterns — things that repeat themselves in some identifiable way. She recognizes that the density of an object and its surrounding fluid determines what sinks and floats; this pattern can be generalized for liquids and gases.

Ok.. Ms. Marquez is ready to go from the point of view of a science teacher...but then she remembers that district in-service on the Common Core. How can she use speaking, listening, writing and reading to help students better understand density?

As a member of the K-12 Alliance, Ms. Marquez has learned to use science notebooks as thinking tools for her students. If she can continue to do use those notebooks – and also think of other areas where students have to "produce" what they understand – that would meet the Common Core.

Reading after an experiment...yes, that might also help! Phew! Daylight is ahead.

RAIN, CONTINUED ON PAGE 9

IN THIS ISSUE...

DIRECTOR'S COLUMN

Crashing Through the Crack

By Kathy DiRanna

A year ago, I suggested that a crack in the ELA/MATH dominated educational scene was opening that would enable quality science education to return to the classroom. I'm thrilled to say that crack in now a thoroughfare, with lots of opportunity for quality education in all subjects.

This has been made possible because of the synergy of the *21st Century Skills, Common Core State Standards for ELA and Mathematics* and *the Next Generation Science Standards*.

The *21st Century Skills* are aimed at creating a workforce that is technologically literate, creative and innovative and that can problem solve, make decisions, and work collaboratively. Business and education leaders, as well as policy makers, are using these skills as a backdrop for the national conversation on improving U.S. education.

The adoption of the *Common Core State Standards in English Language Arts and Literacy in History Social Science, Science and Other Technical Subjects* and the *Common Core State Standards in Mathematics* calls for students to be career and college ready when they leave their K-12 education. These standards focus on application of learning to real-world events.

The *Next Generation Science Standards (NGSS)* being reviewed for national adoption and adoption in California, call for students to understand core ideas in the disciplines of life, Earth and physical science as well as engineering and technology and recognize the cross-cutting concepts that unite these disciplines. Importantly, NGSS also expects students to implement the practices of science and engineering, which form the foundation of many *21st Century Skills.*

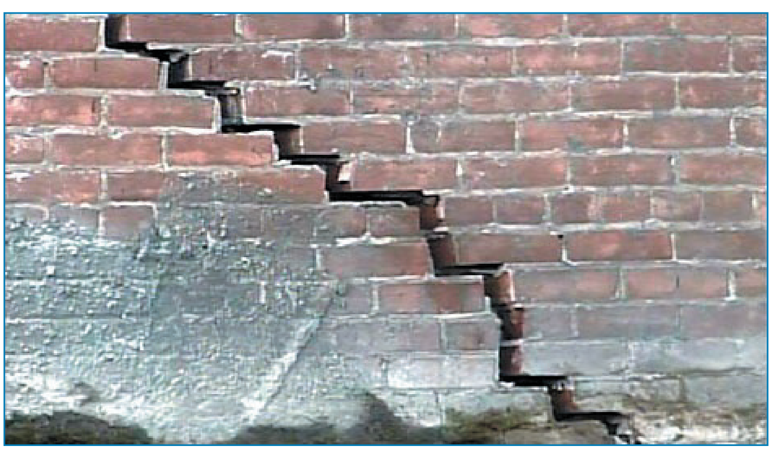
These standards will guide instruction and assessment in the years to come. Their emphasis on thinking, rather than regurgitation/drill and kill, will make our classrooms very different than what they have been for the past 12 years. What an exciting place to be for us as educators!

The transition for teachers and adminstrators, however, will take time. As suggested in *Greatness by Design,* 20120,

> *"Professional learning can have a powerful effect on teacher skills and knowledge and on student learning. To be effective, however, it must be sustained, focused on important content, and embedded in the work of collaborative professional learning teams that support ongoing improvements in teachers' practice and student achievement."*

Here's the good news: the K-12 Alliance has been providing that type of quality professional learning for 25 years and we intend to keep doing the good work — with your help — to make schools a joyful, intellectually stimulating place for all learners.

Jump on the bandwagon and join us as we push through the crack toward a brighter future for our students! ■



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Brenda Rees

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All OK at Oasis

By Karen Cerwin

"...you can choose when you teach science, morning or afternoon. And...it will all be OK."

Oasis School is appropriately named! It is an oasis of science on the east side of Coachella Valley, nearly as far east as the Salton Sea.

At a time when science is on the back burner of most elementary schools, 700 K-6 students (mostly poor and English learners) are engaged in inquiry-based science through FOSS kits (K-5) or Investigating Earth Systems at grade 6.

What is happening at Oasis is the result of a CPEC grant Science Writing Impacts Real Learning funded in late fall of 2010 and the heroic continuous support of Principal Dora Flores.

Dora was a new principal at the school when funding arrived in 2010. She was enthusiastic about supporting the program but she had numerous challenges.

First off, the previous principal, who signed on for the program, moved to another school; then a district riff caused 16 displaced teachers to be reassigned to the remote school site without them having a voice in the move or their grade level.

While the staff had science materials at grades 4 and 5, neither grade had been using more than one kit per upper grade. In fact, science was taught as a reading course just before the Science California Standards Test (CSTs) given only in grade 5.

Perhaps the most challenging for Dora was the fact the school had the lowest science scores in the district – which is why it was selected for the grant by the former superintendent.

Two years later, the story of science at Oasis is very different.

CST science data between 2011 and 2012 indicate the school has moved to a point equal to the highest scoring school in the district, a school with a very different demographic – wealthier and less English Learners – than Oasis.

The greatest significance of the program, however, is that adding access to a quality science program did not decrease ELA or math scores. In fact, ELA scores crept up into a safe harbor!

Students at Oasis have access and equity to a different curriculum than any other high-need school in the area – and their progress is proof that this method works.

Perhaps what has kept Dora and her staff moving forward, is that from the first year to now, Dora had a mantra she used every time she needed to convince her teachers that the changes will be worthwhile: "You have writing time and intervention time for science...and it will all be OK."

The teachers, after all, were fearful of deviating from their previous schedules, believing that all teaching time should be designated to ELD, ELA and math.

Dora stood firm in her mantra, even adding to it the second year. "You have intervention time, ELD time, and writing time as long as you know which ELD and Writing standards are being taught through reading of science and writing in notebooks. In addition, you can choose when you teach science, morning or afternoon. And again...it will all be OK."

Change is always a challenge and change at a high-need school with a new principal is even a greater endeavor. But Dora was – and continues to be – steadfast.

Today, change is still in progress at Oasis, but many teachers believe Dora's current mantra: "You can have the instructional time and it is all going to be OK."

At first blush, supporting science at this struggling school seemed unreasonable; school officials and staff – clinging to a fear of a loss of ELA or math points – were stuck in a holding pattern. But with Dora at the helm, going out on a science limb has taken everyone to the skies.

After two years, Dora and Oasis teachers are elated that science scores had grown, ELA scores are right where they need to be, and mathematics is one point from safe harbor.

This is not just "OK" – it's better than it ever has been for the students and teachers at this Coachella Valley school! ■

The Evolution of the TLC

By David Harris

As members of the K-12 Alliance, we believe in the power of the Teaching Learning Collaborative (TLC) as a process to help collaborative teams learn how to be better instructors. We have seen TLCs transform the way thousands of teachers approach instruction and how students learn.

Escondido Union School District (EUSD) is now shaping the way district-led professional development is done with help from the TLC. Since 2009, the TLC has been used in EUSD with cohorts of 20-40 teachers of math, science or project-based learning with extremely positive feedback. Participating teachers brought what they learned about instruction and collaborative planning back to their grade level teams. Many teams enjoyed increases in CST scores including a fifth grade team that went from passing 11 percent to passing 75 percent of their students in math in just two years!

What we find fascinating is that the TLC process can be very fluid.

Adapting the TLC to varying context has spawned creative variations. The first adjustment to the TLC process came from the summer school model at EUSD. Conceptual Flow and 5E lesson planning were done with the usual protocol, however, because we wanted the process to be used in grade-level planning time in the regular year, we developed a way to conduct the TLC as a self-facilitated process. We provided teams with a written guide that would help facilitate the process.

This self-facilitation model became part of the district's BTSA (Beginning Teacher Support and Assessment) /Induction program. The lesson planning fit perfectly into the *Individual Induction Plan* or *IIP* required of all BTSA teachers. In this plan, BTSA teachers plot a focus lesson that is observed and debriefed with the participating teacher's support provider.

Because BTSA teachers are not in grade level or content teams – and many are in special education classrooms — planning a lesson for more than one classroom was not appropriate. These constraints forced BTSA support providers and leaders to work on a model that retains much of the TLC, albeit with a very different flavor. For example, the Conceptual Flow had to undergo a little change. Here are the revised steps:

I. Teachers complete the usual quick write and transfer ideas to post-it notes.

2. Since they would not be building the flow with a partner, teachers build the flow as a process – with a product used to explain the unit conceptually to another teacher. For example, a third grade teacher would share their language arts unit flow to a seventh grade math teacher who paraphrases the flow to show they understand the logic. The paraphrase needs to be a coherent storyline that, when shared with others, flows like a paragraph and explains important concepts and skills for that instructional unit.

3. Teachers share flows with each other. Each verbalizes their "storyline" and responds to questions about the coherence of the flow. Subsequently, refinements may be made.

4. As the first part of planning their focus lesson, teachers refer to the concept column as a storyline. We found this helped the teachers understand the "so what?" of their teaching, the major concepts (not just isolated facts) they wanted students to know. Making sense of the concept column as a storyline helped teachers and students understand the flow of learning.

5. The rest of the lesson planning is a "regular" TLC

Because this is not a collaborative lesson study, the lesson is taught alone. The support provider (mentor) observes the lesson, however, and transcribes what is said and also debriefs by looking at student work as in a TLC.

EUSD continues to apply TLC to their professional development beyond science and math. They, like so many other educators and teachers out there, realize the TLC is the perfect vehicle for building understanding of the instructional practices called for in CCSS and NGSS. EUSD has shown the power of the TLC is an adaptable and ever-changing process that shows and brings results! ■

Collaborating for Literacy in Science

Confused about the Common Core State Standards and how to implement them in your classroom? Want to get the latest information and examples of the Common Core?

The California Department of Education, in collaboration with content and professional learning experts throughout California, has developed professional learning modules to help with the implementation, making your classroom THE place all students want to be!

Designed to help educators transition to the Common Core, the series includes at least 10 modules that will be completed by September 2013, available in both online and on-site professional learning formats.

Currently, you can access modules for ELA and Mathematics at the Brokers of Expertise at http://myboe.org/portal/default/Group/Viewer/GroupView?action=2&gid=2996.

The Common Core State Standards for Literacy in History/Social Science, Science and Other Technical Subjects will be addressed in additional professional learning modules.

The K-12 Alliance, California Science Project, Orange County and Riverside County Offices of Education are currently developing the 6-hour module for Literacy in Science. The module should be available this summer.

The emphasis of the CCSS Literacy in Science module is the importance of integrating inquiry-based science, oral language, authentic writing from inquiry, and reading to support the science learning. The module addresses the following areas:

Overview: Introductory opportunity to acquaint participants with the standards in an active learning setting that involves a simple observation: ice in water and alcohol. They draw their thinking on whiteboards and then write explanations of their observations, followed by oral presentations and discussion. Finally, participants read about density to add or clarify to their thinking. Participants then take a quick look at how standards are worded at their grade level.

Classroom Examples: Participants think first about how they put science, reading and writing together for student understanding. They view segments of videos at their grade level (primary -- first, upper -- fifth, middle school -- eighth and high school) that illustrates science inquiry, writing and writing strategies for argumentation as well as information writing and reading complex texts with different strategies. After viewing the video, teachers discuss what was observed in the lesson and how those instructional strategies met both science and literacy standards.

Looking at Student Work: Participants learn a process for designing formative assessment (i.e. appropriate student work) that has them identify the science learning goal, the ELA learning goal and the standards that support these goals. They view student work from the classroom examples with a scoring guide and learn ways to analyze science and literacy content as well as the quality of communication.

Notebooking: Participants discuss the rationale for student science notebooks, and learn strategies for encouraging student writing and thinking, providing feedback to students, and developing products from the notebook. Participants examine examples of student notebooks and discuss how they can facilitate deeper student thinking by using notebooks.

Science Literacy for ELLs: Using videos and the new EL correlation to the CCSS, participants explore strategies to differentiate instruction while integrating science, EL and ELA literacy. The emphasis is on productive activities that elicit productive conversation leading to writing and reading.

Planning Template: Participants will find templates for planning lessons, programs and activities that integrate science standards with the ELA CCSS Literacy in Science standards.

Resources: Participants will learn to check the CDE site and other resources such as CISC Strategic Science Teaching when they have questions or concerns.

Much of the design module comes from the good work you all do in the field. Thanks for helping the K-12 Alliance present a practical approach to implementing CCSS so that all students can have a deeper, more satisfying understanding of science! ■

Feats of Engineering

The K-12 Alliance is embarking on a new and exciting adventure providing professional learning opportunities for engineering education via the *Engineering is Elementary®* (EiE) program.

We have recently partnered with the Museum of Science, the creators of EiE, to disseminate the curriculum and will work with educators to provide professional development for elementary teachers (K-6). Some units are also appropriate for grades 7-8.

So, what is EiE? It's a research-based, standards-driven, and classroom-tested curriculum that integrates engineering/technology concepts and skills with elementary science topics.

The lessons not only promote K-8 science, technology, engineering and mathematics (STEM) learning, but also connect with literacy and social studies.

Students will learn that everyone can be an engineer, as they, through the years, tackle an array of projects such as: exploring materials and shapes of sails and windmills, creating water filters, discovering why bridges are shaped differently, designing alarm circuits, testing materials for thermal insulators, making a solar cooker and creating a submersible that can retrieve items from the ocean floor.

In short, it's a whole package of across-the-board learning!

Each EIE module contains four lessons:

- Students get an introduction to an engineering problem through a storybook appropriate for ELA.
- Students discovering the role of the type of engineering introduced in previous lesson.
- Students explore the science connected to the engineering dilemma.
- Students use the engineering design process to solve the problem.

The modules also represent diverse fields of engineering and diverse people who are engineers – just like in real life!

(To review the goals of the EiE program, see end of article, page 7).

If your district, county or region is interested in co-sponsoring a training session for teachers, your co-sponsorship is simple. Just identify a date for the training, find a location, and help disseminate fliers to advertise the training. The K-12 Alliance training team will do the rest (registration, catering and training).

The cost per participant is $250, which includes six hours of professional development, continental breakfast and lunch. Participants can then order a specific binder or binders that relates to their grade level science content ($50 each, not included in the $250). A minimum of 10 teachers is needed for each training session; a maximum of 30 teachers per grade level K-6 is possible.

Don't let this opportunity pass by you and your students!

To schedule a training date or for more information, contact Jody Sherriff at jskidmo@wested.org or call 916-764-4710.

EiE Goals

There are four overriding goals of the *Engineering is Elementary* curriculum.

Goal 1. Increase children's technological literacy. At the elementary school level, technological literacy is defined as acquiring essential understandings and skills that include:

Knowledge (know about):

- What engineering and technology are and what engineers do
- Various fields of engineering
- Nearly everything in the human world has been touched by engineering
- Engineering problems have multiple solutions
- How society influences and is influenced by engineering
- How technology affects the world (both positively and negatively)
- Engineers are from all races, ethnicities and genders

Skills/Experience (be able to do):

- Apply the engineering design process
- Apply science and math in engineering
- Employ creativity and careful thinking to solve problems
- Envision one's own abilities as an engineer
- Troubleshoot and learn from failure
- Understand the central role of materials and their properties in engineering solutions

Goal 2. Improve elementary educators' ability to teach engineering and technology.

At the core, EiE is designed to have students engineer. Interesting problems and contexts are developed and then students are engaged to use their knowledge of science and engineering to design, create and improve solutions.

Goal 3. Increase the number of schools in the U.S. that include engineering at the elementary level.

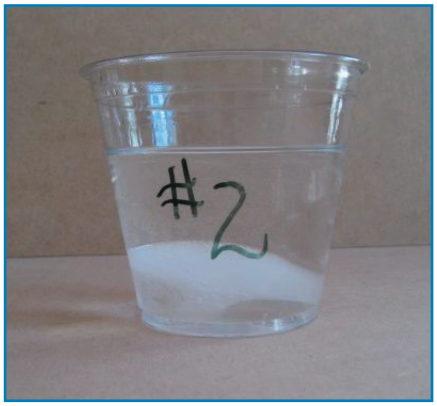
Goal 4. Conduct research and assessment to further the first three goals and contribute knowledge about engineering teaching and learning at the elementary level.

RAIN, CONTINUED FROM PAGE 1

Here is her learning sequence plan.:

Ms. Marquez begins the lesson with two cups, labeled #1 and #2. In both cups, there is a clear liquid. She encourages students to first independently observe the liquids and then share their ideas with a partner.

Next she provides an ice cube for Cup # 2. Students continue to make observations.



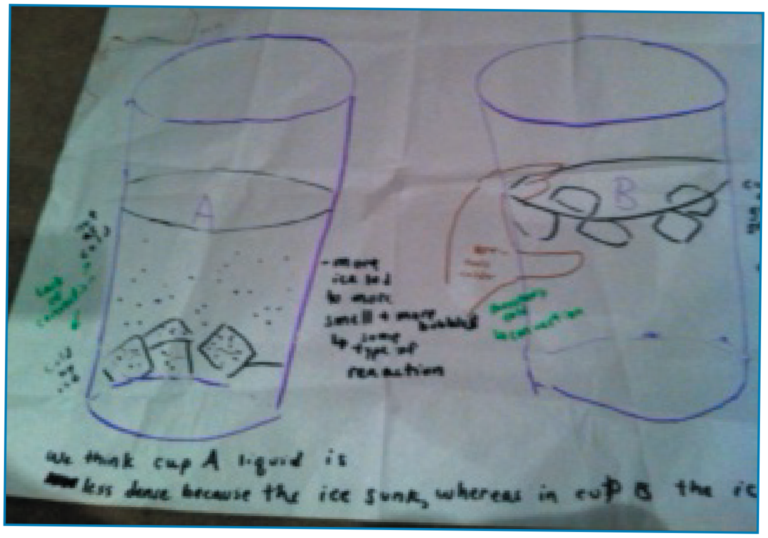
Then she provides another ice cube for Cup #1. Once again, students observe.

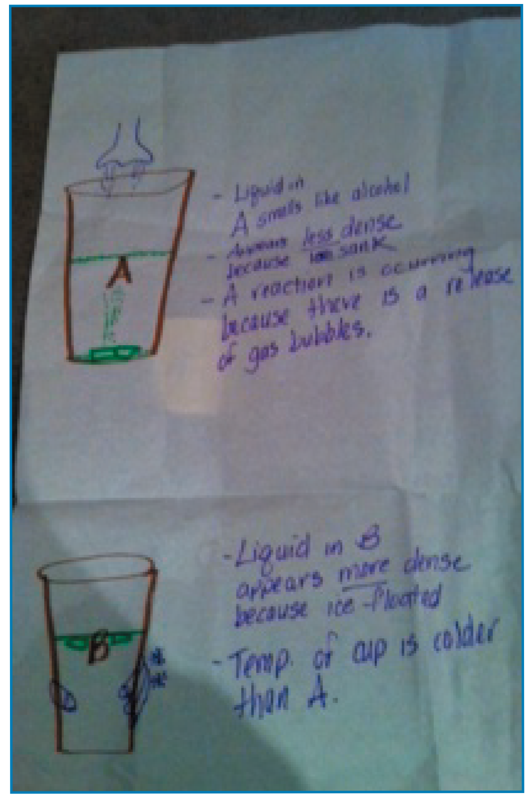
As students share ideas with their partners, Ms. Marquez distributes whiteboards to each group and asks them to draw their thinking and write an explanation of their observations.

RAIN, CONTINUED ON PAGE 9

TALK, CONTINUED FROM PAGE 8

Groups had very different ideas as they reported to the class. Here are two pieces of student work. Both describe density in some way; one group looks as if they are beginning to suggest a molecular model.





As each group presented, Ms. Marquez asked probing questions to better understand how students were thinking about their observations. Once the idea of molecules arose in the student conversation, she decided it was time for a "complex" reading that might help her students.

Before the reading (see At A Glace, page 11), however, she asked students what question they were trying to answer from the reading. Ideas included: Why does ice float in one but not the other? Which is more dense? What makes something dense?

Ms. Marquez had the students use a reading strategy to help them through the text: a post-it with a star provided an answer to their question; a post-it with an exclamation point identified something that they thought was interesting; while a post-it with a question mark was something that confused them, or they didn't understand.

After reading, student partners shared their post-its and continued to think about what they learned from the reading. They returned to their whiteboards and edited their thinking as a precursor of more formal writing which took place later in the learning sequence.

Overall, Ms. Marquez had integrated CCSS-ELA Literacy in Science, and NGSS; she had students working in collaborative groups, communicating with each other, deciding what was critical information and even provided ways they could creatively present their understanding. She had offered a "real world" application of the standards and her students were replying with links in learning!

What Do you You Think?

Here is a Common Core speaking and listening standard—which parts do you think Ms. Marquez addressed?

Present claims and findings (e.g., argument, narrative, response to literature presentations), emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Ms. Marquez's formal writing assignment was for students to do an argumentation writing, make a claim and cite evidence from their experiments and from their reading. Which of these Common Core Writing standards were addressed?

1.Write arguments to support claims with clear reasons and relevant evidence.

a. Introduce claim(s), acknowledge and distinguish the claim(s) from alternative or opposing claims, and organize the reasons and evidence logically.

RAIN, CONTINUED ON PAGE 10

RAIN, CONTINUED FROM PAGE 9

b. Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.
c. Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), reasons, and evidence.
d. Establish and maintain a formal style.
e. Provide a concluding statement or section that follows from and supports the argument presented.

And, as students read, which of these CCSS reading standards applied?

1. *Cite specific textual evidence to support analysis of science and technical texts attending to the precise details of explanations or descriptions.*
2. *Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process phenomenon, or concept; provide an accurate summary of the text.*
4. *Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.*
9. *Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.*

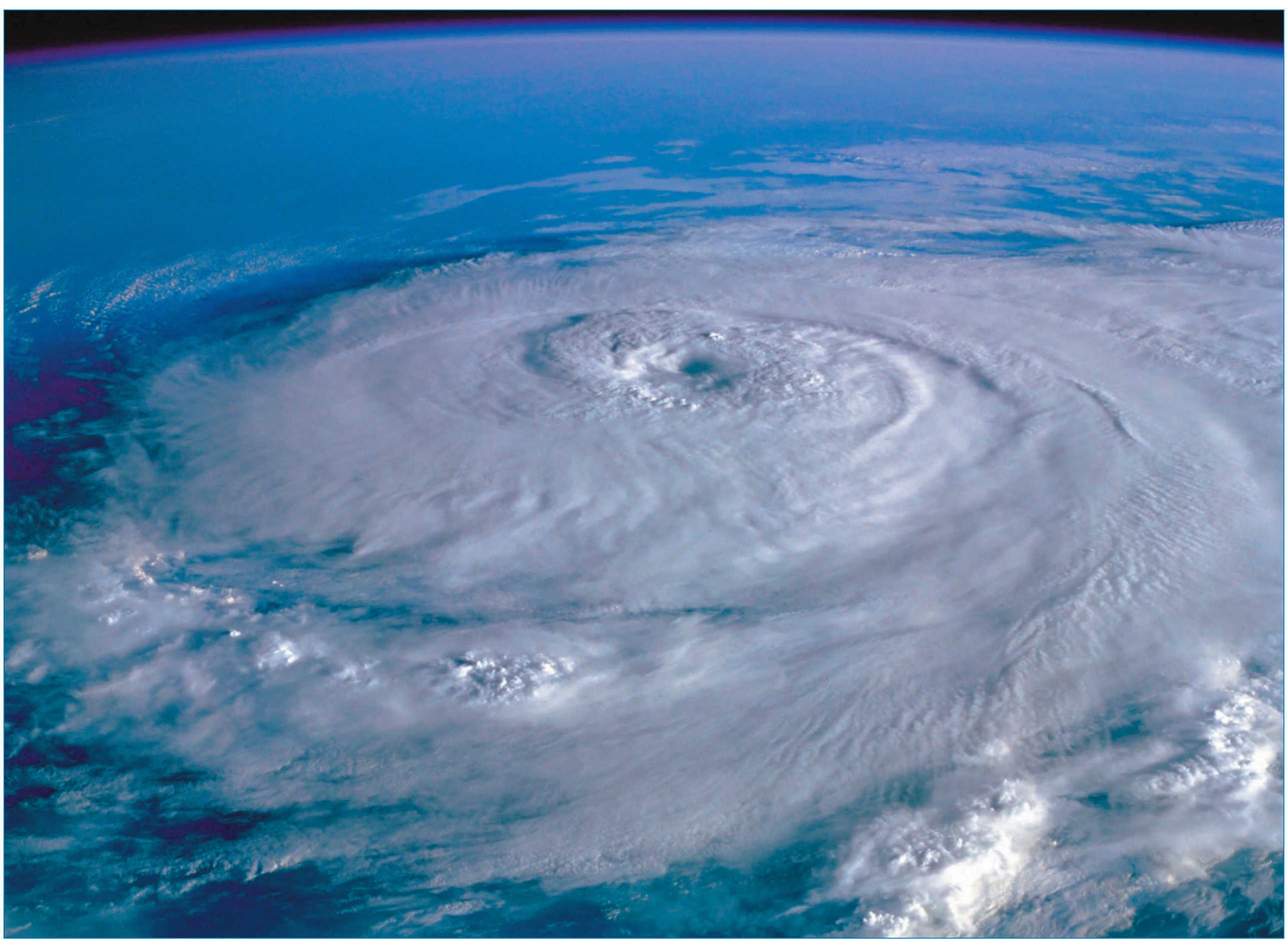
As for NGSS, Ms. Marquez realized that in the learning sequence, students used many practices beyond analyzing data, but she was sure her students could meet the performance expectancy for that practice.

The Common Thread

So how does this example apply if you are not teaching middle or high school? The Literacy in Science Standards for K-5 are embedded in the CCSS-ELA and play out for you as they did for Ms. Marquez. These standards give you license to teach science as the real world context for claims and evidence, explanatory /informational text and critical thinking.

In the next article, we will explore more ways to address the standards by analyzing student work to see how combining these standards deepen students understanding.

Bring on the "Perfect Storm"...for change in education! ■



At a Glance: Standards, Practices and Concepts

Common Core State Standards

The Common Core State Standards for ELA and Mathematics were developed by the National Governors Association Center for Best Practices and the Council of Chief State School Officers and have been adopted by 45 states, including California.

The Standards provide a consistent, clear understanding of what students are expected to learn, so teachers and parents know what they need to do to help them. The standards are designed to be robust and relevant to the real world, reflecting the knowledge and skills that our young people need for success in college and careers.

Assessment of the Common Core Standards will begin in spring 2015.

Next Generation Science Standards

The Next Generation Science Standards, developed by a collaborative, state-led process managed by Achieve, are based on the National Research Council's *Framework for K–12 Science Education.*

The K-12 standards are rich in content and practice, and arranged in a coherent manner across disciplines and grades to provide all students an internationally benchmarked science education.

The standards are written as performance expectancies that combine the three dimensions outlined in the *Framework:* Science and Engineering Practices, Disciplinary Core Ideas and Cross Cutting Concepts.

The standards should be adopted nationally in March, and hopefully by California in November 2013. Currently, there is no national assessment for these standards.

Science and Engineering Practices

The practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world; this also includes the key set of engineering practices that engineers use as they design and build models and systems.

The Standards use the term "practices" instead of a term "skills" to emphasize that engaging in scientific investigation requires not only skill, but also knowledge that is specific to each practice.

The practices are:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and information and computer technology
6. Developing explanations and designing solutions
7. Engaging in argument
8. Obtaining, evaluating, and communicating information

Cross Cutting Concepts

Cross cutting concepts have application across all domains of science. They are a way of linking different domains. These concepts need to be made explicit for students because they provide an organizational schema for interrelating knowledge from various science fields into a coherent and scientifically-based view of the world.

1. Patterns
2. Cause and effect: mechanism and explanation
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter: flows, cycles and conservation
6. Structure and function
7. Stability and change

Why Does Ice Float?

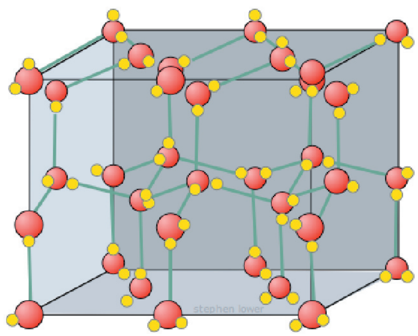
By Anne Marie Helmenstine,Ph.D., About.com Guide

There are two parts to answer this question. First, let's take a look at why anything floats. Then, let's examine why ice floats on top of liquid water, instead of sinking to the bottom.

Answer: A substance floats if it is less dense, or has less mass per unit volume, than other components in a mixture. For example, if you toss a handful of rocks into a bucket of water, the rocks, which are dense compared to the water, will sink. The water, which is less dense than the rocks, will float. Basically, the rocks push the water out of the way, or displace it. For an object to be able to float, it has to displace a weight of fluid equal to its own weight.

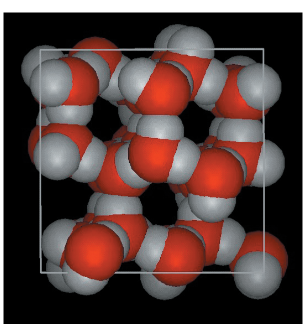
Water reaches its maximum density at 4°C (40°F). As it cools further and freezes into ice, it actually becomes less dense. On the other hand, most substances are most dense in their solid (frozen) state than in their liquid state. Water is different because of hydrogen bonding.

A water molecule is made from one oxygen atom and two hydrogen atoms, strongly joined to each other with covalent bonds. Water molecules are also attracted to each other by weaker chemical bonds (hydrogen bonds) between the positively charged hydrogen atoms and the negatively charged oxygen atoms of neighboring water molecules. As water is cooled below 4°C, the hydrogen bonds adjust to hold the negatively charged oxygen atoms apart. This produces a crystal lattice, which is commonly known as 'ice'.

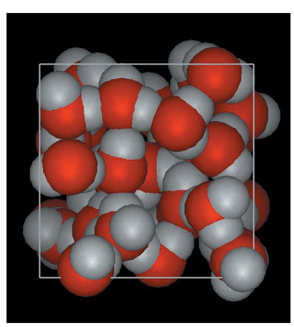


Ice floats because it is about 9% less dense than liquid water. In other words, ice takes up about 9% more space than water, so a liter of ice weighs less than a liter of water. The heavier water displaces the lighter ice, so ice floats to the top. One consequence of this is that lakes and rivers freeze from top to bottom, allowing fish to survive even when the surface of a lake has frozen over. If ice sank, the water would be displaced to the top and exposed to the colder temperature, forcing rivers and lakes to fill with ice and freeze solid.

Here are three-dimensional views of a typical local structure of water and ice (below.) Notice the greater openness of the ice structure which is necessary to ensure the strongest degree of hydrogen bonding in a uniform, extended crystal lattice. The more crowded and jumbled arrangement in liquid water can be sustained only by the greater amount of thermal energy available above the freezing point.



Water molecules in a solid state



Water molecules in a liquid state

The most energetically favorable configuration of water molecules is one in which each molecule is hydrogen-bonded to four neighboring molecules. Owing to the thermal motions above freezing point, this ideal is never achieved in the liquid, but when water freezes to ice, the molecules settle into exactly this kind of an arrangement in the ice crystal. This arrangement requires that the molecules be somewhat farther apart then would otherwise be the case; as a consequence, ice, in which hydrogen bonding is at its maximum, has a more open structure, and thus a lower density than water. ■