Connecticut Journal of Science Education

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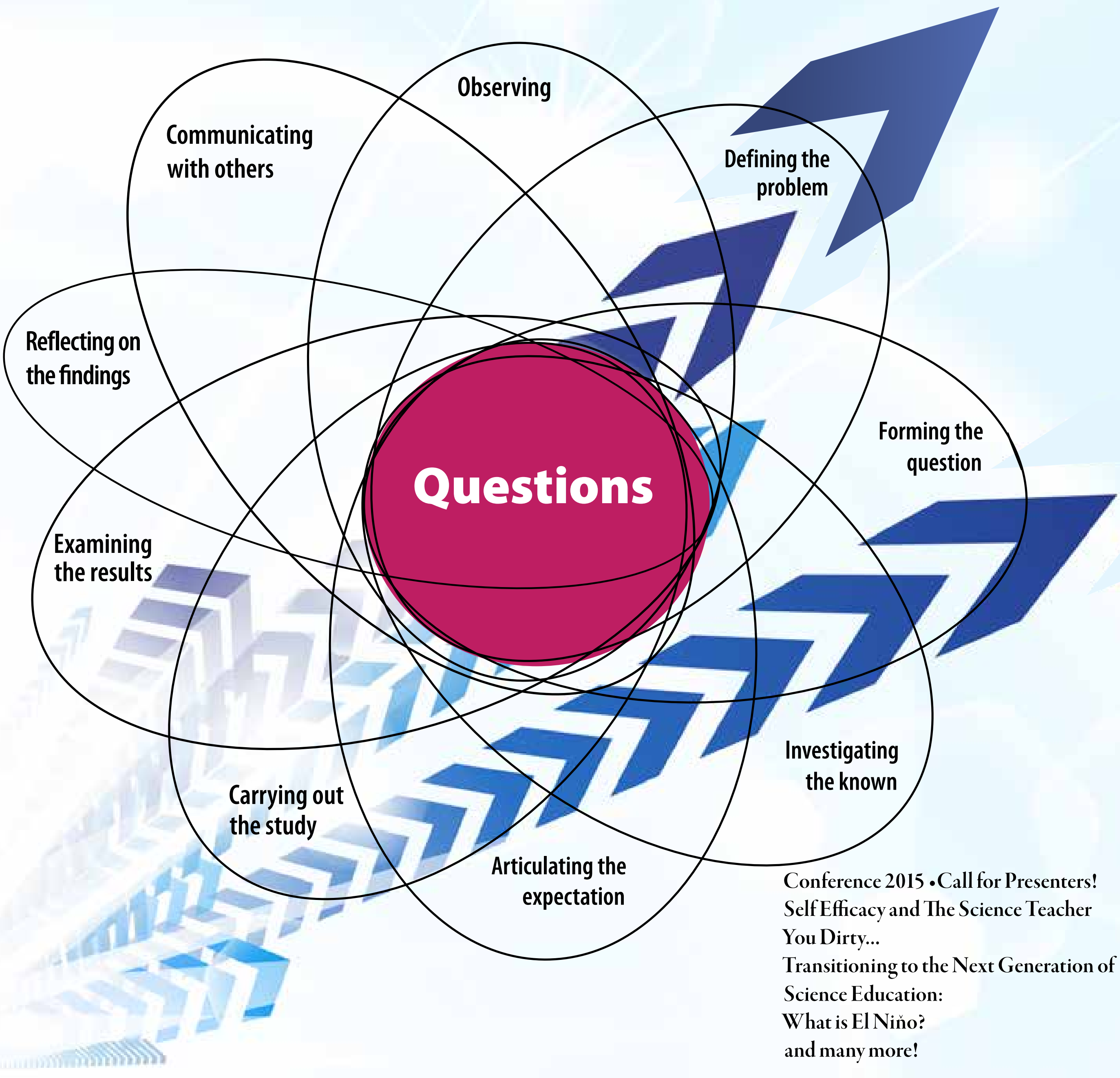

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Self Efficacy and The Science Teacher
You Dirty...
Transitioning to the Next Generation of Science Education:
What is El Niño?
and many more!

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Connecticut Journal of Science Education
Volume 52· No. 2 · Spring · Summer 2015

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Ray Delehant

An Opinion – Looking Back and Forward –

"Change is a Comin". It has been said that the more things change, the more they remain the same. "What comes around goes around." Changes to science curriculums often occur because of certain dynamic events. e.g. Sputnik and the Space Race produced a flurry of new ways to change and improve science teaching and science curriculums. Some may remember BSCS, PSSC, Chem Study, IPS and many other alphabet science curriculum programs. These programs were successful in the 1960's, '70's 80's and lasted into the 1990's. Some had greater success than others and may still be around in some form today. Others faded away to that "Great Curriculum Dust Bin in the sky."

During that time, science & math teachers got to go summer institutes supported by NSF at colleges and universities in various pasts of the country and were paid a stipend while attending summer workshops and institutes. It was also a great way to meet, interact with and exchange ideas and information with teachers from different parts of the United States.

Going forward into the 2,000's. We are now seeing the emphasis on integrated science with an emphasis on STEM. The current idea du jour.

Next up is NGSS which will eventually be adopted by CDSE in one form or another. This adoption seems to be going to be done the right way — Not rushing to adopt NGSS without looking at its pluses and minuses and how NGSS will affect teaching and learning of science in Connecticut classrooms for many years to come. The ride is only just beginning...

Ray Delehant
May 26, 2015

Reader Forum

Readers are invited to comment about stories or issues that have appeared in CJSE ...

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The Connecticut Journal of Science Education published by the Connecticut Science Teachers Association and is produced for the benefit of its membership.

Opinions and comments published herein do not necessarily reflect the policies of CSTA, the CSTA Board of Directors, or the Executive Committee.

Information published was accurate at the time it was received.

The *Journal* is published two times per academic year — Fall Winter and Spring Summer..

Articles/stories from the membership or other science education sources –short or longer– about science education are welcome.

Contact the editors for suitability of story for submission to the Journal.

Deadlines for story submission:
Fall-Winter issue: September 15
Spring Summer issue: March 15

The earlier a story or manuscript is submitted to the editors of the Journal, the easier it is for the editors to review the story for publication in the next edition of the Journal.

Connecticut Journal science Education
Wanted - Editor(s) - volunteer position

Job description:

Gather, report and or write stories of interest to science educators for CSTA Journal of Science Education. Work in collaboration with CJSE editor mostly by electronic communication. Submit stories for publication to editor with your by-line.
Story editors wanted for elementary, middle school, high school for the following topics:

- For content areas
- Biological science
- Earth/Space science
- Ecology
- Chemistry
- Physics
- Science pedagogy, reporting about NGSS
- How to's and labs
- Other stories that would be of interest so science educators.

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We Want to Hear from You

Do have a story idea or announcement that you think we should consider? Do you have a suggestion for how we can make this Journal better? Let us know what you think. E-mail us your suggestions and feedback at delray637@att.net We look forward to hearing from you!

Your editor at work.

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Articles and Authors

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"I love working with bio-engineered food ... this morning, I could swear it said, 'Leaf me alone'."

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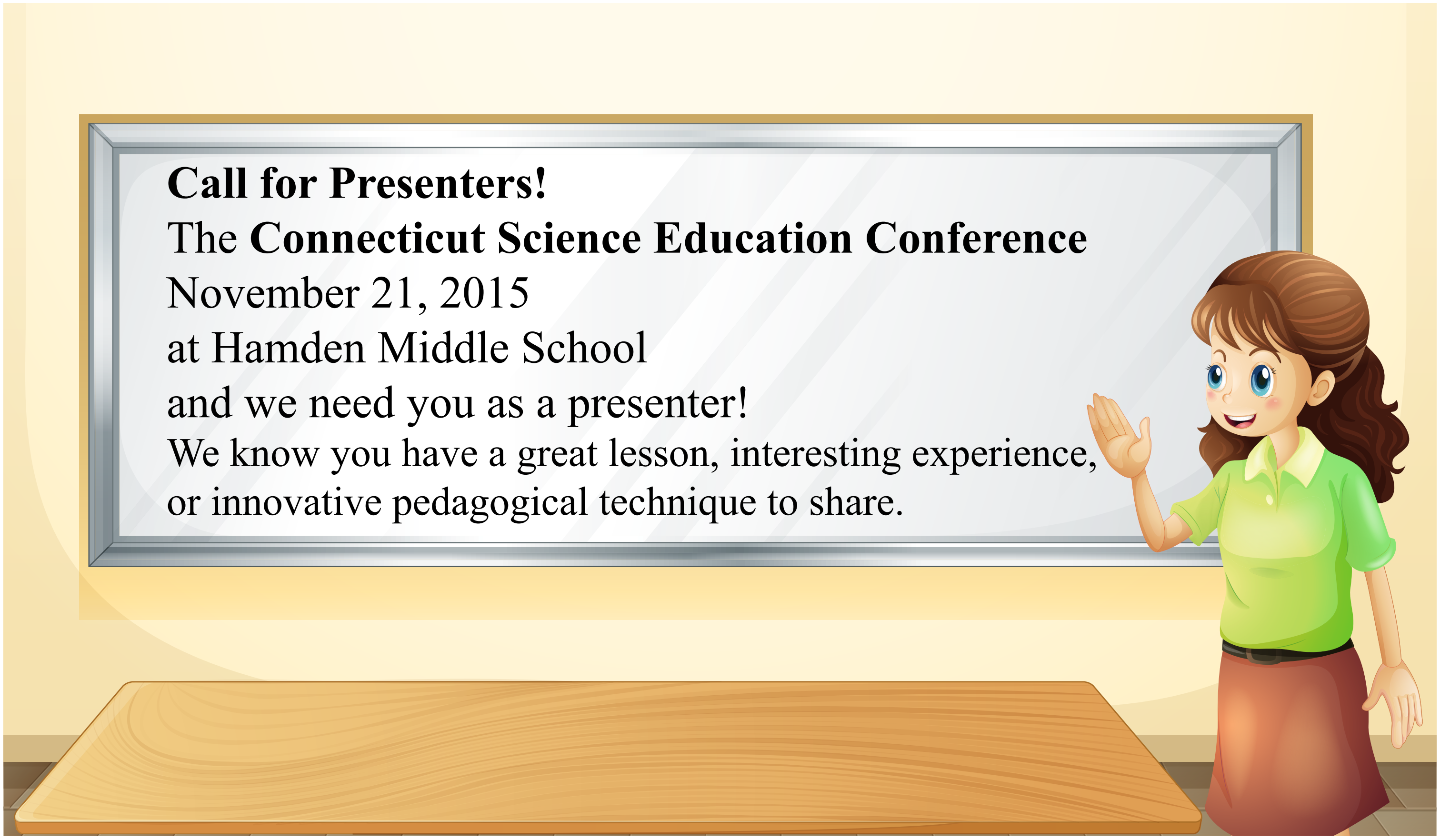

The conference serves science educators in grades K-12, so there is a place for you.
All disciplines (and levels!), from general interest/general science, to biology, physical science, chemistry, earth and environmental science, and physics, K-12 are welcome (and needed!)
NGSS Connections are of special interest, especially engineering practices within topics, and great examples of
Three Dimensional Learning
(connecting content, overarching themes, and science/engineering practices)
If you have never presented before, consider teaming up with a colleague.
As an added benefit, presenters attend the conference for a highly reduced fee!!

Submit your Presentation Proposal online at
https://www.csta-us.org/event_reg_pres.htm?id=2azessfl
Submission Deadline is June 26, 2014
For questions please contact presenter chairs
Laurel Kohl KOHLL@easternct.edu or
Heather Toothaker heather.toothaker@new-haven.k12.ct.us

Call For Submission

Write for The Connecticut Journal of Science Education

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Fall-Winter issue: September 15

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Why YOU should publish

CSTA's *Connecticut Journal of Science Education* allows our members to share their ideas and experiences with all of the science teachers in the state. CJSE's content reflects the needs of our audience - classroom teachers, science supervisors and administrators, and teacher educators. To do this, we ask that members and readers take an active part in its content and development.

The articles in this journal are unique – the voices represented here come from a broad variety of sources. They come from college professors, elementary , middle, and high school teachers, education consultants, and others. This multiplicity of experience is what makes CJSE a valuable resource for everyone.

These are guidelines subject to revision by the editors.

What to submit

- Effective inquiry activities
- Lab activities and how to's
- Integrated science experiences
- Successful partnerships or programs
- Themes of current issues in science education
- Content helpful for teacher training
- Reviews of books, software and technology

Manuscript presentation

- Your manuscript should not exceed 5,500 words — If longer, contact editors for guidance.
- Microsoft Word is the preferred format for document submission, although it may be accepted in any commonly available word application.
- Please choose a file name based on the title or content of your manuscript.
- **Document layout**: Manuscript should be single space.
  - Indents should be one em space (The width of a capitol M or 0.125 inch.)
- Font: Times Roman or Calabri 12 point.
- SI (metric) units should be used throughout the manuscript.
- Tables, graphs, and charts should be appropriately labeled. Text and numbers on X and Y axis should be legible as they will be reduced to fit a column width of 3.8 inches.
- Bibliographies and resource lists should be listed at end of document, alphabetized and limited to current, readily available items.

Photographs

When taking photographs for the Journal, students in laboratory settings must be shown following the appropriate safety guidelines and wearing proper safety attire. Students' faces should be visible, but they shouldn't look directly at the camera. Captions should identify people in photo. Photographer credit should be identified.

Graphics

Graphics should be embedded in the document if possible and identified e.g. Figure 1. Any photo., etc.

Please note that high-resolution files (266 dpi or greater) are preferable for print publication; as a result, file sizes of documents with graphics may be quite large and must be submitted by e-mail.

In order to fit on the page, the maximum width of any graphic – chart, graph, or photo is seven inches. If appropriate, graphic dimensions may be smaller in size. Text must be legible (readable) if font point size is less than 10 point.

The editors are available to answer any technical questions that contributors may have. If you have any problems to submit a manuscript, you may e-mail your query directly to the editors.

How to submit

- Manuscripts should be submitted electronically as attachment via e-mail.
- Include contact information in your manuscript. Name - as you would like it published., e-mail address, home address (so a copy of the Journal can be mailed to you.), school address and grade/subject you teach.
- Identify topic in subject line on your e-mail. e.g. - ***My ABC story for CJSE***. Then the e-mail will not be identified as spam and deleted.
- If you any questions about the submission process, please contact *editor CJSE.*

NOTE: The Journal is published in electronic form as PDF.

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Self Efficacy and The Science Teacher

By Dr. Marlow Ediger
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Self efficacy is an important concept for science teachers to emphasize. Science teachers need to grow in knowledge, skills, and attitudes. This growth is exemplified in teaching quality whereby pupils are the beneficiaries of instruction. The science teacher must achieve in the direction of assisting pupils to realize their individual potential.

Individuals live in a scientific world whereby pupils experience matter in its diverse forms and potentials. Everywhere one looks, hears, smells, tastes, and touches, the world of science is there. Measurement instruments extend these experiences. Thus, it behooves the teacher and pupils to be aware of the scientific world and extend curiosities, interests, and abilities in that direction. Scientific literacy then is becoming increasingly important with its many contributions to society.

Developing Self Efficacy

The science teacher has a plethora of pupils to provide for in teaching and learning situations. They are of diverse ability levels and from different socio-economic levels. The quality of experiences is different one from the other with some having traveled more extensively, visited numerous sites of interest, and have parents who provided for their physical safety, emotional, and esteem needs. The achievement levels in science differs also. Thus, the science teacher needs to become increasingly proficient in teaching pupils whose personalities and past experiences vary. He/she needs to grow in science achievement in terms of subject matter and methods of instruction so that each pupil may be assisted to attain more optimally. Self efficacy then becomes a major goal for the science teacher.

A professional library must be established in a selected room or area to assist science teachers to develop efficacy. Teachers then have numerous opportunities to keep up with the latest trends in teaching. Periodicals, textbooks containing useful subject matter for teaching pupils in diverse areas of science, science eduction textbooks which clearly describe quality methods of instruction, educational psychology texts, sociology/anthropology texts dealing with diverse cultures, among others. Science teachers need encouragement to pursue reading content of interest and purpose in teaching and learning.

Ample opportunities must be provided for teachers to observe other professionals in teaching science. Discussions should follow which enhance professionalism. Establishing purpose for learning, securing interests of pupils, and providing for the needs of each pupil are imperative. Units in science need to be developed with other science teachers. High quality objectives, learning activities to achieve these objectives, and evaluation procedures to notice if objectives have been attained are musts! By mastering elements of the science curricula, the teacher has more strategies in the repertoire for teaching pupils, thus increasing tenets of self efficacy in providing for individual differences. Success in teaching builds upon success in becoming efficacious.

Observing models of excellence in teaching science might well aid the teacher in doing what makes for quality instruction. The model, for example, may come from viewing video clips. A teaching team may analyze the contents and assist in applying what is agreed upon. These vicarious experiences need to be sought out which provide sources for emulation. There are good videos on inquiry learning, problem solving, the project method, among others.

Through conferences and social persuasion, the teacher might also improve instruction. A supervisor, team leader, or coach, strong in human relations and with a wealth of ideas for quality teaching can certainly be an asset to science teachers. They can offer ideas during an observational visit on specific approaches in teaching quality when analyzing instruction. The model presented needs to be such that the teacher accepts innovative subject matter and methodology in teaching. The teacher then wishes to emulate the model with content suggested by a science specialist.

Motivation comes from within the teacher who attempts to overcome complexities and difficulties. Rich past experiences, involving success, build up a reservoir of ideas and challenges which assist in overcoming that which initially might have been perceived as unavoidable. Self efficacy aids feelings of confidence and strength to resolve complex situations. The stronger the self efficacy feelings are, the better the attitudes are in perceived situations. Thus, the efficacious teacher is better able to cope with stressful and depressing situations. Even though challenges are invited, the efficacious science teacher realizes situations which provide difficulties in coping. He/she assesses what is challenging and needs resolutions versus those which possibly exceed talents and abilities possessed. The flexible dividing line here is open ended, but self evaluation provides possible limits. Those who lack self efficacy shy away from difficult tasks. They tend not to be interested in doing what is complex and yet might be achievable with effort. The power of self efficacy in science is in evidence from the following:

* the level of attainment in an ongoing setting
* the learning activity being involved with
* effort put forth in an experience
* choices made in a learning experience
* persistence in the completion of an activity.

Contrast the above bulleted items with those having low efficacy.

Low efficacy stresses ineffective goal setting. These individuals do poorly on tasks to be completed. They choose to work on easier tasks with less effort put forth. These learning activities are less complex to complete. Putting forth as little effort as possible, these pupils may be classified as being "lazy." A low level of motivation is in evidence. Inward motivation of pupils is necessary in these cases and situations as well as scaffolding. The science teacher must have a wide range of teaching skills and methodologies available here.

Teaching for Optimal Learner Achievement

The science teacher may secure and develop excellent guidelines to assist pupil progress. Self efficacy is a goal to attain for pupils, as well as teachers. To start with, the teacher needs to ascertain where each learner is prior to teaching a lesson/unit of study. He/she will increasingly become familiar where each pupil is at the starting point. This occurs with rich experiences in teaching and learning situations. First of all then, the science teacher needs to begin a learning activity with where the pupil is presently in achievement, as well as relate this to the chosen objectives of instruction. As much as possible, this should harmonize with the learning styles of pupils. Styles of learning include working collaboratively versus achieving by the self, deductive as compared to inductive procedures, an explanations approach versus discovery learning, problem solving, as well as project methods of instruction.

In going from the known to the unknown in subject matter and skills learning helps pupils to be successful learners. To completely avoid determining where each pupil is presently in achievement prior to teaching, will minimize pupil efforts due to selected pupils having already having mastered what is taught or it being too complex to attain. There still will be individual differences to provide for and the science teacher may scaffold for those needing additional assistance in learning. Assisting pupils, here, to notice that which needs more attention in learning brings improved order to the teaching/learning situation. Helping pupils to reflect upon past learnings will guide individuals to ascertain what is/is not understood.

Once past achievement is known so that new learnings may be built upon what was previously achieved, the science teacher is ready to introduce new subject matter and skills. There are numerous methods to be used to help pupils attain objectives of instruction including the use of abstract, semi-concrete, and concrete materials of instruction.

Seamless learning in use of these materials makes for quality sequence whereby continuous achievement is possible. Meaning needs to be attached to each fact, concept, and generalization acquired. Thus, pupils understand what is taught; content and skills are not memorized for testing purposes, but are used in discussions, committee work, as well as in every day tasks in school and in society.

Relevant scientific knowledge is then in the offing. Relevancy pertains to important ideas, useful in school and in society. Meaningful learnings then accrue with quality sequence. Inservice education for science teachers should include proper sequencing of subject matter and skills so that new learnings are built, rather continuously, upon what is known.

Evaluation of pupil progress must be ongoing. Teacher observation in the classroom stresses the teacher providing assistance as necessary when help is needed in point and time. Teacher observation must use updated criteria in the assessment process to aid optimal learner progress. Politely, assistance must be provided when utilizing teacher observation to appraise learner performance. Teacher written tests which possess high validity and reliability might also be used to ascertain what pupils have learned, including multiple choice, true/false, and essay test items. Feedback is then provided to the science teacher in terms of what must be retaught. This should help in providing pupils with better sequence in learning. Success in teaching is salient when self efficacy is being stressed. Successful teaching experiences builds confidence within the teacher in meeting needs of pupils. Regardless of the category of the pupil be it gifted, talented, average in achievement, slow learner, mentally/physically handicapped, among others, the efficacious teacher is able to provide for individual differences and assist each to attain as much as possible.

Different Philosophies of Teaching and Learning

The flexible efficacious teacher of science is able to do well under diverse philosophies of instruction. Behaviorism, as one school of thought, stresses the salience of teaching for ends or the measurably stated objectives of instruction. These objectives have little or no leeway in interpretation, be they school wide or stated mandated. The learning activities, chosen by the science teacher, guide pupils to attain the sequential, highly specific objectives. Sequence here resides in the teacher teaching for pupils to achieve each end, or those who selected the mandated objectives. Standardized tests are utilized to measure pupil attainment, generally once a year. Pupils, too, are promoted if each test is passed in grades three through eight. Then, too, an exit test must be passed by secondary students for graduation with a diploma. In addition, the school or school system must pass Adequate Yearly Progress (AYP), each school year until 2014 when the level of competency is reached. Each school year, the yearly test becomes more complex, even though as school district failed to meet AYP standards. The AYP test has frustrated many schools in meeting its standards, perhaps as many as eighty per cent of schools have failed AYP.

Somewhat opposite of behaviorism is constructivism. Constructivism greatly minimizes testing procedures to notice pupil achievement and progress. Rather, the pupils is the focal point of achievement, not attaining the measurably stated objectives which, of course, are not in evidence. They sequence their own learnings in science. Thus, as a science lesson/unit of study moves forward, the science teacher assists pupils to identify problems or broad questions. The problem is delimited in a discussion and subject to evaluation, resulting in an hypothesis. A science experiment is developed by pupils to secure information. The experiment evaluates the one variable and is carefully controlled, resulting in an answer. The answer may then be accepted, modified, or refuted. Pupils are heavily involved during the entire experiment. They identify the problem, locate information, do the experiment, and evaluate the hypothesis, among other necessities. The science teacher is a guide, a facilitator, and a resource person who encourages and assists learners to attain their goals.

Thus, the efficacious is competent and flexible to adapt to diverse strategies of teaching science.

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“You Dirty....”

By Avi Ornstein
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Negative connotations expressed by words such as dirty, diseased and distasteful come to mind when most people hear the word rat. While this rodent may be man’s worst enemy among the mammals, it has also proven to be very beneficial to mankind. A better knowledge of this small mammal might broaden one’s perspective.

First, the term “dirty rat” is only appropriate when referring to lab rats or informers. In the wild, rats are really quite clean, despite the habitats in which they might live. They actually spend quite a bit of time grooming themselves.

They are generalized animals. Like us, they can live almost anywhere and eat almost anything that has any nutrient value. They are the most numerous and successful mammals on Earth, next to man. (The estimated rat population in New York City alone is 28 million!) Their body tissue and eating habits are very similar to those of humans, which have made them play a very important role in health-related research.

The black rat *Rattus rattus* is a common long-tailed rodent of the genus *Rattus* in the subfamily Murinae. The species originated in tropical Asia and spread through the Near East in Roman times before reaching Europe ... Wikipedia

The brown rat, *Rattus norvegicus* also referred to as common rat, street rat, sewer rat, Hanover rat, Norway rat, brown Norway rat, Norwegian rat, or wharf rat is one of the best known and most common rat. Wikipedia

Lab experimentation and observation have also shown that rats are quite intelligent, very adaptable and have a good sense of memory. These factors have also been beneficial in scientific research. In the lab, rats have contributed more than any other animal to the cure of human illness! (In Chinese lore, the rat is noted for its intelligence. It supposedly won a race against eleven other animals by jumping on the back of the bull and creeping forward, leaping off the bull’s head and crossing the finish line first. Thus it starts off the twelve year Chinese zodiac cycle.)

Being a rodent, their cutting teeth—the incisors—grow continuously. It is therefore necessary for them to gnaw. (Rodere—“to gnaw”—is the Latin root for rodent.) If rodents did not wear their teeth down, they would grow through their jaws, making it impossible for them to eat and therefore leading to starvation! Rats can exert 24,000 pounds per square inch with their incisors and are therefore able to gnaw through wood, plastic, plaster, cinder block and even soft metal. Such gnawing, done through insulated wire, is believed to be indirectly responsible for many electrical fires. Even ignoring “fires of undetermined origin,” rats cause perhaps one billion dollars of damage to property every year.

Rats also compete with us by eating about one-fifth of the food we grow. As an example, rats eat at least 48 million tons of rice each year in Asia. That could feed 250 million people! In many third world nations, rats are actually a primary source of protein in people’s diet.

Their survival factors are astounding. A rat can swim a half mile and can tread water for three days. It can scamper right up a brick wall. A rat will survive being flushed down a toilet and can successfully enter a building through the same piping system. It can even fall five stories, hit the ground and then run away unharmed!

The two most commonly known rats are *Rattus rattus* (the black or roof rat) and *Rattus norvegicus* (the brown or Norway rat). White lab rats are actually albino brown rats. The black rat nests in both burrows and above ground. Brown rats are hardier and will displace black rats, but they prefer to live underground. [This fact is an important point later in this article.]

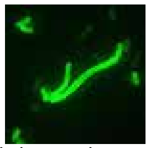
Because of physiological similarities, rats are able to carry over a score of diseases that can be transferred to humans, such as trichinosis and Lassa fever. Lice that live on rats bear typhus and fleas that live on rats transfer bubonic plague—the Black Death.

Returning Crusaders brought spices and black rats—and the Black Death—to Genoa in 1347, and then it spread to northern Europe. The unsanitary condition in cities during the Middle Ages (such as the absence of sewers and trash being dumped in the streets) was a prime breeding ground for these rats. If you think rabbits can multiply,

Spread of the Black Death in Europe (1346–53) consider the fact that, under optimum conditions, a single pair of rats can have 15,000 descendants in one year!

When an army is decimated, it means that 10% of the troops have been destroyed. The bacterium transmitted by the rat fleas did far worse than that. Papal records tell of 200,000 towns that were totally depopulated. In only three years, over 25 million people died. The Black Death killed between ¼ and ½ of the population of Europe!

This was actually the second pandemic (epidemic over a large area) assault of the bubonic plague. The first had begun in 541 AD. A third started from China in 1855. The bubonic plague bacterium was discovered independently by two scientists in 1894 and it was not until 1898 that Paul-Louis Simond finally pieced the picture together while fighting the pandemic in Bombay, India: When an infected rat dies, the fleas carrying the disease seek new hosts, thereby infecting humans.

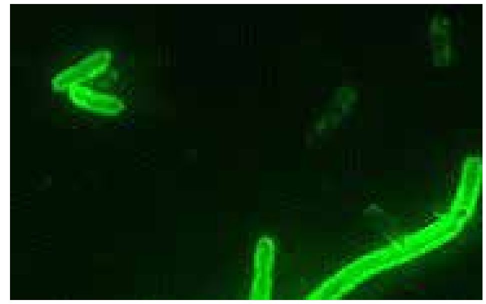


Yersinia pestis (200x magnification). The bacterium which causes bubonic plague.[37] Wikipedia

If the cause had not been discovered until over 40 years into the third pandemic bubonic plague, what saved Europe centuries before that? It was probably the arrival of the brown rat, which displaced the black rat but did not live in such close proximity to people.

Bubonic Plague Organisms

Oriental rat flea (*Xenopsylla cheopis*) infected with the *Yersinia pestis* bacterium which appears as a dark mass in the gut. The foregut (proventriculus) of this flea is blocked by a *Y. pestis* biofilm; when the flea attempts to feed on an uninfected host *Y. pestis* is regurgitated into the wound, causing infection. Wikipedia



The Oriental rat flea (*Xenopsylla cheopis*) engorged with blood after a blood meal. This species of flea is the primary vector for the transmission of *Yersinia pestis*, the organism responsible for bubonic plague in most plague epidemics. Both male and female fleas feed on blood and can transmit the infection. Wikipedia

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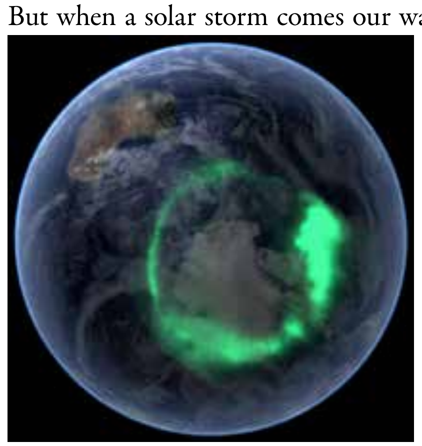
The Cold Never Bothered Me Anyway *(Space Place Astronomy Club Article March 2015)*

By Ethan Siegel

For those of us in the northern hemisphere, winter brings long, cold nights, which are often excellent for sky watchers (so long as there's a way to keep warm!) But there's often an added bonus that comes along when conditions are just right: the polar lights, or the Aurora Borealis around the North Pole. Here on our world, a brilliant green light often appears for observers at high northern latitudes, with occasional, dimmer reds and even blues lighting up a clear night.

We had always assumed that there was some connection between particles emitted from the Sun and the aurorae, as particularly intense displays were observed around three days after a solar storm occurred in the direction of Earth. Presumably, particles originating from the Sun—ionized electrons and atomic nuclei like protons and alpha particles—make up the vast majority of the solar wind and get funneled by the Earth's magnetic field into a circle around its magnetic poles. They're energetic enough to knock electrons off atoms and molecules at various layers in the upper atmosphere—particles like molecular nitrogen, oxygen and atomic hydrogen. And when the electrons fall back either onto the atoms or to lower energy levels, they emit light of varying but particular wavelengths—oxygen producing the most common green signature, with less common states of oxygen and hydrogen producing red and the occasional blue from nitrogen.

But it wasn't until the 2000s that this picture was directly confirmed! NASA's Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite (which ceased operations in December 2005) was able to find out how the magnetosphere responded to solar wind changes, how the plasmas were energized, transported and (in some cases) lost, and many more properties of our magnetosphere. Planets without significant magnetic fields such as Venus and Mars have much smaller, weaker aurorae than we do, and gas giant planets like Saturn have aurorae that primarily shine in the ultraviolet rather than the visible. Nevertheless, the aurorae are a spectacular sight in the evening, particularly for observers in Alaska, Canada and the Scandinavian countries. But when a solar storm comes our way, keep your eyes towards the north at night; the views will be well worth braving the cold! From http://spaceplace.nasa.gov/partners/2015-13/2014_12_NASA_IMAGE_Earth_Obs.jpg .



Auroral overlays from the IMAGE spacecraft.
Image credit: NASA Earth Observatory (Goddard Space Flight Center) / Blue Marble team.

The Impact of the Embedded Science Inquiry Tasks on CAPT Performance

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The following is a brief summary of a forthcoming article investigating student inquiry skills, embedded inquiry tasks and the CAPT. (Full article will appear in 2015-2016 Fall-Winter Journal)

This study investigated the impact of the embedded inquiry tasks on student performance of the science portion of the CAPT. In the fall of 2005, Connecticut introduced revised content standards in science and also established the format for the mandated science testing across grade levels required by No Child Left Behind. One of the most important changes was the placement of inquiry tasks that are embedded within the Connecticut core science frameworks from grade 3 through 10. Called embedded tasks, these inquiry-style activities ask students to demonstrate their ability to construct scientific meaning by solving open-ended questions. These tasks were aligned with the National Research Council position that developing scientific thinking skills takes much more than simple content knowledge. It has been suggested that students should also be able to apply previous knowledge to novel situations.

Using archival data, state average test scores were collected to compare student performance on the science CAPT before the embedded tasks were implemented to those students who had some exposure to them, and to students who participated in them for their entire academic careers. Some evidence suggests that repetitive exposure to inquiry style thinking improves performance. Additionally, students exposed to the inquiry method retain information better, therefore the question is raised as to whether the embedded tasks and the inquiry thinking they required had an effect on student performance on the science CAPT. It could be argued that the class of 2016 should perform significantly better than all other previous graduating classes on the science portion of the CAPT because they had the most exposure to the inquiry skills it assesses.

It was found that students having any form of exposure to the inquiry-style thinking required on the embedded tasks did not perform statistically better than those students who had no exposure to the tasks ($p = 0.213$). The average raw scores for the target years were almost identical, showing no more than a 3.6% variance for the students who were "at goal" and 2.4% variance for students "at or above proficient." Comparison of the scores of the individual content strands that make up the test also showed no statistically significant difference ($p = 0.157$).

The findings of this study suggest students performing the embedded tasks and are then assessed on them on the CAPT seem to show a disconnect between the idea that repeated exposure to inquiry-style thinking leads to increased performance. The performing of inquiry-style laboratories (or scientific and engineering practices, as referred in NGSS) requires more than just repeated exposure. Studies have shown that the ability to perform any type of scientific inquiry is dependent upon a person's level of cognitive development and their overall content knowledge of the subject. There is also some evidence that the reading level of the CAPT may be above that which the students can handle.

Additional studies are needed to review the effectiveness of the placement of the embedded tasks within the curriculum and the way they are assessed on the CAPT. As the science portion of the CAPT is currently under consideration for possible replacement, this is an opportune time to review how students learn inquiry skills

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Transitioning to the Next Generation of Science Education: Leveraging the Current Window of Opportunity for Reform

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Abstract

This case study reports on the processes and products of a multi-year curriculum development and instructional design reform effort in the science department at a comprehensive suburban high school. Key findings are presented and discussed in a case study narrative followed by the implications for programs considering their next steps to improve science education consistent with the tenets of the Next Generation Science Standards. Key findings include significant differences in state-mandated assessment performance scores between groups of students enrolled in the reform sequence of courses when compared with their peers in the traditional track. Additional data sources, including focus groups and surveys, highlight other positive outcomes to result from the case. Important implications for programmatic reform to result from this effort include the need for evidence-based decision-making informed by research, the consideration of the needs of all learners, and allotting adequate time for the piloting, reflection, and revision of new initiatives.

Keywords: Science education, Next Generation Science Standards (NGSS), STEM, Education Reform, Case Study

Introduction

Science education is in the midst of a period of remarkable transition. In fact, we may be facing the most significant developments in our profession since the golden age of science education following the launch of Sputnik in October of 1957. The National Defense Education Act (NDEA) signed into law less than a year after Sputnik provided funding to a broad range of institutions, with the primary purpose of reforming schooling at all levels and across many fields, with particular attention paid to what we now know as STEM (Dickson, 2001). By the time of the first moon landing a decade or so later, the NDEA granted billions of dollars, shaped countless teachers through both pre-service and in-service scholarships and programs, and supported dozens of major curriculum reform projects – many through funding administered by the National Science Foundation (NSF).

The catalyst for today's initiatives also emanate from beyond the borders of the U.S., although the acute sense of urgency to provide for our national defense following that historic autumn day over a half-century ago has been largely supplanted by chronic claims that as a nation the U.S. is steadily loosing its competitive edge in the STEM fields. Once again education is the targeted response. At present, however, reforms are steered by accountability measures as opposed to by large-scale research projects, curriculum initiatives, and policies. Also, unlike a generation ago where increased numbers of defense-oriented STEM personnel was the explicit aim, today we have a broader and more inclusive mission as described in the Executive Summary of the Next Generation Science Standards (NGSS):

> There is no doubt that science and, therefore, science education is central to the lives of all Americans. Never before has our world been so complex and science knowledge so critical to making sense of it all. When comprehending current events, choosing and using technology, or making informed decisions about one's healthcare, science understanding is key. Science is also at the heart of the United States' ability to continue to innovate, lead, and create the jobs of the future. All students whether they become technicians in a hospital, workers in a high tech manufacturing facility, or Ph.D. researchers must have a solid K-12 science education. (NGSS Lead States, 2013, p.1)

There appears significant promise that the catalytic effect of the NGSS, supported by the earlier release of *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), has the transformative potential to impact the STEM fields unlike previous efforts. Although various iterations of science standards documents have been available for decades (AAAS, 1993; NRC, 1995), perhaps in the wake of the momentum created by a comprehensive and unified approach to the their development involving the National Research Council (NRC), the National Science Teachers Association (NSTA), and the American Association for the Advancement of Science (AAAS), among others, there exists an opportunity to advance teaching and learning within the STEM fields in ways that heretofore have not been readily possible. We argue the NGSS offers what Kuhn (1962) would likely call an opportunity for a paradigm shift, that is an episodic opportunity for a period of revolutionary advancements.

How do we leverage this once in a generation opportunity for reform? We must initially recognize the window for this reform has been open for a number of years, and numerous organizations and institutions have begun to consider the implications for a widely adopted framework and subsequent standards. As a case in point, the National Science Teachers Association (NSTA, 2014) has released a position statement on the NGSS, which outlines several key points that distinguish this iteration of standards from previous ones and urges its adoption. Such key points include: students engage in science learning at the nexus of three dimensions – science and engineering practices, crosscutting concepts, and disciplinary core ideas; concepts in the NGSS build coherently from kindergarten through 12th grade; NGSS focus on both deeper understanding and the application of content; science and engineering are integrated; the focus is on college *and* career readiness in preparation for citizenship; and the NGSS are aligned with the widely adopted CCSS already put into practice in many states. An important and vital advancement in the NGSS and the supporting framework is the considerable focus on the science and engineering practices as a means to consider crosscutting concepts and core disciplinary content. This integrated approach has potential to move beyond the false dichotomy of content versus process inherent in so many previous reform documents, and allows for a strategic and purposeful effort to be directed toward learning and not merely curriculum enhancements and/or so-called best practices of doing science. For example, Windschitl (2008) notes that, "Scientists are ultimately engaged in developing persuasive arguments around competing explanations for natural occurrences" (p. 2). He argues science specific forms of talk are what shifts scientists' and students' thinking forward. He describes this talk as four interrelated conversations, including: Organizing what we know and what we'd like to know; Generating a model; Seeking evidence; and Constructing an argument. (p. 3)

Clearly, such research was influential in the development of the NGSS, as modeling is represented as a key element of the science and engineering practices. The essential point being that science discourse is at the core of science instruction, and the NGSS explicitly supports purposeful conversations to promote such learning. Thus, as we consider leveraging the NGSS in this window of reform, exemplars of actual programs that have initiated such reform-minded work are essential in guiding our efforts as we move forward as a field. This paper reports on one such case study.

Context for the Study

The Greenwich Public Schools are located within the town of Greenwich in southwestern Connecticut. The district consists of 15 schools with a total enrollment of about 9000 students in pre-kindergarten through 12th grade. The district is characterized by a moderate degree of socioeconomic and demographic diversity. In the district as a whole, 14.1% of K-12 students are eligible for free or reduced school lunch, 30.5% are identified as students of color, and 17.9% come from a home wherein English is not the primary language. In particular, Hispanic students account for 16.7% of the student population, and Spanish and Portuguese are the more common of the non-English first languages reported for families in the district

The high school is traditional in that students are tracked and leveled, and science is one of the customary secondary departments that essentially operate within a disciplinary silo. At the outset of this reform work, like may science departments across the nation, it could be characterized as one with pockets of excellence offering a wide range of core courses, AP classes, and electives. The faculty is comprised of those along the professional continuum, some with many years in-service to novice teachers in their induction years. Scores on the 10th grade Connecticut state mandated test for science, although showing overall improvement from the five year period 2006 to 2011, were variable across this time period and lower than the overall average for other comparable Connecticut public school districts within its state designated reference group (see Table 1). That period represents the time frame immediately prior to the initiation of this reform effort.

Table 1

Greenwich Public Schools 10th grade Connecticut Academic Performance Test (CAPT) scores for Science for 2006 through 2011, with comparison to overall DRG B average for 2010 and 2011 CAPT Science.

	Greenwich Public Schools						DRG B	
CAPT Science	2006	2007	2008	2009	2010	2011	2010	2011
% Advanced	33.7	33.6	27.0	34.2	37.5	35.5	41.6	42.7
% Mastery	59.1	62.1	52.8	61.9	64.8	62.8	70.3	71.7
% Proficient	90.1	92.1	86.6	92.0	93.8	93.1	95.6	95.3

Reported values represent the percentage of students (%) scoring at Advanced, Mastery, and Proficient levels for each of the indicated testing years. DRG = Demographic Reference Group

Looking beyond standardized state test scores, the mean satisfaction rating by students for their overall experience at Greenwich High School as reported in the 2009-2010 Harris Interactive School Poll Executive Summary was 7.5 out of 10. Thirteen items across the survey sub-categories were identified as areas of concern. In particular, the item "You like what is taught in class" in reference to science was rated as the 7th most pressing area for improvement within the high school as a whole. Within the Quality of Teaching category, the mean satisfaction rating of Greenwich High School students for the sub-category Science Teacher was a 7.2 out of 10. Further analysis of student satisfaction with science teaching indicated that the items, "Science Teacher: Makes the class interesting." And "Science Teacher: You Like what is taught in this class."as were identified the two of most pressing items for improvement.

Thus, both the state assessment data for science and the satisfaction survey data suggested that science instruction at

Greenwich High School could benefit from some consideration of reform. It is important to recognize that at the outset of this case study this was *not* a science department in crisis. In fact, it might be characterized as quite typical in that from day to day teachers taught leveled classes in a disciplinary sequence of biology, chemistry, and so on, as students generally succeeded at "doing school" as was expected of them - like in countless towns across America (Pope, 2003). And yet the seeds of reform were sowed in 2008 as district leaders committed to leveraging best practices for STEM education as seen in comparative international reports on science learning (OECD, 2003), and the subsequent knowledge in the following years that new national frameworks were a real possibility. Perhaps most significantly, Greenwich Public Schools adopted a clear proactive stance and convened a curriculum committee at the high school to consider the development of what they described as a "world class" secondary science program. As such their initial step was to authorize the development of a conceptual framework to guide the curriculum and instructional design work such that the effort would be informed by research (Moss, 2008). The committee subsequently decided that an innovative two-year sequence of core courses (Integrated Science and Biochemistry) could replace the traditional disciplinary sequence as a means to teach through a thematic, real-world curriculum in ways that emphasized the practices of science in instructionally sound ways.

This case study will report on the various sources of data along with the process and products of this multi-year curriculum development and instructional design effort that stemmed from these initial conditions and decisions. Key findings will be presented and discussed in a case study narrative along with the implications and specific recommendations for programs considering their next steps to improve science education consistent with the tenets of the NGSS.

Methodology

Six sources of qualitative and quantitative data were analyzed for this case study, including results from: state academic tests, the Harris Interactive school satisfaction poll, student interest surveys regarding thematic curriculum topics, a STEM attitudes and experiences survey developed for this project, student focus groups, and a college admissions personnel survey. Methodologies and data presented and discussed in the following sections are designed to both substantiate the claims made with regard to the case study narrative in the Findings section of this paper while concurrently highlighting potential sources of data useful to inform the work of reforming science programs.

Connecticut Academic Performance Test (CAPT) Data

As already highlighted in the previous section, standardized science achievement scores can be catalytic in highlighting the need for change. Since 1994, the Connecticut Academic Performance Test (CAPT) has been the state of Connecticut's mandated assessment administered to students in their Sophomore year (grade 10) for the content areas of: Mathematics, Reading Across the Disciplines, Writing Across the Disciplines, and Science. Although the mathematics, reading, and writing CAPT assessments are currently being phased out and replaced with the Smarter Balanced Assessment Consortium (SBAC) test, a standardized online digital assessment based on the Common Core State Standards and administered to students in their Junior year (grade 11), for the immediate near future students in the state of Connecticut will still be assessed for proficiency in the CT State Science Frameworks using the Science CAPT.

The third generation Science CAPT test, instituted in March 2007, consists of 60 selected response and 5 constructed response items administered over two 50 minute testing sessions. The selected response questions are machine-scored as correct or incorrect. The open-ended items are hand-scored using a four point (0-3 points) rubric. Science CAPT questions align with and assess CT State Scientific, Literacy and Numeracy Standards as well as CT State Content Standards within the strands of: Energy Transformations; Chemical Structures and Properties; Global Interdependence; Cell Chemistry and Biotechnology; and Genetics, Evolution and Biodiversity. Scaled scores are converted to a final score of 1-5, using a conversion that has remained consistent throughout all testing years of the third generation test. Students earning a final score of a 3 are rated as "Proficient," those scoring a 4 are rated as achieving "Mastery," and those scoring a 5 are rated as "Advanced." Students scoring at the "Mastery" level or higher are deemed to have met the CT State goal for science competency. Students scoring at the "Proficiency" level or higher are deemed to have met minimum competency requirements. In the Findings section of this paper, additional CAPT score analysis will be presented and discussed specifically with regard to the performance of students in both the traditional and redesigned science course sequences.

Harris Interactive School Poll

The Harris Interactive School Poll is a commercially available questionnaire marketed by Harris Interactive, Inc. for use by school districts to gather and analyze data about stakeholder satisfaction in order to identify and prioritize areas for improvement of educational services within a district. The questionnaire may be conducted in both online and standard paper formats, and is administered to four major categories of education stakeholders within a subscribing school district, including elementary students, secondary students, parents, and district staff. Survey items address stakeholder satisfaction across numerous focus areas including the quality of teaching, curriculum, and overall school satisfaction. Each focus area sub-category includes a variety of dichotomous (yes/no) and/or three point scale ("excellent," "adequate," or "inadequate") questions, as well as ratings of overall satisfaction within each sub-category and for the school as a whole. Using the combined results of stakeholders' responses, Harris Interactive performs an impact analysis applying the principles of multivariate statistical analysis to assess the relative impact of various conditions on both overall stakeholder satisfaction and stakeholder responses within focus area sub-categories. Results are reported to school districts as mean overall satisfaction ratings for the variety of focus area sub-categories, and an "impact index" which identifies the relative contribution of a given sub-category item to the overall satisfaction ratings. Thus, the impact analysis identifies items within each focus area for which improvement is both necessary and likely to strongly impact the overall educational experience. The poll is generally administered every two to three years so as to provide iterative guidance and feedback to facilitate district strategic planning and promote continuous improvement. As noted previously, this poll identified that reforms to the science program are ones that could potentially impact the overall quality of experience from students' perspectives.

Student Interest Surveys Regarding Potential Thematic Topics

In order to maximize student interest in and engagement with the curriculum of the redesigned science courses, survey data was first collected regarding student self-reported levels of interest in a variety of proposed thematic topics. For these surveys, the curricular reform team, consisting of four science teachers and a external science educator, first brainstormed potential cross-disciplinary thematic topics that the team speculated were likely to be relevant and interesting to students and which could be reasonably combined in an authentic and flowing narrative that encompassed major themes in physical, life, and earth sciences. Surveys also included a small selection of topics believed to be highly unlikely to appeal to student interest, in order to gauge the candor of student responses. Surveys were then administered to students, either in pen-and-pencil form (for the Freshman Integrated Science course) or in electronic form (for the Sophomore Honors Biochemistry course). In both cases, students in the Freshman and Sophomore grades were surveyed during normal class time of their current science course. Responses were then tallied to identify the proposed thematic topics receiving the highest overall interest ratings.

Specifically, the student interest survey conducted for the development of the Sophomore Honors Biochemistry course contained a total of 15 proposed unit topics, two of which ("Enzymes and You" and "Chemistry of Photosynthesis") were predicted to receive very low interest ratings. A total of 278 Greenwich High School students in the Freshman and Sophomore grades were surveyed via a Google form during their normal class time. Students were asked to rate each of 15 proposed thematic topics on a four point scale of from 1 "very interested" to 4 "not at all interested". The total number of students providing the indicated interest response for each of the proposed thematic topics and the overall interest rating average for each proposed thematic topic were then calculated and compared. Results will be presented in the Findings section of this paper.

Student STEM attitudes and experiences survey

Greenwich High School students in the Freshman and Sophomore grades were also surveyed via a Google form during their normal class time and asked to rate their level of agreement or disagreement with 43 different declarative statements expressing STEM attitudes and experiences. Items were derived from the Affective Elements of Science Learning Questionnaire (Williams et al., 2011) and the Student Technology Behavior & Attitude Survey (Wai-kit Ma, et al., 2005). Self-reported agreement versus disagreement varied on a 5 point Likert scale of from 1 "Strongly Agree" to 5 "Strongly Disagree." Data were amalgamated based upon science course enrollment, and were subject to Mann-Whitney analysis, a non-parametric test for the significance of the difference between the distributions of two independent samples comprised of ordinal data. Pairwise samples comparisons were made between Freshman Integrated Science versus Freshman Traditional students, between Sophomore Honors Biochemistry and Sophomore Traditional students, and between Sophomore Honors Biochemistry and Sophomore Honors Chemistry students. Overall Likert scale averages for each survey item were also calculated and are reported in a subsequent section.

Focus group

Focus group data was collected using a purposeful sample of students enrolled in the Integrated Science/Biochemistry course sequence. Participation in the focus groups was intended to be representative of Juniors at GHS during the 2103-14 academic year enrolled in these courses, and as such participants were purposefully sampled. Those eligible for participation were drawn from a pool of students with open blocks to minimize class disruptions. An e-mail was sent to all eligible participants based on their availability (with an open block) and they were invited to participate in a focus group. A total of 8 were interviewed over 2 focus group sessions. Topic areas for questions included students' experiences, beliefs, and attitudes regarding assessment, technology, and the curriculum (including curricular resources available to the students). Focus group sessions ran approximately 45 minutes and were audio-recorded. Given that survey questions were open-ended, a grounded approach relying on constant comparison for coding and analysis was utilized (Strauss & Corbin, 1998). Data analysis involved reiterative listening of all recordings and code-mapping (Anfara, Brown, & Mangione, 2002) to develop specific categories of response pertaining to each question. To begin code mapping, responses was analyzed as "episodic units" (Grant-Davie, 1992, p. 276), identified by their singular focus on a particular idea. For instance, a response to the question about a student's notion of a rigorous class might result in the respondent naming "the teacher" "assignments" and "attitude toward the subject" in a single sentence. Each of these was coded as a single episodic unit. Most responses contained more than one episodic unit. Similar codes derived from each question's answers were combined into comprehensive categories.

Institutions of Higher Education Admissions Survey

A survey was developed for use in this study for the purpose of gauging the impact of the new sequence of science courses on potential for student admission to institutions of higher education. That is, an explicit effort was made to help ensure that admission officers would not penalize students who choose to participate in the re-developed sequence of high school science courses. In an initial survey, questions were administered by pen-and-pencil survey to all admissions officers attending the Greenwich High School College Fair in October of 2011. In a second survey conducted in March 2014, questions were administered electronically to 294 admissions officers representing institutions to which Greenwich High School students have been offered admissions in recent years. Between the two surveys, a total of 108 institutions of higher education responded. Six institutions responded twice (i.e., to both surveys). In such cases the more recent response was included in the data set. Both constructed and selected items were developed, and the resulting data was analyzed and will be presented in the following section.

Findings

In any curriculum reform process it is imperative to clearly articulate a conceptual framework for reform. For this case study such principles were derived from the research-based framework developed at the outset of the study (Moss, 2008). From the outset, the reform process was designed to be non-linear and iterative, involving periods of planning, implementation, experimentation, and reflective adjustment. Specifically, the design principles at the core of our curriculum reform process included:

- a strong, consistent, and explicit commitment to and development of science and engineering practices now so explicitly expressed in the NGSS;
- pedagogy supported by research on instructional best practices and emphasizing technology-supported, collaborative work by students engaging in the science and engineering practices;
- rigorous content framed within cross-disciplinary STEM thematic units that engage students in problems and questions of real-world relevance grounded in student interest;
- design of formative and summative assessments that accurately measure students' progress toward mastery of STEM skills and content; and
- responsibility to meet state standards and to prepare students for standardized assessments.

Our reform work encompassing the development of new a sequence of Freshman and Sophomore core science courses presented and discussed in this case study spanned a period of over 4 years. A timeline and key steps by which we approached and managed this effort is outlined following:

Phase I
(2010-11)

Activities & Accomplishments:

- Reviewed Best Practices literature
- Reviewed draft new framework (Next Generation Science Standards in development)
- Conducted Student Interest Surveys for Possible Integrated Science thematic Units
- Developed Integrated Science course outline, with four thematic units: Survival; Sports and Human Performance; Earth from Space; and Sustainability
- Designed Integrated Science custom published textbook

Challenges:

- Selecting curriculum reform team
- Ensuring proper teacher subject area certifications
- Securing the necessary technology (iPads)
- Communication with parents, students, and middle and high school faculty, staff, and counselors to explain Integrated Science course, recruit students, and enlist support
- Establishing priorities and managing limited non-instructional time

Phase II
(2011-12)

Activities & Accomplishments:

- Initiated Integrated Science pilot with 5 sections (total of 100 students and 4 teachers)
- Conducted student experience surveys of current Integrated Science students
- Conducted student interest surveys for possible Honors Biochemistry thematic Units
- Developed Honors Biochemistry course outline, with four thematic units: Enhancing and Evolving to "Perfection"?; Causes and Treatment of Cancer; Consciousness and Personality; Drugs and Poisons
- Designed Honors Biochemistry custom published online eTextbook
- Conducted initial Institutions of Higher Education Admissions Survey
- Secured all necessary faculty dual certifications

Challenges:

- Dual path scheduling
- Management of new technology resources (iPads)
- Acquisition of necessary resources (such as lab equipment) for Honors Biochemistry
- Communication with parents, students, and middle and high school faculty, staff, and counselors to explain Integrated Science and Honors Biochemistry courses, recruit students, and enlist support

- Establishing priorities and managing limited non-instructional time

Phase III
(2012-13)

Activities & Accomplishments:

- Expanded Integrated Science sections
- Initiated Honors Biochemistry pilot
- Conducted student experience surveys of current Integrated Science students and current Honors Biochemistry students
- Reviewed and revised Integrated Science curriculum based upon pilot year data

Challenges:

- Scalability issues, including: dual path scheduling; management of technology (iPads) and laboratory equipment; and proper certifications for increased number of teaching staff
- Ongoing communication challenges (see Phase II)
- Establishing priorities and managing limited non-instructional time

Phase IV
(2013-14)

Activities & Accomplishments:

- Conducted student experience surveys of current Integrated Science students and current Honors Biochemistry students
- Reviewed and revised Integrated Science curriculum based upon expansion year data.
- Reviewed and revised Honors Biochemistry curriculum based upon pilot year data.
- Analyzed CAPT data for first cohort.
- Began collecting and analyzing course enrollment and performance data for dual paths.
- Conducted second Institutions of Higher Education Admissions Survey

Challenges:

- Ongoing scalability issues (see Phase III) and communication challenges (see Phase II)
- Convergence of alternate paths in Junior year science course enrollment
- Release of final Next Generation Science Standards versus lag period of state-by-state adoption of the NGSS: What will our state standards actually be? What will state mandated testing look like under those new standards?
- Establishing priorities and managing limited non-instructional time
- Identifying strategic next steps

These courses included a Freshman Integrated Science course and a Sophomore Honors Biochemistry course that were offered as an alternative to the more traditional, single discipline Freshman Biology to Sophomore Chemistry track. Although this timeline includes details specific to this case study, and which would likely vary somewhat for other schools and districts based upon their unique needs and experiences, it is anticipated that these details and data provide useful benchmarks underpinning a multi-year curriculum reform process.

The essential activity of Phase I of the curriculum reform process was the development, implementation, and analysis of a student interest survey by which to select the rigorous, interdisciplinary, and relevant thematic units around which a new science course was to be built. For such surveys in this case study, the reform team brainstormed potential topics that were likely relevant and interesting to students and which could be reasonably combined in an authentic and fluent narrative that encompasses the required content standards of the proposed course, and which inherently supported the pursuit of the Science and Engineering Practices. For the Freshman Integrated Science Course, from an original list of ten proposed thematic topics, high levels of reported student interest collected via pen-and-pencil surveys supported the development of four thematic units encompassing the themes of: Survival, Sports and Human Performance, Earth from Space, and Sustainability. Design principles were then applied to construct unit outlines around these four themes utilizing to the Understanding by Design (UbB) model (Wiggins & McTighe, 2005) which explicitly described unit content, objectives, performance tasks, and assessments with embedded STEM practices and best-practices pedagogy. Objectives and performance tasks were selected to immerse students in problem solving around real-world issues and questions that incorporated a wide variety of skills and content across the scientific disciplines. Topics for the Integrated Science course are arranged not in traditional disciplinary categories, but in support of the practice of pursuing evidence and explanation to support thematic learning. Please refer to the following for an overview of the content strands and performance tasks for each of the four thematic units of the Integrated science curse:

UNIT I - Survival

Content Stands include:

- plate tectonics, convection currents, Earth's internal energy, weather, and catastrophic events
- energy transformations including conduction, convection, radiation, and specific heat
- energy as a requirement for human survival
- combustion reactions
- thermodynamics including specific heat, phase changes, and how heat released is related to efficiency of a fuel source
- disease transmission including differentiation between prokaryotes and eukaryotes, virus versus bacterial infections, treatment methods, and sanitation methods

Performance Tasks include:

- analysis of global weather patterns data from the National Oceanic and Atmospheric Administration (NOAA)

- analysis of data concerning mortality of climbers ascending Mt. Everest from the *British Medical Journal*
- thermodynamics lab to evaluate the relative heat outputs from combustion of various fuel sources
- water lab to evaluate and compare various treatment methods to purify water contaminated with bacteria
- solar cooker engineering lab which emphasizes the engineering design cycle to blueprint, build a prototype, test, and refine the prototype for the most effective solar cooker

UNIT II - Sports and Human Performance

Content Stands include:

- atomic structure, including Bohr's model and valence electrons
- chemical bonding including covalent versus ionic bonds and Lewis Dot structures
- synthetic polymers including high density polyethylene and low density polyethylene, and the correlation between chemical structure and bonding of materials with the specific properties (i.e. tensile strength, puncture resistance, abrasion resistance, flexibility) of these materials
- macromolecules and organic compounds, especially as they relate to nutrition and chemical energy
- electrolytes as they pertain to the proper neurologic functioning of the human body
- electricity and circuits including relationships established through Ohm's Law

Performance Tasks include:

- analysis of data correlating nutrition and cognitive functioning as from primary peer-reviewed articles published in the journal *Physiology & Behavior*
- evaluation of nutrition labels to justify which food products will provide the most efficient type of macromolecules and organic compounds required to sustain human performance
- sports equipment engineering lab in which students design a polymer-based article of athletic equipment and then conduct a series of tests to ensure polymer quality and proper function of the equipment based upon desired polymer properties
- website design challenge where students plan, design, create, and publish a web-based site to promote both their polymer-based piece of sports equipment and a nutritional food product, emphasizing the scientific evidence for each product

UNIT III - Earth From Space

Content Stands include:

- acid-base chemistry including pH, neutralization reactions, acid rain, and the impact of pH balance on the biotic and abiotic world
- biogeochemical cycles, including carbon, nitrogen, and hydrologic cycles, and their cooperative function to support life on Earth
- the Greenhouse Effect, climate change, and impact on the habitability of Earth
- electromagnetic spectrum, including its use for/in satellite technology, space exploration, imaging, and data analysis
- evaluation of our solar system's planets and moons to determine habitability based upon the requirements for life

Performance Tasks include:

- analysis of exo-planet research data from the Planetary Habitability Laboratory (PHL)
- acid rain and habitability lab investigating the effect of pH on the growth of plant (lettuce seed) and animal life (goldfish)
- biosphere design challenge to create a self-sustaining aquatic or terrestrial micro-environment capable of maintaining a heterotrophic life form (such as worms, crickets, and/or fish)
- maintenance of and analysis of data from an greenhouse aquaponics apparatus supporting goldfish, lettuce, tomatoes, and basil plants

UNIT IV - Sustainability

Content Stands include:

- concept of the Tragedy of the Commons
- key moments in history that caused paradigm shifts in our environmental perspectives and policy
- population dynamics including carrying capacity, age structure diagrams, and factors affecting population trends; pollutants and brownfield and/or superfund sites including history and current events
- bioaccumulation
- eutrophication including the nitrogen cycle, the hydrologic cycle, hypoxia, dead zone mapping, watersheds, and how humans contribute to the issue
- waste management including recycling, composting, landfills, sewage, and septic systems
- global climate change including the carbon cycle and how humans impact the Greenhouse effect
- energy generation including an evaluation of renewable versus nonrenewable energy sources in terms of their cost, safety, efficiency, and sustainability

Performance Tasks include:

- analysis of data concerning flounder populations in the Long Island Sound as from the Long Island Sound Study (LISS)
- evaluation of the risk associated with the Hudson River Drudging controversy
- "Smart Growth Community" project in which students evaluate the sustainability of their current community and/or propose and justify a plan for the design and construction of a new sustainable community

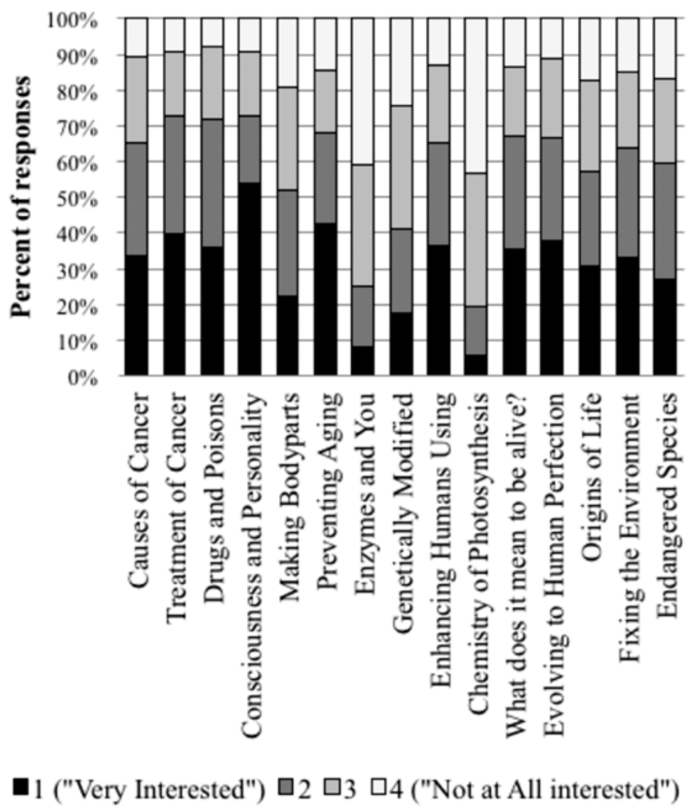
Results for the student interest survey conducted by the Greenwich High School team during Phase II for the development of the Honors Biochemistry course are presented in Figure 1. This survey indicated the highest level of self-reported student interest was in the proposed topic "Consciousness and Personality," which became a stand-alone thematic unit. Similarly, the highly rated "Causes of Cancer" and "Treatment of Cancer" were combined into a single Causes and Treatment of Cancer unit, which was designed to also incorporate the concept of "Preventing Aging." The highly rated "What does it mean to be alive?" and "Evolving to Human Perfection" were combined into a single unit titled Enhancing and Evolving to "Perfection"? Finally the highly rated "Drugs and Poisons" was written as a fourth unit. Similar to the Integrated Science development process, UbD design principles were then applied to construct unit outlines around the four themes, in which topics were arranged in support of the practice of pursuing evidence and explanation to support thematic learning..

Figure 1.

Results of student interest survey for possible Honors Biochemistry thematic units.

A total of 278 Greenwich High School students in the Freshman and Sophomore grades were surveyed via a Google form. Students were asked to rate each of 15 proposed thematic topics on a four-point scale of from 1 ("Very Interested") to 4 ("Not at All Interested").

The percent of students providing each of the indicated interest responses for each of the proposed thematic topics is shown.



Please refer to the following for an overview of the content strands and performance tasks for each of the four thematic units of the Honors Biochemistry course:

UNIT I - Enhancing and Evolving to "Perfection"?

Content Stands include:

- evolution, including Darwin, natural selection, the fossil record and other evidences for evolution (such as homologous and analogous structures), biochemical evidences for evolution (including DNA and protein sequence comparisons), phylogeny and evolutionary trees, and hominid evolution
- antibiotic resistance as a biologic and societal problem of human impact on evolution, including viral versus bacterial infectious diseases, transmission and treatment of infectious disease, and explanation of the mode of action of antibiotics, including comparisons of eukaryotic versus prokaryotic cells, and of bacterial, plant, and animal cells
- genetic engineering and genetically modified organisms as another relevant instance of human impact on evolution, including the techniques of genetic engineering, recombinant DNA, bacterial transformation, and transgenic organisms
- heredity and genetics, including DNA structure, the Central Dogma and protein synthesis, mutagens and mutations, meiosis and sexual reproduction, chromosomes, genetic disorders, pedigrees, mode of inheritance, monohybrid and dihybrid Punnett Squares, and phenotypic and genotypic ratios

Performance Tasks include:

- Bacterial Transformation Lab to generate transformed, antibiotic-resistant *E. coli* that express the recombinant green fluorescent protein (GFP)
- human evolution writing assignment to describe and evaluate heritable structural, biochemical, and/or behavioral adaptations that distinguish modern humans from more primitive hominids
- antibiotic resistance writing assignment to describe human activities that have contributed to the evolution of antibiotic resistance, evaluate its impact on society, and develop strategies to prevent the spread of antibiotic resistance
- Genetically Modified Foods (GMFs) research assignment to research and defend a position in favor of or opposed to the use of genetically modified foods (GMFs)

UNIT II - Causes and Treatment of Cancer

Content Stands include:

- cell cycle and cancer, including mitosis, regulation of the cell cycle, cell cycle checkpoints, oncogenes and tumor suppressors, carcinogens and pollutants, mutagens and mutations, and morphologic and cell cycle defects of cancer cells
- atomic structure and radiation, including the electromagnetic spectrum, radioactive materials, atomic structure and the Periodic Table, nuclear chemistry (including nuclear decay reactions), ionizing radiation (including ionization energy, DNA damage, and DNA repair mechanisms), and relative risk of exposure to radiation as both a cause of and a treatment for cancer

- cellular aging and cancer, including telomerase, reactive oxygen species, oxidation-reduction (redox) reactions, oxidizing agents, and anti-oxidants
- enzymes, including activation energy (E_A), catalysts, substrates, active site, optimal temperature, and optimal pH

Performance Tasks include:

- Morphology of Normal and Cancer Cells Lab (from CellServ at the NIH) to prepare and observe microscope slides in order to describe, evaluate and compare normal versus cancerous cells
- Chromosome Spread of HeLa Cancer Cells Lab (from CellServ at the NIH) to prepare chromosome "splats" of HeLa cancer cells (an *in vitro* cervical cancer cell line), observe the slides under a microscope, and perform chromosome counts to examine abnormalities of total chromosome number
- Enzymes Lab to design and conduct an experiment to evaluate the effect of pH and temperature on the rate of an enzyme catalyzed reaction
- Cancer and Genes Writing Assignment to describe a particular type of cancer, including symptoms, diagnosis, prognosis, treatment, epidemiology, specific gene mutation(s) responsible therefore, and resultant alterations of the cell cycle
- Environmental Pollutants and Cancer Risk Research Assignment to identify and evaluate a primary peer-reviewed published cancer risk study concerning a specific environmental pollutant, and analyze and evaluate the data to determine relative risk of exposure to different specific chemicals
- Antioxidants and Cancer Research Assignment to evaluate the validity of the claim that consumption of antioxidants can help to prevent aging and/or cancer by identifying and evaluating published cancer risk studies concerning the impact of oxidants and/or anti-oxidants on aging and/or cancer risk

UNIT III - Consciousness and Personality

Content Stands include:

- the neuron and cell structure, including basic neuron structure, organelles and their functions, plant and animal cells, homeostasis, structure and function of the plasma membrane as a semi-permeable phospholipid bilayer, aqueous solutions and solubility (including ions, polar molecules, and non-polar molecules), diffusion, osmosis, and forms of cellular transport
- the nerve impulse, including active transport by the sodium/potassium pump to establish resting membrane potential, adenosine triphosphate as an energy carrier, creation of an action potential by voltage-gated facilitated diffusion through ion channels, synaptic transmission by inhibitory and excitatory neurotransmitters acting on iontropic or metabotropic receptors, and synaptic clearance
- electricity, including circuits, Ohm's Law, and the power equation; electrochemistry, including galvanic (voltaic) cells, corrosion, plating, oxidation-reduction, and standard reduction potential; and the electrochemical basis of neurologic disorders

Performance Tasks include:

- diffusion lab to design and conduct an experiment to compare the diffusion of dyes across a cellulose membrane
- osmosis lab to design and conduct an experiment to determine the concentration of unknown sucrose solutions by applying the principles of osmosis
- Neuron Action Potential Design Challenge to design and create a simple circuit that models the electrochemical signal of a neuron
- Neuron Action Potential Design Challenge Reflection Essay to compare and evaluate how a simple circuit is and is not an accurate representation of the structure and function of a neuron
- Neurologic Disorders Presentation Assignment to describe and evaluate the electrochemical basis of a specific neurologic disorder, including symptoms, treatment, epidemiology, and neurons and neurotransmitters impacted

UNIT IV - Drugs and Poison

Content Stands include:

- environmental toxicology, including LD_{50} assays, other dose-response bioassays, pollutants and routes of exposure, regulatory mechanisms and agencies, and *in vitro* versus *in vivo* toxicology assays
- cytotoxic agents, including colchicine, microtubule formation, mitotic spindle, cell cycle, multi-nuclearity, giant cell formation, cellular vacuolization, aberration index, and TD_{50}
- fundamentals of pharmacology, including drugs, ED_{50}, TD_{50}, LD_{50}, therapeutic index and relative risk, chemotherapeutic agents and other narrow therapeutic index pharmaceuticals, and regulatory mechanisms
- environmental pollutants and relative risk, including heavy metals, hydraulic fracturing and petroleum products, organophosphates, insecticides, pesticides, mercury, PCBs, asbestos, and carbon monoxide
- cellular respiration and the toxins that disrupt it, including glycolysis, the citric acid cycle, the electron transport chain, ATP, and toxins that disrupt cellular respiration (such as rotenone, cyanide, carbon monoxide, dinitrophenol, and oligomycin)

Performance Tasks include:

- *Daphnia magna* LD_{50} Dose/Response Bioassay Lab to design and conduct an experiment to evaluate the toxicity of a common household chemical or drug as measured by its affect on the survival (LD_{50}) of *Daphnia magna*, a simple aquatic organism

- Effects of Toxic Chemicals on Cells Lab (from CellServ at the NIH) to observe, describe, and quantitate the cytotoxic effects of colchicine on cells cultured *in vitro*
- Environmental Pollutants and Human Health Risk Research Assignment to research and evaluate the relative risk of exposure to a specific environmental pollutant, including pollutant origin, primary peer-reviewed data regarding potential impact on human health and ecosystem health, regulation, and remediation
- as part of the formal summative assessment for the course a document-based-question format final exam in which students describe and evaluate a primary-peer reviewed journal article in the field of environmental toxicology

For each course, ongoing with the development of the written curriculum, the reform team consulted with commercial vendors to create custom published textbooks to meet the unique cross-disciplinary needs of the new courses. Both textbooks were created for use as text-searchable online e-Textbooks to support student needs both within and without of class time.

During the implementation of the two new courses a variety of data have been collected to evaluate the success and efficacy of the new science course sequence as described following. The first cohort of students enrolled in the new Integrated Science to Honors Biochemistry course sequence completed the state of Connecticut required 10th grade Science CAPT test in March of 2013. The performance of Integrated Science-Honors Biochemistry students on the 2013 and 2014 CAPT tests was compared to that of Greenwich Public School 10th grade students as a whole, as well as to that of Traditional Biology-Chemistry Sequence 10th grade student sub-population (see Table 2). Notably, Integrated Science-Honors Biochemistry students scored above the overall Greenwich Public Schools district averages for percentage of students scoring at the Proficient, Mastery, and Advanced levels on both the 2013 and 2014 Science CAPT. Similarly, students from the redesigned course sequence scored above the traditional Biology-Chemistry sequence for percentage of students scoring at the Proficient, Mastery, and Advanced Levels.

See Table 2 next column

Table 2.
Greenwich Public Schools 10th grade Connecticut Academic Performance Test (CAPT) scores for Science for 2013 and 2014 testing years, with comparison to overall DRG B average.

Greenwich Public Schools								
	GPS District Overall		Traditional Sequence		Integrated Science Honors Biochemistry		DRG B Average	
CAPT Science	2013	2014	2013	2014	2013	2014	2013	2014
% Advanced	40.7	45.7	41.4	50.4	45.8	59.8	46.8	47.4
% Mastery	69.9	69.3	69.1	71.2	81.2	89.7	73.4	73.7
% Proficient	93.7	91.8	93.0	92.3	100	100	95.6	94.8

Reported values represent the percentage (%) of students (%) scoring at Advanced, Mastery, and Proficient levels for each of the indicated testing years. DRG = Demographic Reference Group

As a second source of data to evaluate the new course sequence, a survey was used to evaluate the STEM attitudes and experiences of Integrated Science and Honors Biochemistry students as compared to those of students enrolled in the traditional Biology and Chemistry course sequence. Survey results indicated that Freshman Integrated Science students showed statistically significant differences from Freshman traditional Biology class students for 10 out of the 43 survey items concerning STEM attitudes and experiences. In every instance, the difference reflected a more positive attitude towards STEM experiences. In particular, Freshman Integrated Science students showed significantly stronger ratings of agreement with survey items relating to interest in and enjoyment of science class; including the statements "I can succeed in science," "I want to succeed in science," "The activities in science class trigger my curiosity," "I enjoy science class," "I like planning scientific investigations," and "Science is interesting." Integrated Science students also showed significantly stronger ratings of agreement with the skills based survey items of "I can create scientific explanations using evidence," and "Scientific Investigations are useful to me."

These differences in self-reported agreement with statements about STEM experiences and attitudes were even more pronounced for Sophomore Honors Biochemistry students, who had already completed Integrated Science and were engaged in their second year of the redesigned course sequence. Sophomore Honors Biochemistry students showed statistically significant differences from Sophomore traditional Chemistry class students for 20 out of the 43 survey items concerning STEM attitudes and experiences. Again, in every instance the difference reflected a more positive attitude towards STEM experiences.

As discussed previously, a major impetus for the reform effort was Harris poll data regarding student satisfaction with science teaching at Greenwich High School which indicated that the items, "Science Teacher: Makes the class interesting." and "Science Teacher: You Like what is taught in this class." were the two most pressing items for improvement. Our survey data indicates that Integrated Science and Honors Biochemistry students showed significantly stronger levels of agreement with the statements "The activities in science class trigger my curiosity," "I enjoy science class," and "Science is interesting." Thus, our data suggests that the reform effort has been successful in the explicit aim of enhancing student engagement with and enjoyment of science instruction at the high school.

Further data on student experiences, beliefs, and attitudes concerning the newly implemented courses were collected via focus group sessions of students enrolled in the Integrated/Biochemistry course sequence. When discussing why they enrolled in these classes, a student noted, "I need science classes for real life..." articulating they wanted courses that were relevant. However, the overriding consideration for why students enrolled in these newly developed courses related to the innovative instructional design principles and pedagogy of the courses as communicated through the recruitment and enrollment process. Students were keenly aware that these courses were being "taught differently" – in fact, every student cited this as the most significant difference between Integrated/Biochemistry classes and other science courses, and specifically noted they were drawn to notions of student centered pedagogy.

In terms of the courses themselves, students articulated both positive and negative elements of the courses. Negative elements were most often associated with teacher actions (lack of availability, etc.) as opposed to course content. Students discussed rigorous courses were those that challenged them and concurrently supported them in their intellectual endeavor. That notion of support revealed itself in many ways as students commented that when they worked in teams on a project (central to the design of Integrated/Biochemistry) under the close guidance of the teacher they believed the teacher was invested in their learning, and they were very positive about their experiences, noting:

> "...I learn most when I get to interact with people around me and use their knowledge and my knowledge combined to help figure stuff out. This was the case for Integrated & BioChem. A combination of learning from the teacher and learning from one another is what worked best..."

> "...BioChem was hard but she was such a good teacher – we learned a lot and it was applicable – it was hard – but she did everything in her ability to help you...we had multiple opportunities to improve."

Students hold clear and powerful notions of good teaching and effective courses. In school reform we often think of curriculum as the key element to an improved learning environment, yet data here suggests that investing in teacher professional learning around instructional design and student-centered pedagogies might also yield significant improvement from the perspective of students. Such learning might be in the areas of classroom discourse and scientific modeling consistent with project-based work and the Next Generation Science Standards (NGSS, 2013).

The CAPT testing data, STEM attitudes and experiences data, and focus group responses discussed above all indicate that the science curriculum reform efforts at Greenwich High School have been successful across a number of domains. The Integrated Science and Honors Biochemistry courses have provided an alternative to the traditional science course sequence, and in doing so have achieved strong results in student performance on standardized assessments and in student interest in and engagement with science courses, content, and practices. Such advances have not come without challenges that will also be addressed in the final section of this paper.

Beyond the aims discussed thus far to improve student experiences and learning, such efforts also bear a responsibility to promote future student success in post-secondary education. In acknowledgement of this responsibility, surveys were conducted to gauge the impact of the new science course sequence on potential for student admission to institutions of higher education. In two separate surveys, admissions office staff from a total 108 institutions of higher education responded to both constructed and selected survey items. Of the responding institutions of higher education, over 70% stated unequivocally that the new Integrated Science-Honors Biochemistry science course sequence would be accepted as a viable alternative to the traditional Biology-Chemistry sequence. About 20 institutions requested additional detailed information about the courses prior to providing a response. Approximately 5% of institutions responded negatively due to a specific concern about the new course sequence. Such concerns included: verification that the courses involved a laboratory component and statements of the requirement for completion of a physics course. Only 6 out of 108 of responding institutions explicitly stated they preferred the requirement for the traditional Biology-Chemistry course sequence. To address the requests and stated concerns of the responding institutions, detailed course summaries for both the Integrated Science and Honors Biochemistry courses have been sent to all survey respondents who indicated the need for further information. Such course summaries have also been sent to an additional 40 institutions of higher education to which Greenwich High School students frequently apply, but who did not respond to our survey. The need for such proactive communication during the reform process will be addressed further in the next section.

Implications

This final section will address key implications to emerge from the case study with the explicit aim of informing those who seek to leverage this window for reform into action given the publication of the Next Generation Science Standards (NGSS Lead States, 2013). We will address the notion of informed data-driven decision-making, and subsequently speak to issues of scalability.

Perhaps the most important considerations for programmatic reform include the notions of evidence-based decision-making and allotting adequate time for the piloting, reflection, revision, and implementation of new initiatives and curriculum. Our project unfolded over a multi-year horizon with measurable aims bounded by a spirit of innovation. It simply could not have occurred within the context of a single school year - or even two. As leaders consider planning for reforms consistent with the NGSS, efforts must be conceptualized to unfold over a multi-year time frame to allow for the necessary data required to inform the numerous decisions to be made over the duration of such an effort. Key decisions range from whether courses will be revised or crafted anew to implications of staffing, assessment, and how to best serve the diversity of learners seen in any school setting. Of course the strategic and measured pace of reform must be balanced with a real sense of urgency, thus we recommend that schools immediately begin planning for the transition to the next era of STEM education. Recall that our effort was launched with the development of a research-based conceptual framework that served to guide the work (Moss, 2008), and was subsequently supported with an ongoing and robust plan for collecting and utilizing data to make informed decisions. Regardless of the trajectory of any given reform effort, we advocate that core model should guide each effort.

Although the notion of data driven informed decision-making has permeated many aspects of K-12 schooling, perhaps most notably the use of data teams to assess student learning, it is critically important that such evidence-driven notions are applied to large-scale reform agendas as well. Such work involves not merely teams of teachers meeting occasionally over the course of an academic term, but backing from administration and other stakeholders is essential to support what typically amounts to a time and resource intensive process. It is a process that must account for the likelihood of significant revisions and re-thinking of initial decisions and trajectories based upon data as it comes available over time. It is a process that is neither linear nor one that should be undertaken without adequate resources. For our project, such resources came in the form of release time for teachers and summer stipends for curriculum development work. Beyond financial resources, support came in the form of building and district leadership that encouraged faculty to innovate in the service of student learning. In that sense, support came in the form of commitment to reform – which we believe to be as necessary as funds.

Such innovation often yields unanticipated outcomes and challenges that surface as the effort is scaled up. For our effort three issues emerged that upon reflection were not fully addressed at the outset of the study, but that became fundamental issues as the project unfolded. The first are challenges underpinning the "dual path" of course sequences available during the pilot period. That is, in our case study certain groups of students were enrolled in Integrated Science and Honors Biochemistry while concurrently others were taking the traditional Biology and Chemistry track. This challenge largely remains at the time of writing this case study. Much of the issues surrounding this ongoing challenge pertain to communication - or a lack thereof – both with and among the stakeholders of this effort, including high school teachers, parents, students, and middle school teachers. Benefits and potential drawbacks of certain courses, fit of the curriculum with the child, and implications for the honors program were but a few of the areas that could have been better dealt with if a more proactive and sustained system for communication was established at the outset of the work. Students transitioning from either pathway as Juniors was also an area that could have received more explicit planning earlier in the project.

Faculty professional learning was a second challenge that emerged during the scaling up of the effort. Although adequate resources were allocated for the core curriculum team, when it came time to scale up the course offerings, the project team underestimated the professional learning necessary to bring additional teachers on board with both the instructional design principles underpinning the courses as well as up to speed on the course content. Our effort leaned toward preparing teachers for the course content, and underrated the time and effort involved in bringing a new group of teachers up to speed on the instructional approaches fundamental to their design. The new courses blended the content and scientific and engineering practices, and thus teachers required support in considering how to bring to life the practice-based approach of the course. Thus, reform was a delicate balance of both what and how to teach.

The third issue underpinning scalability was the professional certifications of the departmental faculty. In Connecticut, separate certifications are required to teach biology, chemistry, physics, and Earth Science, and even general science is its own designated area for certification. For courses aligned with the NGSS, a teacher certified in a single area (such as biology) may no longer be adequate as we transition to a more authentic approach in the consideration of the STEM disciplines. More fundamentally, the traditional certifications may no longer make sense at the teacher preparation level, and we advocate that school districts work closely with their respective state departments and/or bureaus that are charged with overseeing teacher certification. Although this issue seems at one level beyond the scope of any individual reform effort, as teachers can be encouraged to seek dual certifications in interim periods as was done in this case study, ultimately it impacts the long term potential for such efforts to deeply take root and thrive.

In summary, results from this case study were achieved by students completing a course sequence that explicitly and deliberately emphasized student interest, real-world relevance and context, and science and engineering practices over a model characterized by teacher-centered delivery of stand-alone traditional content strands. As noted, challenges remain, and we acknowledge our case study in no way represents a one-sizefits-all approach to reform, yet we hope the core elements of our reform effort described within the narrative of this paper offer schools a framework to consider the possibilities open to us all in this current window of reform.

Acknowledgements

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This NBII site is developed and maintained by the Center for Biological Informatics of the U.S. Geological Survey
http://www.nbii.gov/disciplines/botany/science.html

Sci4Kids Plant Page

http://www.ars.usda.gov/is/kids/plants/plantsintro.htm
Read about the plant hunters, scientists who collect samples of plants from around the world to try to trace the history of a plant's evolution. Learn about how plants fight off insects and diseases. Find out why plants come in so many colors. See how many seed species you can identify. For grades 4 and up.

People and Plants

http://www.units.muohio.edu/dragonfly/plants/index.htmlx
Miami University
What is an ethnobotanist? How do Tirio Indian children from the Amazon use plants to make toys? How do Native Americans carve totem poles from trees? Find out here! For grades 3 and up.

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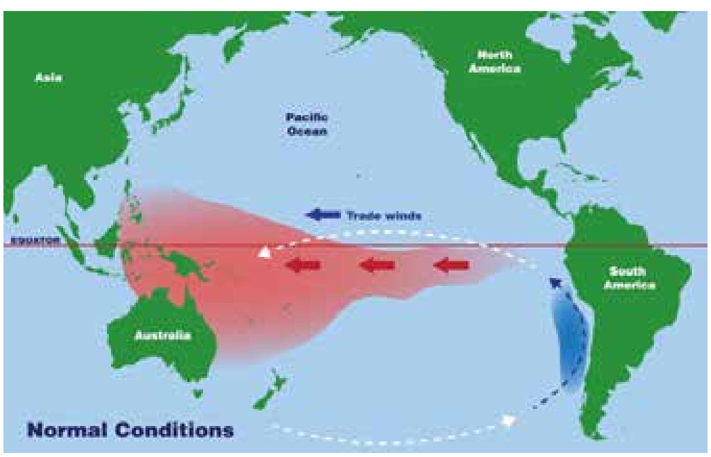
What is El Niño?

http://scijinks.jpl.nasa.gov/el-nino/

SciJinks

http://scijinks.jpl.nasa.gov/

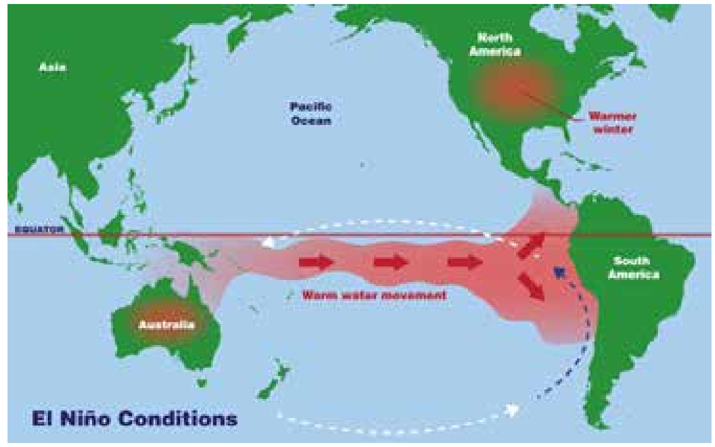
El Niño is a weather pattern that occurs in the Pacific Ocean, but it is so big that it affects weather all over the world.



Weather depends a lot on ocean temperatures. Where the ocean is warm, more clouds form, and more rain falls in that part of the world. In the Pacific Ocean, near the equator, the Sun makes the water especially warm on the surface.

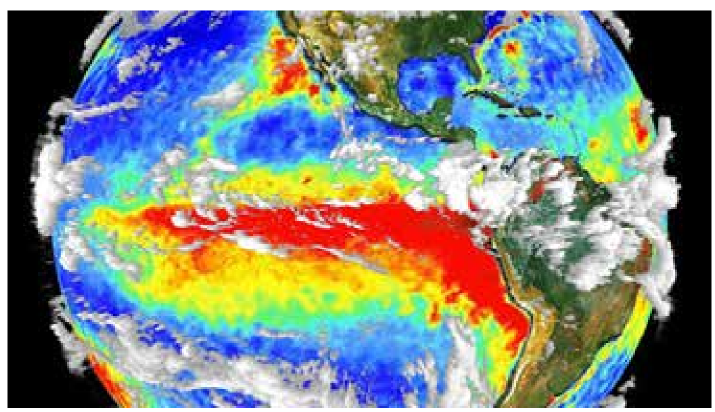
Normally, strong winds along the equator push the warm surface water near South America westward toward Indonesia. When this happens, the cooler water underneath rises up toward the surface of the ocean near South America.

However, in the fall and winter of some years, these winds are much weaker than usual. They actually blow the other way (toward South America instead of Indonesia) in October. So the warm surface water along the equator piles up along the coast of South America and then moves north towards California and south toward Chile.



Many fish that live in the normally cooler waters off the coast of South America move away or die. Fishermen first called this condition of warm coastal water and poor fishing "El Niño." El Niño means "the Christ Child." They call it that because it typically occurs at Christmastime.

In El Niño years, lots of rain clouds form over this warm part of the ocean. These clouds move inland and dump much more rain than usual in South and Central America and in the United States.



3-D cloud and surface temperature data are combined in this image from the Terra satellite, which shows a well-developed El Niño condition. The red area is warm water sitting off the coast of western South America.

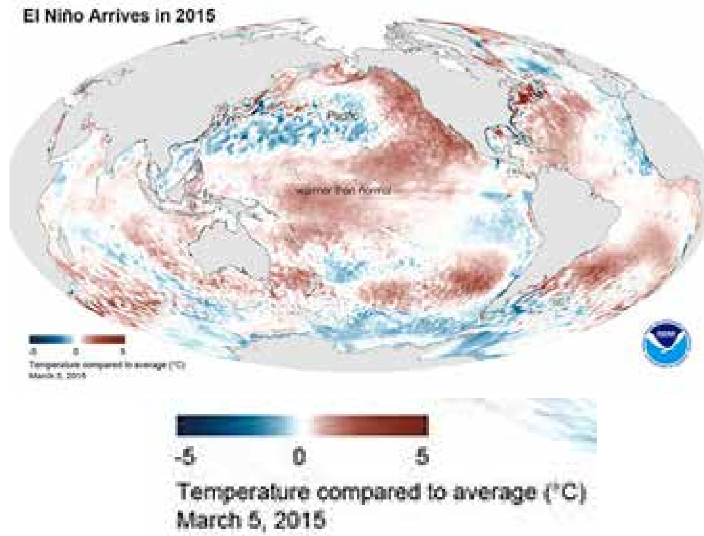
Meanwhile, other parts of the world can suffer drought. Weather patterns all over the world may be unusual, making lakes out of deserts and charcoal heaps out of rain forests.

What about 2015?

Early 2015 brought a weak El Niño condition. Such a weak El Niño doesn't usually cause widespread or significant global weather effects. However, it can still affect spring weather in parts of the Northern Hemisphere. For example, the U.S. Gulf Coast might get more rain than usual.

How do you take the ocean's temperature from space?

How do we know what is happening to the ocean temperatures around the Earth? One way is to use data from weather satellites in space.



El Niño arrives in 2015. This image (on right) shows the temperature of the ocean's surface during February 2015. The measurements were made by NOAA satellites. The large area of red shows warmer than average waters in the Pacific Ocean near the equator. This warmer water creates a weak El Niño condition. Credit: NOAA

One of the jobs of the new GOES-R satellite will be to measure the temperature of the ocean's surface. It will be able to more accurately detect conditions such as El Niño while they are forming.

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Simple Ways to Protect the Earth

Helping kids understand where food comes from may encourage them to try different kinds of fruits and veggies, and gardening itself is a great school or family activity. http://www.pbs.org/parents/special/article-earthday-gardening-with-kids.html

Best Bets for Gardening with Kids

By Bridget Bentz Sizer

Your kids can probably help you find the baby carrots or frozen French fries in the grocery store, but do they know where carrots and potatoes really come from? How about onions or strawberries?

Gardening expert and author Sharon Lovejoy recalls standing in front of a group of schoolchildren with a raw carrot in her hand as the children tried to guess where it had come from. One said the market. Another guessed a truck. Then Lovejoy, whose books include *"Sunflower Houses: Garden Discoveries for Children of All Age"* and *"Roots, Shoots, Buckets & Boots: Gardening Together with Children,"* pulled a packet of seeds out of her pocket and told them that the carrot had been grown from the seeds. "A little boy yelled, 'That's a miracle,'" Lovejoy recalls.

Rose Judd-Murray, an education specialist with the National Garden Association, says that stories like Lovejoy's are not surprising. "There is a disconnect [in kids] when it comes to understanding where our food comes from," she says. "Kids will pull something so basic out of the ground and they are unsure—'Do we eat the top or eat the bottom?'"

By teaching children not just where the food comes from but also how to grow it, we can increase their awareness of the world around them—and make them more likely to eat, say, tomatoes in their native form instead of just ketchup: "As kids touch and feel where the food comes from, they have a greater desire to eat fruits and vegetables," adds Judd-Murray. More than that, gardening is a way to reconnect our kids with the wonder of the earth, the miracle that a seed the size of a fingernail clipping could grow into a big orange carrot. "Kids really feel that this is a magical experience," says Lovejoy. Gardening can also be used to teach science and to reinforce positive character traits like respect, responsibility, the value of work and cooperation with others, notes Judd-Murray.

Now that we've established what fun it can be, are you ready to dig in? Here are some tips to get you started.

1. Start small. A common mistake beginners make is being too ambitious with their garden plans, only to be discouraged when weeds or pests take over the plot. "Make it so small that your child can water it and see everything," recommends Lovejoy. Rather than tilling a section of your yard, consider planting in containers, which will help keep weeds at bay and give your child a focus for watering. You can buy pots at a garden store or even use an old beach bucket—just be sure to poke holes for drainage. "Containers are great for herbs or patio-type tomatoes," says Susan Heidebrecht, a horticulturalist and garden designer who lives in Reisterstown, Maryland. But be

warned: If you're using containers, you may have to water your plants more frequently than if you had planted in the ground. "Things can dry out really quickly [in containers]," says Heidebrecht.

2. Follow your child's lead. Not sure what to plant? Take your child to a garden store and let her pick the out the seeds. Your best bet will be flowers or vegetables with relatively fast germination periods (the better for short attention spans!). When it comes to flowers, Judd-Murray likes shasta daisies, cosmos and zinnia, while Heidebrecht recommends nasturtiums, which are an easy-to-grow edible flower. For vegetables, Judd-Murray, Lovejoy and Heidebrecht all recommend cherry tomatoes and, for a quick, three-to-seven-day germination, radishes. Lovejoy swears that kids will eat radishes when they grow them.
3. Buy kid-sized tools. A well-meaning child with a garden hose can blast a baby seedling away in a matter of seconds, but you can avoid garden floods by equipping your little helper with a kid-sized watering can. "You're rarely going to have an accident if the child has a tool that's the proper size," says Judd-Murray. In addition to a watering can, consider purchasing a child-sized clipper, trowel and shovel, as well as a magnifying glass, so you can get up close and personal with your plants.
4. Don't be afraid to experiment. Some of your plants might grow like weeds, others might be stifled by weeds. The key is to figure out—with your child—what works and what doesn't. A garden can become a living science experiment, in which you can compare what happens when one seedling receives fertilizer (or water or sunlight) and one doesn't. Not everything will grow in the way you expect, and that's okay. "Don't be afraid to fail," says Judd-Murray.
5. Make it fun. Gardening shouldn't feel like a chore, so don't treat it like one. Instead of inviting your child to "go work in the garden" with you, consider asking him if he wants to go peek under the leaves to see what he might find. Then grab the magnifying glass and start exploring!
3. No outdoors? No problem! Not everyone has access to an outdoor garden space, but apartment dwellers and others with limited outdoor space can also develop green thumbs by focusing on indoor plants. Judd-Murray recommends snipping off a piece of a spider plant and setting it in water to watch it grow new roots. Or plant aloe vera, which grows easily and can be used to treat household burns.

Heidebrecht adds that if all else fails, a visit to a local pick-your-own farm provides kids without extensive gardens the chance to see foods "in their natural habitat."

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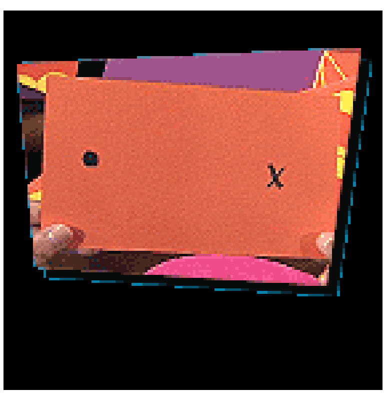
ZOOM: Blind Spot

Grade Range: 3-5, 6-8

Discover the blind spot in the human eye with a simple experiment, then alter the experiment to discover the size and shape of your blind spot.
http://pbskids.org/zoom/activities/sci/blindspot.html



Sent in by:
Alissa of Rochester, NY

Find a spot in your eye where you can't see anything!

Materials Needed

- paper
- marker
- ruler

Instructions

- To find your blind spot, take a piece of paper and draw a small X on the right side.
- Now, take your ruler and measure about 5 inches to the left of the X.
- Draw a dot there about the size of a penny.
- Hold the paper in front of you and close your right eye.
- Look at the X. Even though you're looking at the X you should be able to see the dot out of the corner of your eye•
- Slowly move the paper in front of you. Try moving it left and right or closer and farther away. Remember to keep looking at the X. At a certain point, the dot will seem to disappear out of the corner of your eye.

Here's the science scoop on why this works: On the back of your eye, your retina, you have cells called rods and cones that catch light and send messages to your brain along your nerves, which are like wires. All your nerves go through your retina in just one spot. In this spot, there are no rods and cones. Since you don't have any rods and cones there to catch light, you can't see with that part of your eye.

The reason you don't notice your blind spot is because your brain fills in that part of your vision with what it thinks should be there. So when the dot goes into your blind spot, your brain fills in that space with the color of your paper because that's what surrounds it.

How big is your blind spot? Will the dot still disappear if it's as big as a quarter? How about if it's a different shape, like a square or a star?

Your results:

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Ten Websites for Science Teachers

Edutopia
September 25, 2013
Ten Websites for Science Teachers

http://www.edutopia.org/blog/websites-for-science-teachers-eric-brunsell?utm_source=SilverpopMailing&utm_medium=email&utm_campaign=enews%20092513%20(6am%20AB%20actives%2030%%20throttle%2040K)%20A&utm_content=&spMailingID=7032159&spUserID=MjcyNzUxMDMxNzIS1&spJobID=89933220&spReportId=ODk5MzMyMjAS1

Eric Brunsell Asst Professor of Science Education @ UW-Oshkosh
http://www.edutopia.org/user/114
February 7, 2012

We all know that the web is full of excellent web resources for science teachers and students. However, unless you live on the web, finding the best websites can become quite a challenge. This isn't a "Top Ten" list -- instead, it is a list of websites that I either use on a regular basis or just find interesting. From teaching resources for the nature of science and authentic field journals to wacky videos about numbers, I am sure that you will find something in the following list the works for you! Please share your favorite science web resources in the comment section!

1) Understanding Science

UC Berkeley's Understanding Science http://undsci.berkeley.edu/ website is a "must use" for all science teachers. It is a great resource for learning more about the process of science. The resource goes much deeper than the standard "PHEOC" http://wiki.answers.com/Q/What_is_PHEOCmodel of the scientific method by emphasizing peer review, the testing of ideas, a science flowchart and "what is science?" checklist. Understanding Science also provides a variety of teaching resources http://undsci.berkeley.edu/teaching/index.php including case studies of scientific discoveries and lesson plans for every grade level.

2) Field Research Journals

The Field Book Project frhttp://www.mnh.si.edu/rc/fieldbooks/om the National Museum of Natural History and the Smithsonian Institution Archives intends to create a "one stop" archive for field research journals and other documentation. You can find plenty of examples from actual field research journals for your classes.

3) Evolution

Berkeley's Understanding Evolution http://evolution.berkeley.edu/ website is the precursor to their Understanding Science efforts. The Understanding Evolution website provides a plethora of resources, news items and lessons for teaching about evolution. Lessons http://evolution.berkeley.edu/evolibrary/teach/index.php provide appropriate "building blocks" to help students at any grade level work towards a deeper understanding of evolution. The Evo 101 http://evolution.berkeley.edu/evolibrary/article/evo_01 tutorial provides a great overview of the science behind evolution and the multiple lines of evidence that support the theory.

4) PhET Simulations

PhET http://phet.colorado.edu/ from the University of Colorado provides dozens of fantastic simulations for physics, chemistry and biology. The website also includes a collection of teacher contributed activities, lab experiences, homework assignments and conceptual questions that can be used with the simulations.

5) Earth Exploration

The Earth Exploration Toolbook http://serc.carleton.edu/eet/index.html provides a series of activities, tools and case studies for using data sets with your students.

6) EdHead Interactives

Edheads http://edheads.org/ is an organization that provides engaging web simulations and activities for kids. Current activities focus on simulated surgical procedures, cell phone design (with market research), simple and compound machines, and weather prediction.

7) Plant Mentors

Do you teach about plants? Check out http://www.plantingscience.org/ to connect your middle or high school students to science mentors and a collaborative inquiry project. From the project:

Planting Science is a learning and research resource, bringing together students, plant scientists, and teachers from across the nation. Students engage in hands-on plant investigations, working with peers and scientist mentors to build collaborations and to improve their understanding of science.

8) Periodic Table of Videos

Check out The Periodic Table of Videos http://www.periodicvideos.com/ for a wide array of videos about the elements and other chemistry topics.

9) More Videos!

Students can read and watch video about 21 Smithsonian scientists http://www.smithsonianeducation.org/scientist/index.html including a volcano watcher, fossil hunter, art scientist, germinator and zoo vet.

10) Even More Videos!

How many videos were watched on YouTube last year? If you said 22 BILLION, you are sort of correct... Those 22 billion views only represent the number of times education videos were watched! Last October, YouTube announced a project to create new video channels for education. The first channels released focused on science and math. Here are a few to start with.

- SciShow http://www.youtube.com/scishow is all about teaching scientific concepts in an accessible and easy-to-understand manner. This channel includes a variety of short (3 minute) and long (10 minute) videos. New videos are released weekly.

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edutopia

Can Innovation Skills Be Learned?

http://www.edutopia.org/blog/creating-innovators-tony-wagner

Author, educator, and thought leader Tony Wagner looks at innovation and creativity, and how anyone can develop these habits when their natural human curiosity is encouraged.

The "DNA" of innovators might be considered a set of skills that are essential elements in design thinking. http://www.edutopia.org/blog/creating-innovators-tony-wagner One cannot have empathy without having practiced the skills of listening and observing. And integrative thinking begins with the ability to ask good questions and to make associations. There is also a kinship between collaboration and networking. [At the root of innovation is] the importance of experimenting -- an activity that, at its root, requires a kind of optimism, a belief that through trial and error a deeper understanding and better approaches can be discovered.

Putting the research together, some of the most essential qualities of a successful innovator appear to be the following:

- Curiosity, which is a habit of asking good questions and a desire to understand more deeply
- Collaboration, which begins with listening to and learning from others who have perspectives and expertise that are very different from your own
- Associative or integrative thinking
- A bias toward action and experimentation

But as an educator and a parent, what I find most significant in this list is that it represents a set of skills and habits of mind that can be nurtured, taught and mentored! Many of us tend to assume that some people are born naturally creative or innovative -- and others are not. But all of the experts whom I've cited share the belief that most people can become more creative and innovative -- given the right environment and opportunities. Indeed, Judy Gilbert's job is to continue to develop the capacities of Google employees to become more innovative.

Tim Brown writes, "Contrary to popular opinion, you don't need weird shoes or a black turtleneck to be a design thinker. Nor are design thinkers necessarily created only by design schools, even though most professionals have had some kind of design training. My experience is that many people outside professional design have a natural aptitude for design thinking, which the right development and experiences can unlock."

Dyer, Gregersen and Christensen agree. In the conclusion of their article, the authors argue, "Innovative entrepreneurship is not a genetic predisposition, it is an active endeavor. Apple's slogan 'Think Different' is inspiring but incomplete. We found that innovators must consistently act different to think different. By understanding, reinforcing and modeling the innovator's DNA, companies can find ways to more successfully develop the creative spark in everyone."

So DNA, then, turns out not to be the right term, after all. It's not primarily what you are born with that makes you an innovator -- though clearly some people are born with extraordinary gifts. These authors seem to agree that what you have learned to do is more essential. Yes, there's nature -- but there is also nurture, what the environments around us encourage and teach.

But here's the problem: It is often difficult in our society to "act differently in order to think differently." To do so requires radically altering our adult behaviors. When Dyer and Gregersen were interviewed in a blog about their research, Hal Gregersen talked about the loss of creative capacity. "If you look at four-year-olds, they are constantly asking questions and wondering how things work. But by the time they are 6½ years old, they stop asking questions because they quickly learn that teachers value the right answers more than provocative questions. High school students rarely show inquisitiveness. And by the time they're grown up and are in corporate settings, they have already had the curiosity drummed out of them. 80% of executives spend less than 20% of their time on discovering new ideas. Unless, of course, they work for a company like Apple or Google."

Gregersen is hardly alone in his views. Sir Ken Robinson's recent book, The Element, and his TED Talks http://sirkenrobinson.com describe many of the ways curiosity and creativity are discouraged -- "educated out of us," he often says. Dr. Robert Sternberg, a psychologist who has studied creativity, agrees. He writes, "Creativity is a habit. The problem is that schools sometimes treat it as a bad habit . . . Like any habit, creativity can either be encouraged or discouraged."

For more information about the book, please visit Creating Innovators. http://creatinginnovators.com/the-book/

http://creatinginnovators.com

More than a book on innovation, Creating Innovators is itself innovative in its format. Using Quick Response Codes for smartphone, readers can access more than 60 online videos further explaining the story.

These short videos take readers to innovative schools like MIT's Media Lab, Stanford's Design School, High Tech High and Olin College. And readers get to know the young innovators in a unique way – traveling as far away as Guatemala and Africa.

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Water Works on the Blue Planet

Water, water, every where,
And all the boards did shrink;
Water, water, every where,
Nor any drop to drink.

. . .

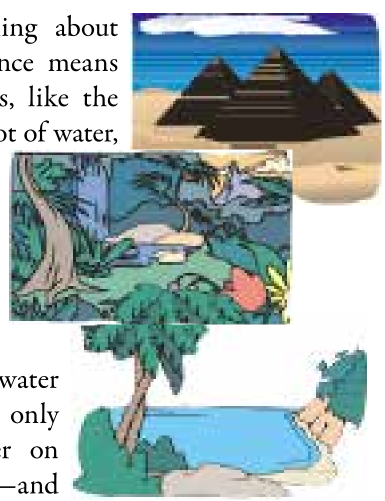
And every tongue, through utter drought,
Was withered at the root;
We could not speak, no more than if
We had been choked with soot.

From The Rime of the Ancient Mariner, Part II
By Samuel Taylor Coleridge

In Coleridge's poem, the Ancient Mariner is adrift on a windless sea, surrounded by water too salty to drink. (Sorry, we couldn't find a picture of a ship with windless sails!)

When we consider that almost three-fourths of Earth's surface is water, it's hard to imagine there could ever be a shortage. But of all that water, 97.5% of it is too salty to drink. That's how much of the water is in the oceans. As for the rest, we land creatures need to take very good care of it.

Haves and Have-nots



That's the interesting thing about water. Its presence or absence means life or no life. Some places, like the Brazilian rain forest, have a lot of water, while other places, like the Sahara Desert, have none. Some years a place is flooded with rain and snow. Other years that same place is dry as a bleached bone.

But one thing about water doesn't change. There is only a certain amount of water on Earth—no more, no less—and that total doesn't change.

What changes is how it is distributed. The process by which water moves around the planet is called the Water Cycle or—to be technically fancy—the Hydrologic Cycle.

Living on a Fixed Budget

How the water is divided up among the oceans, the land, and the atmosphere is called the Water Budget. Budgets are usually about money. If you have a paying job or receive an allowance, you know how much money you will receive each week or month. You must plan how you will divide this money up to buy the things you need. This process is called budgeting your money.

Earth's water budget, however, is really more like a Monopoly™ game than one person's budget. In real life, you might be able to work more to make more money. Or you might choose to stash your money under your mattress, taking it out of circulation altogether. Monopoly is a board game which pretends to be like real life. In Monopoly, players earn money each time they go around the board. They have chances to buy land, houses, and hotels, and to collect money from other players who land on their property. Players can even get into trouble, losing some of their money or landing in jail.

Unlike in real life, however, in Monopoly the total amount of money available for all the players remains the same. You can't just go printing more Monopoly money when you run short! The game is all about how that fixed amount of money gets spread around. Does one player get rich, leaving the other players poor? Or does the money get distributed more evenly? When each player rolls the dice, makes a move, and then spends money, wealth gets redistributed in some way.

In the Water Cycle "game," wealth (that is, water) gets redistributed by several means. But the difference between this game and Monopoly is that no matter what happens during any particular turn in the Water Cycle game, the "players" all end up with very close to the same amount of wealth they had at the beginning. Who are these players?

The players are the oceans, the land, and the air.

In the Water Cycle game, fair or not, the oceans have and keep almost all the wealth. The total of all the fresh (that is, not salty) water on land, including lakes, rivers, streams, ponds, puddles, bathtubs, kitchen sinks, and all the water under the ground, comes to only 2.4% of Earth's water. The atmosphere contains the rest, only .001% (that's 1/100,000th), in the form of water vapor and clouds.

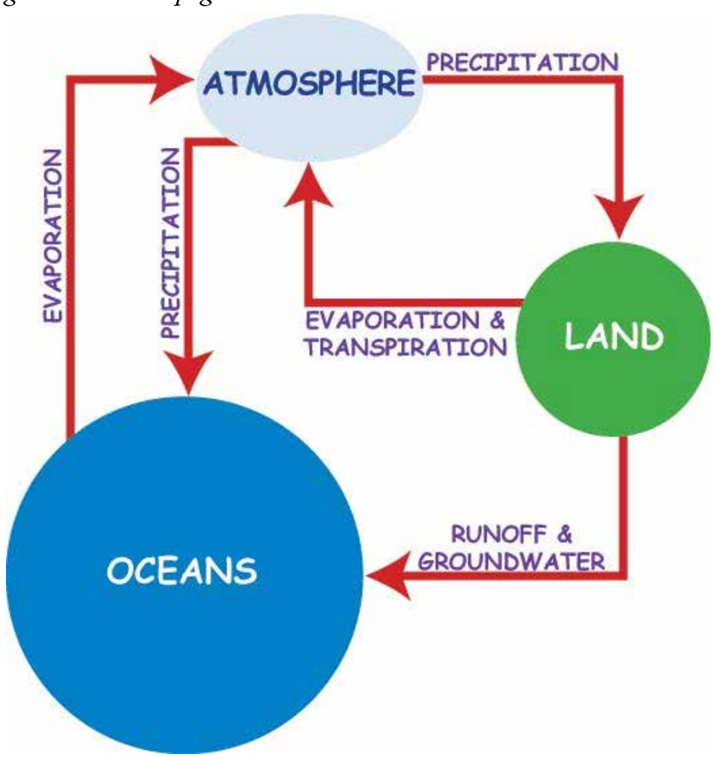
This tiny percentage of the water that is in the atmosphere at any given time is what keeps the whole system moving. The atmosphere is the transportation system that enables the water to, well . . . cycle. Just to give you an idea how hard the atmosphere works to move water around, imagine the entire sky, horizon to horizon, top to bottom, over the whole world being filled with dark, gray clouds. This is how much water the atmosphere can hold. Each year, the total amount of water that gets dumped out of the sky (in the form of rain, hail, snow, sleet, etc.) is 30 times more than the atmosphere's total capacity to hold water!

Water's Ups and Downs

Water gets from Earth's surface into the atmosphere in three different ways: *evaporation, sublimation,* and *transpiration.*

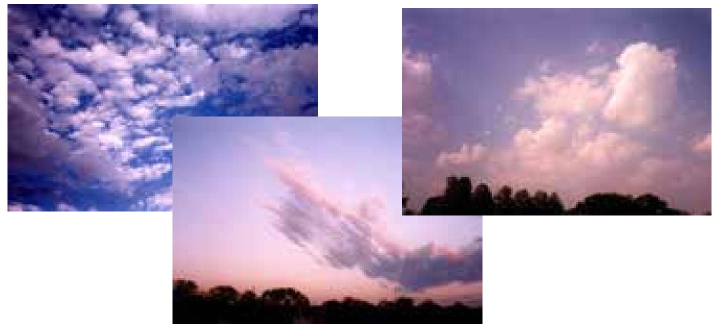
Water gets back from the atmosphere to Earth's surface by *precipitation* and *condensation.*

Water also gets from the land back to the oceans by *runoff and groundwater seepage.*



Evaporation is the process of water turning from a liquid to a gas. After a rain, any little dip in the ground becomes a puddle. When the sun comes out, the puddle disappears. Where does the water go? It becomes water vapor (which is an invisible gas) and lifts up into the atmosphere.

Water is evaporating off the surface of the oceans all the time. (Luckily for us, the salt is left be- hind!) Lakes, rivers, swimming pools, all contribute to the water vapor load in the atmosphere.



Sublimation is the process of water turning from a solid (snow or ice) directly to a gas (water vapor) without melting first.

Transpiration is the process of plants giving off water and oxygen as waste products of photosynthesis. As far as the water is concerned, this process is similar to evaporation, but simply refers to the water coming from the ground up through the plants, rather than coming from the ground directly.

Anyway, once the water vapor gets into the air, it rises and cools, *condensing* into water droplets again. Collections of these water droplets are called clouds. Clouds get pushed great distances by atmospheric winds, and thus become the long-distance trucking industry of the water cycle. This part of the water cycle is called *transport*. Water vapor can also condense out of the atmosphere as dew or frost.

So far, the atmosphere has lifted water into the sky from one place and carried it to another place. Now it sets the water down again in the form of dew, frost, rain, snow, hail, or sleet.

When the water hits land, some of it soaks in and some runs off into lakes, streams, or rivers. The water that soaks in is called groundwater. Groundwater and runoff water all eventually get back to the ocean.

All these processes—evaporation, sublimation, transpiration, condensation, transport, precipitation, runoff, and groundwater seepage—are going on all the time all over the Earth. And still, the total amount of water on our little blue planet remains the same.

Now for an Illustration

(and an activity for you)

Make a poster (perhaps working in pairs) **or a large mural** (working with the whole class) depicting the Water Cycle on planet Earth. You can include all different kinds of terrain—forests, deserts, farmlands, mountains, plains, rolling hills, cities—all different kinds of clouds, rivers, lakes, streams, calm oceans, angry oceans, glaciers, cross-section views of the underground, rain, blizzards, thunderstorms, hurricanes—whatever seems interesting and dramatic and shows all the different ways water moves up into the air and back down again to the surface. Label the water elements of the picture to show which of the processes of the water cycle are being shown.

If you like, you can cut the clouds out of separate pieces of paper to make a dynamic water transport system. You can show how the clouds "pick up" water from one part of the picture and carry it to another.

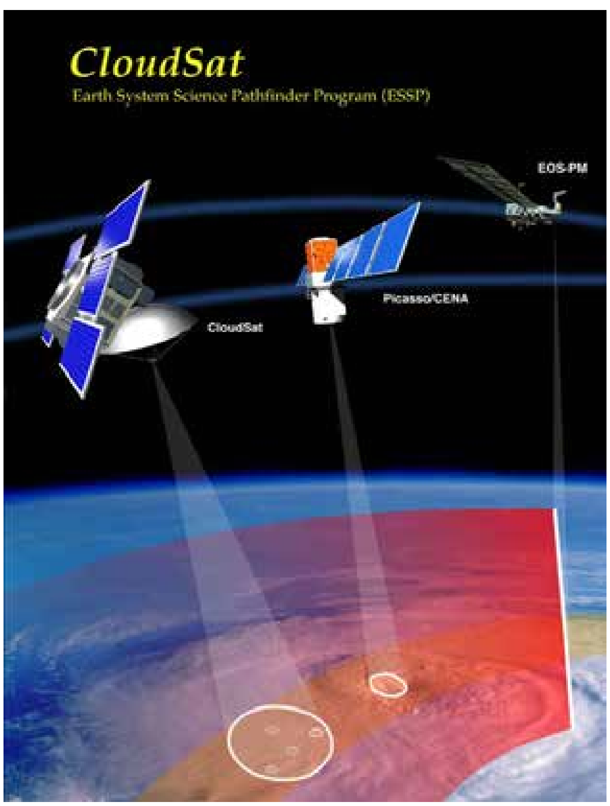
Of course what drives evaporation and precipitation are the basic laws of physics. But things could be different and not violate any laws of physics. For example, what do you think would happen if all the continents were well above sea level, but perfectly flat? What if it were warm enough on Earth that all the water was in liquid about the vertical structure of the clouds to really understand them form (no ice)? Given that the atmosphere cannot hold any more water than it already does, what if precipitation fell equally on all parts of Earth?

Learning More About Clouds

Clouds are the key element of the water cycle, since they are the transporters that move water from one place on Earth to another. They are also important in determining how much of the sun's energy is absorbed and trapped in the atmosphere. They are thus very important in altering the temperature of the air and Earth's surface. The warmer the air, the more water it can hold. And the warmer the oceans, the faster water evaporates from them. And the more water in the air, the more the sun's energy is trapped, making things still warmer.

It is a very complex cycle, and scientists need to understand better how clouds affect climate.

Current weather satellites give scientists information about how clouds look from the top, and even how high they are. But they don't reveal enough about the vertical structure of the clouds to really understand them.



Cloudsat is a space mission that will study clouds, taking 3-D images of them using advanced radar technology. Cloudsat will orbit Earth, flying in formation with other satellites that take cloud measurements using different kinds of instruments. Cloudsat will measure how much liquid water and ice are in the clouds at what heights, and how these measurements affect the clouds' ability to reflect or trap the sun's energy. Data collected by the satellites will be combined to give a better understand- ing than we have ever had before of how clouds work and how they affect climate all over Earth.

Cloudsat was launched in 2003. It is a joint project between Colorado State University, NASA's Jet Propulsion Laboratory, the Canadian Space Agency, the U.S. Air Force, and the U.S. Department of Energy. To learn more about Cloudsat, see http://cloudsat.atmos.colostate.edu/.

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