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THE SCIENCE EDUCATION REVIEW

Ideas for enhancing primary and high school science education

Did you Know?

Cardiac Catheterisation

In 1929, the human heart was off-limits. Little was known about it, and exposing or touching the heart was thought to kill. However, motivated by drawings of veterinarians accessing a horse's heart via the jugular vein, Werner Forssmann, an intern in a small hospital near Berlin, was very keen to try it. However, his surgeon boss denied him permission to perform the procedure on dying patients and also forbid him from being the subject.

Knowing that locked-away sterile equipment would be required, he began to charm the Chief Nurse, who had the key. Taking advantage of her passion for medicine by talking with her about surgery at length and the like and eventually mentioning the experiment he was so keen to do, she not only provided access to the equipment but volunteered to be a subject. When an opportunity arose, he tied her arms and legs loosely to an operating table, sterilized her arm at the proposed incision point, left the room, and didn't return.

Forssmann had no intention of putting her at risk. Rather, he cut a vein in his own arm and inserted narrow rubber tubing through it to his shoulder, noting a burning sensation. He returned to show the nurse, who was furious at his deception, and persuaded her to help him to the X-ray department so he could watch the tube moving towards his heart. Upon the subsequent entry of the radiography technician and a colleague of Forssmann and the colleague moving to remove the catheter, he received a hard kick in the shins by Forssmann. With the catheter at the heart, all that as needed was a photo as evidence of the medical milestone.

The published paper did contain some lies, though. Forssmann ignored his boss's advice to say that the procedure had been performed on a cadaver first and ran with the story of an imaginary colleague who, after starting the procedure, became too concerned to continue, leaving Forssmann to finish it by himself. However, the true story did eventually come out.

Forssmann was also a brave and honourable researcher, refusing to use prisoners as guinea pigs for medical research during World War II. Serving in the army, he found himself a prisoner of the Allies at the end of the war. However, while imprisoned, two allied physicians read about his self-catheterisation and used the idea to diagnose cardiac diseases. In 1956, the 3 of them were jointly presented the Nobel Prize in Physiology or Medicine.

Source

Brooks, M. (2011). *Free radicals: The secret anarchy of science*. London: Profile Books.

Teaching Ideas

Techniques, demonstrations, activities, alternative conceptions, critical incidents, stories, and other ideas

Heating a Tuning Fork

Take two identical tuning forks. Hold one safely (e.g., using oven mitts) in a flame or place it on a hot plate. Immerse the other in ice water, or simply leave it at room temperature. Heating a tuning fork does two things; increases its length and decreases its stiffness (i.e., changes its Young's modulus). The former has a negligible effect on the frequency of a tuning fork whereas the latter produces a decrease in frequency. For safety, when listening to especially the hot tuning fork, it may be best to listen using an amplified microphone. Also, sounding both tuning forks together will produce beats.

Source

Lincoln, J. (2013). Ten things you should do with a tuning fork. *The Physics Teacher*, *51*, 176-181.

The Flipped Classroom

In a flipped classroom (Brunsell & Horejsi, 2013a,b), students are assigned lecture video podcasts to watch for homework prior to class, thus making more class time available for active learning experiences such as laboratory investigations, activities to promote the understanding of content, collaborative problem-solving, and getting help from the teacher. The videos comprise teachers talking their way through a series of small whiteboards. The example is provided of a teacher finding, or creating, 16 videos for a 2-week unit and, in another project, the practitioner reporting that a 60-minute lecture can be delivered in as little as 10 minutes via video.

The advantages of this approach include:

- Unlike a lecture, a video can be replayed to help understand a point.
- Increased student achievement and engagement.
- More class time for active learning and to differentiate instruction.
- No need for teacher to repeat lectures from class-to-class or year-to-year.
- Increased teacher job satisfaction.

However, on the negative side, the example is given of nearly one-quarter of a class not having watched many of the videos and therefore coming to class unprepared. These students can "bog down" the introductory class discussion and frustrate prepared students. Possible solutions include the teacher previewing the video(s) at the end of class in an attempt to motivate students and implementing regular online, and in-class, quizzes on video content. Fizz (n.d.) provides a wealth of resources to help implement a flipped classroom including a training program, suggestions for preparing a whiteboard lecture video, sample lecture videos, and ideas for differentiation.

References

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Smartphone to Monitor Centripetal Acceleration

A smartphone can be used to monitor the radial acceleration of a merry-go-round found in some children’s playgrounds. Suitable apps are SPARKvue (for an iPhone or an iPod touch) and Accelogger (for an Android device). Accelerate the merry-go-round from a standstill to some maximum value and then allow friction to slow it down.

Source

Vogt, P., & Kuhn, J. (2013). Analyzing radial acceleration with a smartphone acceleration sensor. *The Physics Teacher, 51*, 182-183.

Students’ Alternative Conceptions: Light

Students’ alternative conceptions have been variously called misconceptions, prior conceptions, preconceptions, preinstructional beliefs, alternative frameworks, naive theories, intuitive ideas, untutored beliefs, and children’s science. The tasks in this regular section of *SER* are based on the literature and may be used at the beginning of a constructivist learning segment to arouse the curiosity of students and to motivate them, while simultaneously eliciting their ideas or beliefs. They are designed to address areas about which students are likely to have an opinion, based on personal experiences and/or social interactions, prior to a specialist learning sequence, or areas that might be considered important for the development of scientific literacy.

A birthday cake, with candles lit, is sitting 10 metres away from you on the other side of a large room. The candle light:

A. travels all the way to you.
B. travels about 5 metres from the candle flame.
C. travels about 1 metre.
D. travels a few centimetres.
E. stays on the candle flame.

Explain your thinking. Drawing a diagram may also be useful.

Source

Keeley, P. (2012). Birthday candles: Visually representing ideas. *Science and Children, 50*(3), 32-35.

Holiday Light Failure

A string of incandescent, mini holiday lights commonly comprises 50 bulbs connected in series and costs only a couple of dollars. (Often, two such strings are connected in parallel to provide a 100-bulb arrangement.) In times gone, the failure of one bulb in a string would cause all bulbs in the string to go out, and finding which bulb to replace could be a time-consuming exercise. Modern strings have a different design, and studying the failure of one or more bulbs in the string can provide for an interesting lesson in potential differences, currents, and power in series circuits.

Inside each bulb in a modern string of holiday lights is a shunt resistor placed in parallel to the filament. The shunt is made from aluminium wire coated with an oxidation layer that has a sufficiently high resistance to prevent conduction through it when the voltage across each bulb is the typical 120/50 V = 2.4 V. When one filament blows and current in the circuit stops, the full 120-V voltage across the shunt causes its oxidation layer to burn and electricity to once again pass through the entire string and light all bulbs. The burnt oxidation coating leaves a blackened discolouration on the inside of the bulb.

A bulb failure in a string of lights can be mimicked by simply twisting the bulb in its holder so that the two wire leads cross and touch. The crossed wires cause the current to bypass the filament just like a shunt does. However, with only 49 bulbs now in the circuit, each bulb will experience a slightly higher 120/49 V across it. The higher current through the bulbs will make them glow more brightly and a power meter may be used to display the increased power output.

Causing a second bulb to fail will result in a further increase in current and bulb brightness. Continuing in this way, when only 12-15 bulbs remain, the current will have reached a value that will cause all the remaining bulbs to burn out almost instantly; a catastrophic failure.

Source

Schuetz, A. (2013). Cascading failure of holiday lights. *The Physics Teacher, 51*, 186-187.

Students' Alternative Conceptions: Radiation

By: Susanne Neumann & Martin Hopf, University of Vienna, Vienna, Austria
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1. Which of the following objects emit(s) radiation: a sheet of paper, a nuclear power plant, a cat, a flower, a candle, a mobile phone, the Sun, an ice cube?

   Answer: All of them. When confronted with the term *radiation*, many students automatically think of nuclear radiation. They think that radiation, in general, is something artificial and harmful. Infrared radiation, or thermal radiation, as it is sometimes called, is emitted by all objects. The idea that even "natural things" like flowers emit infrared radiation poses a challenge to many students.

2. Which of the following three statements is/are true?

   a. The human body has sensory organs to detect radiation.
   b. X-rays are harmless--otherwise they would not be used in hospitals.
   c. Every electrical device emits harmful radiation.

   Answer: Choice *a*. The fact that light is a type of radiation is difficult to understand for many students. The eyes and the skin are both sensory organs that detect a certain type of electromagnetic radiation. Some students think that ionizing radiation, when used in medicine, poses no threat. Another widely spread misconception is that all electrical devices send out radiation that can harm the human body.

Source

Neumann, S., & Hopf, M. (2012). Students' conceptions about 'radiation': Results from an explorative interview study of 9th grade students. *Journal of Science Education and Technology, 21*, 826-834.

The Dice Tower

Exploration. Stack five or six dice, one on top of the other on a table, to build a tower. Insert a coin horizontally into the tower between the second and third dice from the bottom. The coin should be somewhat larger in diameter than the width of a die and preferably have little surface structure (i.e., be as smooth as possible). Challenge students to use the ballpoint pen provided to remove the coin from the tower without touching the dice, leaving the tower intact and standing in the same place on the table. Students will typically try various approaches without success.

Concept introduction. The pen provided needs to be one in which the inner refill is attached to a spring. Push the top of the pen in to compress the spring and position it next to the coin so that, when the top of the pen is released, it strikes the coin and propels it sideways. The top of the pen should not strike a die. The coin moves so quickly that the frictional force acting on the dice on either side of it imparts only a very small impulse to them. The dice have sufficient inertia to keep the tower intact.

Concept application. Use any of the many standard inertia activities that are available to reinforce the foregoing explanation.

Optional fun. Have a competition to see who can achieve this task with the most dice above the coin.

Source

Vollmer, M., & Möllmann, K-P. (2013). Removing coins from a dice tower: No magic – just physics. *The Physics Teacher*, *51*, 212-213.

Science Poetry

Reading and/or listening to poems composed by other children their own age can inspire and reassure students as to their ability to understand and write poetry, and the science poems in this regular section of *SER* may be used for this purpose. Please find information about the *International Science Poetry Competition* at http://www.ScienceEducationReview.com/poetcomp.html .

Leaf

A leaf of a tree
Or a bush or a plant
Helps plants to live
Without them they can't.
They are often bright green
Or similar hues
They are where many plants
Make their own foods!
Leaves are an organ
That grow above ground
They have many shapes
From needles to round.

Leaves collect sunshine
Can turn towards the sun
Some can catch insects
Snap closed, and it was done!
In fall, leaves may leave
The branch of their tree
Fly in the wind
Full colored and free!
Leaves, an amazing
Part of a plant
Help plants to live
Without them, they can't.

Siti Nur Aisyah Binti, Mohamad Dahlan
9 years, Malaysia

The Science- Sarah Hartnell

The cogs are turning
The chemicals churning
Around and around
There's no stopping the motion
That constant commotion
ln the sky and the ocean
It's moving
And breathing
And growing
And reaching
Creating the things
You care about
Care about
It's moving the earth around: science

Does it blow out your mind
That your genes are combined?
That they are a mingling of
Your parents' best pieces?
That you're a part of a species
That develops and grows
That changes and evolves?
That you are a relation
Of previous generations?
That your blood tells your story
Better than you can?
That we know your story
Better than you do?
And we know how it works too
That blood
And those genes
We know how it works
We know all these things
We know
science

Does it freak you out slightly
That your brain is more mighty
Than the thoughts that you think?
That it's more intricate
Than your internet links?
That right at the moment
There are a hundred components
It's making your arms do that moving
That it's making you breathe
And thinking about it
That it fights off disease
But knows what a brussel sprout is
Does it freak you out slightly
That right at the moment
Your mind's doing
science?

And does it make you amazed
That one day
Our world will burst into flames
Or be iced over completely
And we won't be here?
We'll have been dead for years
We'll have decomposed in the earth
We'll have been eaten by worms
But that the world will keep spinning
That the planets will still align
That the sun will still supernova in time
For the end of existence
It'll shoot out stardust
And that we're made of that stuff rhythm
And all of it
All of it is
science

Don't you think that it's cool that
The cogs are turning
The chemicals churning
Around and around
That there's no stopping the motion
That constant commotion
ln the sky and the ocean
It's moving
And breathing
And growing
And reaching
Creating the things
You care about
Care about
It's moving the earth around:

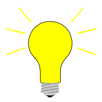
Working and blinking
To make you comprehend
The thoughts that you're thinking
And the things that you're doing?

science

It's doing this stuff
And it doesn't care much

Whether we know it or not
It's still science

Sarah Hartnell, 15 years
Australia



Ideas in Brief

Ideas from key articles in reviewed publications

Paired Placements for Student Teaching

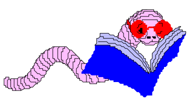
Mau (2013) draws attention to the potential benefits of student teachers being placed in schools in pairs, with both students and the cooperating teacher being present in a room at the same time. The research cited suggests that, in paired placements, pre-service teachers can:

- engage in more frequent and varied communication,
- find methods for collaboration and cooperation in the process of teaching,
- increase their willingness to take pedagogic risks,
- have better classroom management,
- find ways to increase the learning of school students,
- improve their levels of reflection, and
- find strategies to handle tensions in perspective and performance.

Paired placements facilitate the same kind of collaboration and cooperation that occurs during the early years of employment in many other professions such as surgery, accountancy, and architecture.

Reference

Mau, S. (2013). Better together? Considering paired-placements for student teaching. *School Science and Mathematics*, *113*(2), 53-55.



Research in Brief

Research findings from key articles in reviewed publications

Working Memory: The Key to Successful Understanding

By: Norman Reid, University of Glasgow, Glasgow, UK dr_n@btinternet.com

In the field of biology, genetics has proved to be one of the most difficult areas for learners. Yet, it can be argued that an understanding of the basic ideas of genetics is very important for all learners, given the way genetics research has changed and is changing progress in medical fields, quite apart from the way the genetics revolution is affecting agriculture and food production.

In an analysis of the area, Bahar, Johnstone, and Hansell (1999) appreciated that the difficulties lay in the multi-level nature of genetics, an idea developed much more fully by Chandi, Reid, McWilliam, and Gray (2009). When a learner has to work at multiple levels, the working memory will overload easily, making understanding a casualty (Ali & Reid, 2012; Baddeley, 2002; Chu & Reid, 2012; Johnstone 1991; Kirschner, Sweller, & Clark, 2006; Reid, 2009b,c).

In Chu and Reid (2012), it was found that measured working memory capacity of 141 Taiwanese students aged 13-14 years correlated highly significantly with measures of performance in genetics ($r = 0.61$). Previous studies have shown that the relationship is cause-and-effect (Johnstone & El-Banna, 1986, 1989). In addition, measured field dependency also correlated highly significantly with measures of performance in genetics ($r = 0.48$).

Working with another group of 361 students aged 13-14 years, one half were taught using materials that had been developed specifically to minimize the load on working memory while the other half were taught using the normal written materials. The same content was taught over the same period of time. Their understanding at the end of the genetics course was measured by the traditional examination and also by a word association test (known to give a measure of links between ideas). In both measures of performance, the experimental group, taught using written materials designed to minimize working memory overload, was found to perform highly significantly better.

Many studies have now demonstrated that the limitations of working memory capacity explain why specific topics in the sciences pose problems for learners (Reid, 2009a,b,c), while many studies have also shown ways by which working memory overload can be minimized, with very large learning gains occurring (Danili & Reid, 2004; Hussein & Reid, 2009; Reid, 2008; Reid, 2013). It is important that all written materials are re-thought in the light of working memory limitations while assessment approaches also need to take account of the problems. This is not to suggest in any way that courses need to be "watered down." Indeed, the evidence suggests that the demand of level of science courses can be increased, provided that the way the material is presented does not generate working memory overload.

References

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Chandi, S. S., Reid, N., McWilliam, A., & Gray, D. (2009). Exploring the usefulness of a systems-based model from the perspective of biology students. *Scottish Educational Studies, 41*(1), 68-85.

Chu, Y-C., & Reid, N. (2012). Genetics at school level: Addressing the difficulties. *Research in Science & Technological Education, 31*(1), 1-25.

Danili, E., & Reid, N. (2004). Some strategies to improve performance in school chemistry, based on two cognitive factors. *Research in Science and Technological Education, 22*(2), 203-226.

Hussein, F., & Reid, N. (2009). Working memory and difficulties in school chemistry. *Research in Science and Technological Education, 27*(2), 161-186.

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Reid, N. (2009c). Working memory and science education. *Research in Science and Technological Education, 27*(2), 245-250.
Reid, N. (2013). Successful chemistry education. *La Chimica nella Suva, 34*(3), 290-297.

ICT Integration to Engage Students

Mobile phones are becoming ubiquitous, even within disadvantaged communities. Wilson and Boldeman (2012) began “where young people are at” in their highly-connected, technology-rich lives and used ICT in the form of Web 2.0 technologies to try to reengage a group of lower-secondary male students in North Queensland, Australia who found themselves outside the mainstream secondary schooling system, including some with a recognized learning disability. Techniques involving iPads that were used included the following:

- Viewing YouTube clips to find how others had done the Coke and Mentos and water rocket activities, as well as finding explanations for these.
- Using a Wind Tunnel app to see wind flow patterns across different shapes as a tool in designing a water rocket.
- Accessing online, interactive activities related to Newton’s laws of motion.
- Viewing YouTube videos showing how to make a paper glider to overcome the difficulty students had with following paper-based instructions.

The fact that an iPad was not available for every student proved beneficial, as it facilitated collaboration and peer mentoring. The use of ICT was effective in revitalising students’ interest in science education and creating links to real-life situations.

Reference

Wilson, K. L., & Boldeman, S. U. (2012). Exploring ICT integration as a tool to engage young people at a flexible learning centre. *Journal of Science Education and Technology, 21*, 661-668.

Readers’ Forum

A Dichotomous Key Organizes the Science Lab Zoo

The world of science labs in education has become complex. The words used to describe them often have fuzzy definitions that depend on who's speaking and that person's agenda. A few definitions and a nice dichotomous key should help out a great deal. So, here goes.

Two phrases overused in these discussions must be tossed out. “Virtual lab” carries with it too much baggage. Usually, it's used to indicate the opposite of the other overused phrase “hands-on lab.” Because these words have different connotations for different people, they are not used here to develop the dichotomous key for science labs. You'll find proposed clarifying definitions at the end in the wrap-up.

There is a very important word, “lab,” that must be handled with care. In *America's Lab Report* (ALR) (Singer, Hilton, & Schweingruber, 2005), the National Research Council provided the following definition of a science lab: “Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science” (p. 32). Because nearly everyone ignores this definition and keeps on calling activities that do not meet this definition of labs, this practice will continue here. That does not mean that I condone the practice. It is just that it's convenient for the purposes of this writing.

ORDER: real or model. Taking the concept from biology, you might have kingdom, phylum, class, order, family, genus, and species. To keep things simple here, only three levels for labs above species are considered. Beginning, then, with order, the test is whether the lab is real or a model of reality. Models are sometimes called simulations, but that word too has too much baggage. All science labs that I have seen fall into one of these two categories. So, the first dichotomous test is that of reality. Real means that the data originate in what ALR calls the material world. If the data originate from a formula, an algorithm, or just someone's imagination, they are not real, and the order is that of a model.

FAMILY: wet or online: The next dichotomous test is for the mode of delivery of the lab. Either it is “wet,” meaning that you touch the materials and equipment with your own hands in the process of performing the lab, or it is not. While you can imagine alternatives to wet other than computer-mediated, they are unlikely to appear. A good, short word for computer-mediated these days is *online*. The family, therefore, will be either wet or online. Although computer-mediated labs may run on a standalone computer, there is no theoretical reason why they cannot be run online. Therefore, this word should suffice. Both orders can have either mode.

Taking into account both order and family therefore gives the following types of labs: *real-wet, real-online, model-wet, or model-online*. As you ponder these combinations, examples of all may not spring to mind. Here is a quick summary with examples:

- Real-wet: Traditional 19th-century labs.
- Real-online: MIT iLabs (remote robotic labs).
- Model-wet: Simulating radioactive decay by throwing dice or flipping coins.
- Model-online: Any typical simulated lab such as PhET (2011).

You might like to make up clever names for these combinations, but that may confuse more than improve the situation. It makes sense to leave it as it is for now.

GENUS: manual or automatic. The final dichotomous key concerns the mode of data collection; either manual or automatic. You certainly could be creative and choose more keys such as open-source or not, fee or free, available on tablets or not, and so on. However, these would not affect the learning impact. If you have suggestions for further classification that does affect learning, please comment or write directly to me.

These two data collection modes have very distinct operations and impacts on students. Manual data collection is very familiar because this is how labs have functioned since they were introduced into secondary education in the late 19th century. Students take readings from meter sticks, thermometers, multimeters, and so on with pen and paper. Automated data collection requires electronics. In the real-wet world, an example is probeware, automated devices connected to sensors.

Accounting for order, family, and genus now allows us to arrive at the following categories of labs: *real-wet-manual, real-wet-automatic, real-online-manual, real-online-automatic, model-wet-manual, model-online-automatic*. "But wait," you might say, "you left some out." Two combinations don't really exist in the actual world and so have been left out. The wet-model labs will always involve manual data collection. These involve dice for radioactive decay, pop-beads for meiosis, and so on. The data must be recorded manually in these situations. Thus, wet-model-automatic labs have been eliminated. The other one, model-online-manual, could be created but with no purpose. As the data are generated voluminously by a computer, there's simply no reason to force students to perform some manual operation for each data point. These labs have a mode of "pick parameters, see data."

Much professional scientific data is collected automatically and then processed. The Mars rovers do this, and so do experiments at the CERN collider. Many companies have built automated analysis apparatus to reduce error and lab technician time. That is what our future scientists, lab technicians, and those in lab-oriented fields will encounter when they enter the workforce. So, shouldn't we do the same in school? No!

Except in training specifically for science-related majors, we should provide maximum exposure to the nature of science and scientific thinking, as well as maximum engagement. Manual data collection best serves both of these goals. It gives students a feel for the data and a sense of ownership of them. It requires students to exercise individual care and judgment while taking the data, a factor that is absent with automatic data collection.

Further discussion requires that I disclose my personal involvement with these issues. While I am a former university professor and a recognized expert in science education, I have created the Smart Science (2013) project to create software and content based on one of the six genera of science labs developed in the foregoing: namely, real-online-manual. Further, my company's offering is the only species in that genus of which I am aware. The following judgments that I make on this lab "zoo" reflect my own opinions based on over a decade of research in this field but, despite my efforts to avoid it, may contain bias.

Real-wet-manual: This is your grandfather's lab. These are relatively expensive, time-consuming, and occasionally hazardous. Yet, the best ones are very good indeed. The poor ones, as with the girl in the Longfellow jingle who could be either very good or very bad, are horrid. The best of the best will be relatively inexpensive and illustrate the nature of science well while providing plenty of material for practice in scientific thinking. We must hang onto as many of these as we can.

Real-wet-automatic: Mostly, these are probeware labs, but may use other automated equipment. As mentioned above, these take some of the experimental work out of the hands of students. This sort of thing is very appropriate for college science majors who already have some sophisticated understanding of the process of data capture. For the average middle- or high-school student, the value is unclear. It trades engagement for efficiency and may remove an important aspect of learning science from the experience. These are clever devices but are unnecessary in middle- and high-school science education today, except for long-term data recording.

Real-online-automatic: The MIT iLabs exemplify this category. These are remote robotic labs. You program, usually by selecting parameters, a remote piece of equipment that runs your experiment and returns a data stream to you. These have proven to have great value for college engineering majors. Providing a data set from a distant automated piece of equipment through a computer interface seems a bit remote for ordinary students. It is tantamount to handing students a piece of paper with data that the instructor has assembled.

Real-online-manual: This sort of lab was not feasible until the late 1990s. The concept is rather simple. Videos record real experiments, the videos are edited to facilitate data collection and understanding, and the videos are made available from the Internet together with software that enables manual data collection. The videos contain no data. Rather, these come from students using their own care and judgment to capture data interactively.

Model-wet-manual: These are, as mentioned earlier, the simulations done with various stand-ins for the real thing. The dice for radioactivity is an obvious one. For many, this is a hands-on lab. Because it is not real-wet-manual, it does not provide the same benefits. Primarily, it is a visualization exercise oriented toward learning science concepts. There is nothing wrong with doing these activities as long as the students are given to understand that they are working with a model, and all models are imperfect representations of the real world. You also should not use precious lab time on these activities. They belong in the category of lectures, book reading, videos, and demonstrations.

Model-online-automatic: These are the typical virtual lab and have divided the science education community, with one side despising them while the other praises them. This division resulted from a misunderstanding of their purpose and value and of their abuse by some. Those against them see them as potentially usurping the place of the real-online-manual labs. Those for them point to learning gains as evidenced on tests. Those tests assess concepts, explicit knowledge that may be acquired by memory. Both are correct as should be obvious on reflection.

All online lab approaches have the potential for aggregation to determine how well learning is progressing, for collaboration by sharing data and other information, and for early intervention based on analysis of assessments and other information contained in the online server database.

So, after all of this, what are virtual labs and hands-on labs? A virtual lab may or may not be a simulation (a model). It must have a computer in between the experimenter and the experiment, although you wouldn't count a trivial computer interface such as a probe. A hands-on lab, in my definition, has several aspects. It need not be wet. It must:

- deliver data from the real world,
- use manual (the *hands* in hands-on) data collection,
- require care and judgment from students to take data,
- have natural systematic and random errors, and
- possibly contain complexity and ambiguity that require deeper thinking.

I judge this to be a sufficient list. Others may disagree, and I welcome their well-reasoned opinions.

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Science Topics not Related to Needed Reforms

To some science educators, the term *topics* is a favorite word to use in lesson planning, teaching, curriculum frameworks, vocabulary mastery, and assessing student learning. But, for many, such a focus misses the point and the purpose of science in the school program. It fails to provide real help with student learning across the curriculum. It only provides a means for indicating retention of "information" used to characterize science courses. The term topics alone does not have any relationship to doing science, which starts with questions, wonderment, and thinking. Instead, topics provide a way of classifying what goes into textbooks and teachers' plans and what will be used for assessment purposes.

It is common to see lists such as major words and titles for chapters in a textbook. Often, topics are also words that will be encountered when studying a given chapter. They often are offered as definitions for students to use to indicate their "knowing" their own personal meaning as well as for teacher use. Topics make the act of teaching clear, but they have nothing to do with actually doing science in terms of the reforms of science teaching and/or a focus for indicating student learning. The word is not useful for meeting the first and most important goal (justification) for teaching science in the 1996 National Science Education Standards (National Research Council [NRC], 1996). Unfortunately, the final draft of the Next Generation Science Standards (NGSS) (Achieve, 2013) refers to such topic designation!

And yet such inclusion of topics is where major arguments arise! Which must be included in the course? Which are out? In what order? Reports and arguments among experts are involved. Most reform efforts had gone beyond topics when the 1996 Science Education Standards were released. These were exciting times because there were deliberations, discussions of what was desired for the future, and people arguing. *Science for All Americans* (American Association for the Advancement of Science [AAAS], 1990) was the blue-print for the AAAS reform titled Project 2061. Again, the NGSS take us back to the benchmark term!

The development of benchmarks was another major effort of Project 2061. These were produced to gain National Science Foundation (NSF) funding; they were requested by NSF funders to outline what science was needed for use in accomplishing the reform efforts outlined in *Science for All Americans*. I was one who helped decide what Life Science information should be included in the benchmarks. It was disturbing for me to see the arguments related to importance (i.e., what to include). Even the term benchmark suggests the inclusion of topics (i.e., the results from the debates among the experts selected by the leaders of Project 2061).

But, dealing with the acts of science as something scientists do was not tackled or even considered! Even the National Science Teachers Association (NSTA) Scope, Sequence, and Coordination (SS&C) project (NSTA, 1990) accepted science as something little more than an indication of the content of the new 1996 efforts with reforms. But, NSTA remained concerned that there are topics that should/must be included, as the term Scope and Sequence suggests. Some involved with SS&C were anxious to ignore specific topics in the K-12 science sequence, and not even use them as the framework for school science, even as AAAS succeeded with publication of the benchmarks, but mainly in order to get federal funding to work toward realizing visions framing the Project 2061 results.

We seem to be going in the same wrong direction with the 2013 New Generation Science Standards. Leaders and funders seem only concerned with what content is to be included and where. There appears to be no worry about how the lists of science processes were used as an example of reforms more than three decades earlier. There is no interest in new goals to replace, or extend, those in the 1996 National Science Education Standards. There was no interest in messing with the nine features for the reform of science teaching. No one cared what the 1996 Standards considered important in terms of curriculum topics. Wiggins and McTighe (1998) were praised for their work with Backward Design, which recommended deciding on assessment strategies before considering content. All of this happened with no mention of topics, or specific content, used to organize actual courses to illustrate the new reform efforts.

Instead, we are back with chemistry and physics combined as physical science, along with life science and earth/space science. Only now it is popular to also include technology and engineering. It makes it easy to talk “newly” about STEM education and all the re-thinking needed to define content and to use it to assess student learning.

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The Flipped Classroom and Student Workload

Brunsell & Horejsi (2013a,b) report glowingly on the benefits of the flipped classroom. In this approach, students are assigned lecture video podcasts to watch for homework prior to class, thus making more class time available for active learning experiences such as laboratory investigations, activities to promote the understanding of content, collaborative problem-solving, and getting help from the teacher. However, I wish to flag what I see as a potential obstacle.

Let me use the example provided by the authors of the teacher who required the viewing of 16 videos during a 2-week period, and assume that each video required 10 minutes viewing time. Students studying six subjects, say, in which this approach is being implemented would find themselves with about an additional 1.5 hours of homework each night (assuming they have two nights off required homework each week). This increased demand on time seems excessive and likely to impact negatively on a balanced lifestyle, which sees students quite legitimately participating in social, cultural, and/or sporting experiences in addition to academic pursuits).

I therefore wish to suggest two possibilities aimed at helping to implement a flipped classroom:

1. Use the videos as homework as suggested but reduce other homework demands on students (i.e., something would need to go!). I am sceptical, though, that the latter would be easy to achieve. My experience has been that students in some educational jurisdictions have already experienced what some regard to be excessive academic demands on out-of-class time, especially in situations where a move has been made from external examinations to more school-based summative assessment, and this situation has not been helped by teachers of different subjects typically not liasing to consider the overall workloads demanded of students. I hope the implementation of flipped classrooms would not be another contributor in this undesirable direction. In any case, my experience has also been that teachers find it very difficult to leave out things that they have become used to doing, with innovations tending to see demands being added on to what is already being expected of students.
2. Reduce overall course content (at the syllabus level) and incorporate the videos in class time. This approach would overcome the prime concern with the flipped classroom mentioned by Brunsell & Horejsi (2013b) of students coming to class unprepared.

References

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Responses From the Authors

I do not think that the homework issue is unique to a flipped classroom. Excessive homework across multiple subjects can be an issue with any instructional format. The appropriate amount of homework assigned in any class is very dependent on a variety of course and school factors.

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Peter, I do believe you are correct, and have an 8th grade daughter who would also agree with you. However, while Eric and my column often highlights the leaders and forward thinking practices at the intersection of science and technology, it rarely reflects the average situation found in schools today. And, in fact, that is the point of the column.

With the simplicity of recording and creating digital content within the grasp of almost all modern teachers, it will take little effort by the school's administration to encourage such practices which could then reinforce the infrastructure necessary for the appropriate use of the flipped classroom concept. But alas, as you point out, until then it could become an ineffective time sink at best, and a detriment to extracurricular education at worst. But as luck would have it, the speed of change when technology is involved may limit this dark period of classroom flipping to a year or two.

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? ? ? ? ? Your Questions Answered ? ? ? ? ?

This section of *SER* responds to readers' queries, so please submit your question to The Editor at editor@ScienceEducationReview.com . Have that long-standing query resolved; hopefully!

A Contextual Approach

Do we have evidence to support the notion that contextual teaching in science education (i.e., using everyday contexts to develop science concepts) produces better outcomes for students than a concept-followed-by-applications approach (i.e., where concepts are developed and then linked with everyday applications)? If so, would you kindly supply references.

There has been an A-level (post-16) exam course in Biology (Salters' Nuffield Advanced Biology) that offers common exams but two different approaches; context or concept. There are associated textbooks written for both styles of approach. Recently, Braund, Bennett, Hampden-Thompson, and Main (2013) carried out a study to compare the two approaches.

Reference

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Sue Howarth, University of Worcester, UK

(*Editor:* This study suggests that there is a place for both approaches, reflecting the notion that in education there is typically no panacea. *Peter Eastwell*)

Laboratory Safety Guidelines

This section presents a series of 40 laboratory safety guidelines kindly provided by Dr James A. Kaufman, President, The Laboratory Safety Institute (LSI), USA. Please visit http://www.labsafety.org for further information, products, services, and publications.

#19 of 40. ***Do not Allow Food to be Stored in Chemical Refrigerators***

Prohibiting the storage of food in chemical refrigerators is another one of the basic rules of good practice. Like the foregoing rules in this series, it is intended to prevent the ingestion of toxic or infectious materials. The food will absorb the vapors from the chemicals in the refrigerator and then they'll be consumed.

Post a clear warning sign on any chemical refrigerator: "Chemicals Only; Do Not Store Your Food Here." Assign one person the responsibility for each refrigerator. They can check it periodically to be sure there's no food and no unlabeled containers. They can also see that the inventory list is up-to-date and that the refrigerator is functioning properly and does not need to be defrosted.

A related problem is caused by carrying a pack of cigarettes in your pocket while working in laboratories. The tobacco adsorbs chemicals from the air, just like a dosimeter. Then when you go outside to "clean air," the adsorbed chemicals are burned and inhaled. Illnesses have been traced to the inhalation of these chemical combustion products.

The storage of food and beverages where they may be exposed to hazardous substances is specifically prohibited in the OSHA sanitation standard 29CFR1910.141(g)2/4. Tufts University's Safety Office produced a good check list for refrigerator inspections and copies are available from LSI.

Further Useful Resources

Physics Teaching for the 21st Century (http://c21.phas.ubc.ca) A resource for teachers who are interested in teaching physics concepts in real-world contexts.

Departing Space Station Commander Provides Tour of Orbital Laboratory A YouTube video in which a female astronaut provides answers to the questions that many ask, such as: “How do you sleep?” “How do you go to the toilet?”

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The Science Education Review (*SER*) is an international, peer-reviewed periodical aiming to provide primary and high school teachers with the latest, and best, ideas in science education from around the world. *SER* also publishes original articles, including research articles, and much more.

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Contributions are welcome, as are expressions of interest in joining the Editorial Review Board. The latter role requires the periodic review of submitted contributions, and is not onerous. Comments, questions, and article proposals may be sent to The Editor, Dr Peter H. Eastwell, at editor@ScienceEducationReview.com .

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