Understanding Our Gifted

Dedicated to helping gifted children reach their full potential

Science, Technology, Engineering, Math

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Online Options for Math-Advanced Students

Suki Wessling

Suki Wessling *is a writer and a homeschooling mom of two children. She writes about homeschooling, parenting, and gifted education in various publications and on her blog, Avant Parenting. Her book, From School to Homeschool, a guide for parents taking their gifted learners out of school, was published by Great Potential Press in November, 2012. More information at www.SukiWessling.com.*

Once upon a time, a student well advanced past grade level in math would have had few choices. Advanced students would invariably outpace the skills of their elementary teachers, and due to age wouldn't have options such as going to the middle school or community college for classes. Soon thereafter, students would enter middle school only to find that they had exhausted middle school curriculum, and again they would have to wait or go to the high school for classes. Some high schools would be able to accommodate an advanced student, but many other would have the same advice: wait.

The age of the Internet has changed every facet of education, but for the advanced student, the availability of math resources has possibly been the most fundamental change of all. Math learning is an explosive area in online curriculum, from math games to online math classes. Literally anything that an advanced math student cannot get from his or her school can be found on the Internet.

The keys are knowing what you want, and knowing where to look, which means that math-advanced students benefit from having a guide to help them find what they need. Where they get that guide depends on their individual situation.

"Whenever the student outpaces the parent [or teacher], a guide is a good idea," says Sue VanHattum, a mathematician who blogs at mathmamawrites.blogspot.com. "Although an in-person, local tutor is always best, that guide might also be an online tutor, a teacher in a homeschooler's class, or an online teacher."

Parents and teachers can also act as guides if they are willing to do the legwork to help students find what they need. Depending on whether students are looking to supplement their in-person learning with further exploration or planning to join online classes, parents and teachers can help them research the options and make decisions.

Online tutors

An increasing number of independent teachers are viewing Internet collaboration tools like GoToMeeting.com as a way to reach a wider range of students. High level math tutors can now look for their students anywhere in the world, rather than just in their immediate area. On the flipside, it used to be that math-advanced students would have to take whatever was offered in their immediate geographic area. Now they can find appropriate tutors no matter where they live.

There are different approaches to finding a good fit with an online tutor. The most successful tutors work by word of mouth, so one place to start would be asking local parents with math-advanced children who may have found someone through their networks. Math departments at nearby (or not so nearby!) colleges might know of graduate students who are interested in tutoring. These days, online bulletin boards and e-mail lists for gifted education will probably turn up the best recommendations.

"There's really no limit to what can be done—I've got students in Greece, Italy, Yugoslavia, and India," says John Rosasco, a popular online teacher whose website is mathandmusicstudio.com. Rosasco says that most of his clients find him through the Davidson parent bulletin board at davidsongifted.org. "As long they can speak English and they want to learn math or music, I can help them."

Tutors work one-on-one with students to develop their math skills and interests, so flexibility is the key. You may want to give the tutor free rein to explore topics in math with the student, or you may want to specify an area that the student is interested in or needs more guidance in.

Rosasco says that online tutoring is a great solution for kids whose needs aren't being served in school, and who aren't necessarily looking to follow a set curriculum.

"I talk to the kids and see what they're interested in," Rosasco explains. "The idea is to be able to share high level knowledge with young people that want to learn it. Assuming kids go to a public or private school, curriculum is set rigidly. I don't set rigid curriculum—if a student is capable they can do anything they want."

Online classes, live or self-paced with instructor

The obvious thing people think of when sending a math-advanced student out onto the Internet is the guided class. There are plenty of these, ranging from pre-made videos and problem sets to individual math teachers working with groups of students in real time. Not all of them are suitable for a student gifted in math, however. Some students' needs may be served simply by accessing a more advanced level of math, but most gifted math students benefit from an approach directed at their speed and depth of learning.

Like working with tutors, online math classes can take advantage of the full range of Internet tools. Some classes are text only, with students and teacher typing into chat windows. Some classes require entry into a meeting location where students and teacher can share sound, a whiteboard, their screens, and even video. Other classes are comprised of self-paced learning monitored by an instructor instead of a class component.

A student's specific skill set and preferences will have a lot to do with which options will work best for him or her. Students who are slow typists will be left behind in fast-moving online classes that work in text only. Students who are frustrated by listening to a variety of speakers might want a class where audio is only from the teacher. A student who wants the benefit of direct communication with a teacher may choose a class that is self-paced but includes working with a live teacher.

Some online math classes popular with gifted learners include:

Art of Problem Solving: www.artofproblemsolving.com

"The most exciting online resource I know of for mathematically advanced students is artofproblemsolving.com, whose classes receive universally positive reviews," VanHattum says. "The organization could not have existed without the Internet bringing together the advanced math students who are their main clientele."

AoPS offers real-time classes that are known for their quick pace and high quality teachers. Students should be ready for a text-based environment that requires good typing skills. Not all students in AoPS classes go to competitions; however, parents report that AOPS classes are great for students who plan to compete.

AoPS recommends that new students take their placement test to find the best class for their level.

EPGY: epgy.stanford.edu

EPGY classes, from Stanford's Online High School, can be accessed through Stanford or through a variety of other programs such as CTY (cty.jhu.edu) or brick-and-mortar schools. According to their website, "All EPGY courses use the computer as an essential instructional resource. EPGY offers two types of online courses: 1) self-paced/directed study, in which students work individually on the computer with support from an EPGY instructor, and 2) seminar-style courses, of which the online classroom is the defining feature."

EPGY has an application process for their courses, so interested students should apply well in advance of the time period in which they want to take a class. EPGY has recently added an Open Enrollment option in which students can take self-paced classes monitored by their parents or teachers.

eIMACS: www.eimacs.com

eIMACS is the Internet arm of an old and respected organization which has provided advanced math instruction to high school students for many years. Their program is a hybrid self-paced/instructor-led system in which students are assigned an instructor and have 40 weeks to finish curriculum. Users report a high level of satisfaction with the program.

eIMACS has a placement test which determines the level of placement for the first course.

Self-paced courses

Truly self-paced courses (with no live teacher component) are available in droves on the Internet. They vary widely in the level of detail provided, the technology used for teaching, and the sort of student they serve. Most children, whether 9 or 15, need guidance when using a self-paced course. Some of these courses include a coaching or monitoring component, which can be very useful to a parent or teacher who is helping a math-advanced student focus on a particular area of study.

Some self-paced courses popular with gifted students include:

Art of Problem Solving: www.artofproblemsolving.com/Videos

AoPS's free videos work well as a companion to their books, a supplement to their fast-paced classes, and also as a supplement to any other course of study. Presently they offer exhaustive videos in pre-algebra, algebra, and counting & probability, with more to come.

The videos do not include online problem sets or any sort of teacher/coach component, so they are best used either as a supplement to other studies or directly with AoPS's textbooks.

Elements of Mathematics: Foundations: www.elementsofmathematics.com

This new set of self-paced courses from IMACS are high school-level courses that were specifically designed for high-caliber students with the purpose of providing a deep and lasting understanding of mathematics.

"The EMF site does provide a Help Forum where students are able to ask questions, [which] can be answered by more advanced EMF students or by our staff in some cases," explains Terry Kaufman, president of IMACS. "We have gone to great lengths to build interactive tools into our curriculum to help students understand the most challenging concepts without the need of an instructor."

Khan Academy: www.khanacademy.org

By now everyone knows about Khan Academy, but most parents and teachers haven't explored the finer aspects of the system. The videos made Khan famous, but the online "practice" environment is what makes Khan most useful for math-advanced students and their guides. Problem sets are arranged in a learning tree environment, so that students can pursue one particular branch of math study or jump around to different subjects that catch their interest. The system recommends the next subjects to study and also offers review questions. (Students who find the review aspect annoying quickly learn that you can dismiss a review set with one correct answer.)

Parents and teachers can now sign up as “coaches” and monitor their students’ progress through their own accounts. Khan breaks down each student’s progress by time and subject, and coaches can see informative diagrams that illustrate mastery on a subject-by-subject basis. To learn more, go to Khan Academy and choose “Coach” at the top of the screen.

Saylor.org:
www.saylor.org/majors/mathematics

A new foundation-supported free website, Saylor has compiled courses using a variety of technology, from online textbooks to videos, though a scan of their math courses shows a heavy emphasis on traditional textbook/worksheet format. Saylor offers math from algebra through some advanced mathematics topics.

Coursera:
www.coursera.org/category/math

Coursera offers university-level courses from a variety of respected universities with a hybrid self-paced/teacher-led approach. Course materials are released on a fixed schedule and there can be limited interaction with teaching staff in some courses, but the work is largely self-paced. Online exercises are integrated with the videos, and some courses offer certificates of completion.

MIT Open Courseware:
ocw.mit.edu/courses/#mathematics

MIT has archived a number of their course offerings online. How much is provided with each course varies widely, from courses only offering videos of lectures to courses offering full textbooks or quizzes and answer keys.

Creative inspiration

Though many gifted math students are focused on moving up into higher levels of math, some students crave more math play and creativity than they get at school and at home. Younger students especially may have their math cravings satisfied by online fare that suggests new ways to approach math.

Some favorites of gifted math students include:

Vi Hart:
www.khanacademy.org/math/vi-hart

It’s hard to understand the importance of what Vi Hart is doing with her Youtube videos (now hosted by Khan Academy) until you see a young person inspired by them. Vi’s videos almost exclusively feature her hands and her voice. The hands “doodle” fun pictures while the voice patiently explains how math teachers are getting it all wrong: math isn’t boring! It’s fun! Just look what Vi does when her boring teacher is droning on about graphing or number theory. With paper, pencil, and markers—along with occasional other tools—Vi doodles her way through a deep understanding of what math really means.

Numberphile: numberphile.com

A collection of British mathematicians post videos about math and numbers, from whimsical to serious. Chinese numbers, Borromean Rings, Yatzee, Batman, Usain Bolt, the flag of Nepal, Graham's Number, Lucky numbers… This site could keep a math-hungry student busy for a long time.

The Story of One by Terry Jones: videosift.com/video/The-Story-Of-One-Terry-Jones-BBC-number-documentary-5904

This fun historical documentary of the number one by Terry Jones of Monty Python fame features lots of silliness while explaining the significance of our first number.

Best math Youtube videos: www.mathishtoenglish.com/the-best-math-youtube-videos

You can find legions of math videos on Youtube, ranging from the brilliant to the embarrassing, so it can be very helpful to view someone else's culling of the best of them.

Extra-Terrestrial Math: How different could it be?: www.youtube.com/watch?v=9MV65airaPA

This lecture is for your math-hungry kid who is also interested in the possibility of extraterrestrial intelligence.

Donald Duck in Mathmagic Land: www.youtube.com/watch?v=YRD4gb0p5RM

Remember when the people making animated films for kids were unabashed intellectuals? This charming Donald Duck feature describes the history of math with classic goofiness and plenty of detail for young mathematicians.

Brain teasers and games

A fundamental part of an advanced math learner's world can revolve around playing games and testing their skills in a more creative setting. New websites for math enthusiasts pop up every day, but here are some that have already attracted attention from gifted students:

Alcumus: www.artofproblemsolving.com/Alcumus

Alcumus from AoPS is a math problem-generating engine of more than 9000 problems. The engine attempts to adjust problems to the user's skill level, and uses problems drawn from a range of math competitions.

WolframAlpha: www.wolframalpha.com

WolframAlpha is a massive engine with the lofty goal of "making knowledge computable." Students can input any question they'd like into the engine to see what it comes up with. For a more focused exploration, from the home page choose Resources & Tools then Examples by Topic. This page presents a huge range of topics to explore. The Blog and Forum links contain discussions about a wide variety of topics and ways to use WolframAlpha.

Math Playground:
www.mathplayground.com

For younger kids, this truly is a playground of math fun. Set them loose and see what they find.

MathCounts's Math Arcade:
mathcounts.org/arcade

This site features a number of math-related games recommended by AoPS.

What next?

The infinitely expanding Internet is likely to keep up with advanced math students' needs, but how this will all play out in the field of education is still to be seen. Teachers and administrators who balk at allowing their students free access to advanced learning online may find themselves left behind.

"In grad school you have an advisor—I'm doing the same thing with the kids I work with," John Rosasco says. "If kids want to do research projects, I just steer them in that direction and let them go."

Kaufman points out that gifted math students don't need the same thing faster, but something altogether different. "By definition standards-based curriculum is designed for average to below average students," he explains. "Gifted and talented students who speed through standards-based curriculum are not inspired by this approach and do not get a true sense of what mathematics is all about."

The old way of doing things, having a set curriculum that all students follow at the same age, will give way as more students are able to access learning opportunities that match their skills and interests. Rosasco points out that what he and others on the Internet are doing with individual students is going to have a big effect as it ripples outward to more tutors, more kids, more math, and more learning:

"The institutions are going to have to modify the way they do things in order to keep up with these kids." •

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Keeping Young Gifted Students Engaged Through Science

Dennis N. Corash and Melinda Jones

Dennis N. Corash *has been an educator in the field of gifted education for over thirty years. He taught gifted and highly gifted self-contained classrooms before moving into an administrative role. He is currently an assistant professor of Elementary Education at Metropolitan State University of Denver. He is the father of three, gifted twice-exceptional, now young adults.*

Melinda Jones *taught gifted children in preschool through second grade in both private and public programs. She is an assistant professor of early childhood education at Metropolitan Sate University of Denver. She is the mother of three energetic gifted young men.*

It was a cool day in early spring, just a little too cool to go to the zoo. Walking into the museum young Sam was very excited. In fact, he was ecstatic. Sam suddenly came to a dead halt, as he looked wide-eyed at the giant polar bear that had greeted visitors for years and loomed large in front of him. “Daddy, can I touch the bear?”

As Sam walked around the museum, he was thrilled by the exhibit of prehistoric times and spoke “dinosaur” with his father. He gazed with intrigue at the collection of rocks and minerals, especially those that fluoresced under the black lighting.

What fascinated Sam’s dad (and the museum curator standing nearby) was the oration Sam began as he entered the room showing life size displays of indigenous life in North America. He began to describe the scenes in great detail, pointing out interactions and interdependencies between the animals, the plants and the insects.

Sam’s obvious knowledge of the concepts presented in the display, and the vocabulary he used to explain them, were well beyond his years. He used advanced terms, noting intricate details about the animals. At one point, Sam queried, “Dad, do you see that deer’s tail standing straight up? He is warning the other white tail deer of danger.” Sam went on to explain that the deer was an herbivore and was being hunted by a carnivore, the puma seen hiding in the tall grass. Sam used great detail to describe his understanding of the scene, even explaining the role that beetles play in the decay of matter on the ground.

The curator stepped forward and introduced himself to Sam's father. He wanted to know how Sam had acquired this knowledge. To be truthful, Sam's father was also stunned. He turned to Sam and asked, "Sammy, where did you learn about these animals?" Sam casually replied that after lunch, when he could watch the television, he did not care for Sesame Street but really liked the program on the other channel about animals, Wild Kingdom. Later, in checking with his mother, Sam indeed had been watching the program. She often saw him reenact scenes from the show with his stuffed animals and even combined the information from different shows to produce original and accurate situations. Sam would soon turn three. He had been enthralled with animals, insects and science all of his short life.

Many children fall in love with science at an early age. There is just something about exploring critters, crud, gears, pulleys, and other "stuff" that has fascinated generations of young students. Unfortunately, in many schools across our nation, science in the elementary classroom is relegated to the back burner as other curricular areas have become more important in the eyes of many teachers, parents, schools, and districts. It is frequently the subject replaced by practice for high stakes testing. When it is offered, it is commonly textbook based reading about science rather than truly doing science.

The purpose here is not to argue for science to remain in early childhood and elementary curriculum. Few in the world of gifted education would dispute the need for science to be offered to all children. The intent of the authors is to assert that science, the real "doing" of science, is a highly effective avenue by which many gifted students stay engaged and motivated to learn throughout their formal education; remaining passionate to learn the worlds' secrets, answer many of its questions and solve some of its most pressing problems

Gifted children often digest science content on their own as young Sam did above. They are hungry for it, curious about the natural world and how it works. Young gifted children are reading (or listening) to learn long before they can independently decode the words. A trip to the aquarium prompts a library visit dedicated to shark books; their drawings elicit elaborate oral stories about strange fish that live in the dark; private whispered speech attributed to plastic fish having a discussion about life in the deep can be heard from the car seat on the way to the grocery store. Pullout programs that include science are not enough to sustain this scientific interest in our young students. The study of the world through science education must become a significant part of the curriculum, demonstrating and supporting scientific habits of mind that come so naturally to young gifted children. This pedagogy should begin in early childhood and continue throughout children's formal education.

It is widely accepted that when taught well, science will indeed increase elementary students' concepts and vocabulary (background knowledge which is positively correlated to reading comprehension), geometric skills, reasoning ability, and perhaps even creativity. It has been argued that teaching science "may be used as a tool to preserve right hemisphere imagery, and prevent the Torrance drop in creativity … caused by over teaching of left-hemisphere activities …" (GCQ 79)

What does this mean for practice in gifted education? All students need experience with science; but science can "hook" gifted students and they are able to take concepts to another qualitatively different level, often at an accelerated pace. Science education for young gifted students should provide ongoing and intentional opportunities to develop a keen understanding of the science process skills and to practice them in meaningful contexts. These skills are often referred to as the tools, or habits of mind, of science and learning. In teaching them, students are provided with guided opportunities to think and act like scientists; to implement effective scientific investigations as they pose questions, test their original ideas, collect and evaluate their data, construct new knowledge, draw conclusions and pose new questions.

The process skills should be intentionally introduced at an early age and systematically increased to complex levels as children's cognitive abilities increase. Developmentally appropriate pedagogy in early childhood encourages teachers to integrate curriculum around a topic of exploration. Effective inquiry based curriculum naturally facilitates "wondering" about the world and implementing the effective use of process skills to answer children's questions. Unfortunately, with the current focus on grade level reading, teachers are discouraged from a constructivist approach to curriculum and are required to teach skills in isolation, without a meaningful context. As a result, learning opportunities for both literacy and science process skills are lost. This is especially destructive for young gifted children. They anticipate going to school to learn about things of which they are highly interested, yet soon associate learning with isolated and abstract bits of information.

Defining Process Skills

Process skills used in effective science explorations and learning include:

- planning,
- investigating,
- observing,
- measuring,
- hypothesizing,
- classifying,
- making predictions and inferences,
- asking questions,
- gathering and interpreting data, and
- communicating with others about both the process and the results.

Process skills are not dependent on curriculum. They can be interwoven into all science content areas and across all topics of exploration. Neither are they practiced in isolation; rather process skills are weaved together as a coherent set of skills used in meaningful contexts. It is the teachers' role to break the mind set that science education is a set of content learning activities and rather consider it a set of experiences that support students' development of stronger, more complex, processing and investigative skills. We are short changing our students and our society by requiring that gifted students simply understand content, ignoring the tools scientists use to pose good questions, conduct effective investigations, and construct new knowledge.

Sam utilized many combinations of processing skills in his explanation to his father about the events presented in the diorama. He used the skill of observation to gather information about the scene unfolding in front of him. He classified the wildlife into categories; animals, birds, and insects. He identified the differences and similarities between each of them, the role each played and the interdependencies among them.

Sam also drew the distinction between those that ate grass and the meat-eating predators. Sam drew many inferences from his observations; for example, identifying the signal the white deer appeared to be sending to alert the others. He quickly identified a problem at hand, i.e. a present danger lurking in the tall grass. This interpretation was based on what he saw before him (his current observations), and the information he had learned about the relationships of the animals from the television show (his prior knowledge or schema).

Interestingly, Sam asked many questions not only of himself, but also in his dialogue with his father. Sam attempted to elicit his father's ideas and impressions about what he was observing about the scene. This is the skill of questioning. The questions led to further discussion about what was obvious in the scene and possible outcomes, which could not be answered from the available data.

Sam was also hypothesizing when he integrated his current observation and prior knowledge to suggest that the white-tailed deer was using an alert signal to warn the others of impending danger. Sam pointed out that he was not sure if the deer had identified the danger by seeing, hearing, or smelling the puma. This also was a form of hypothesizing, demonstrating Sam's awareness that more than one rationale could fit the evidence.

Sam made good use of the evidence before him when he predicted a possible outcome. Sam stated that the deer would probably run away from the danger. This was his prediction, his forecast of what would happen next. He based it again on his prior knowledge and the observation of current events. This prediction went beyond the available data and explored a potential future outcome of the event.

Sam used measurement, another science process skill, in a general sense when scrutinizing the distance between the puma and the deer herd. Employing this skill can include the use of standard or non-standard units of measure to quantify a variable. In this situation, Sam spoke of proximity (rather than using actual instruments) to describe the distance between the animals.

Sam was obviously well skilled in the process skill, communication, which he used to effectively support and demonstrate his thinking. Later in the day, Sam again used communication when he returned home and drew a picture reflecting his prediction of what would happen when the puma gave chase to the herd of deer. Much to his dad's surprise, the puma remained hungry and did not catch the deer. Sam remembered from the television show that most chases do not end with a kill.

Sam did not use all of the science processing skills. For example, he did not use planning or investigating. These skills are often called experimenting or controlled investigation. In this instance it would not have been possible for Sam to test to see if the deer escaped. He simply made a prediction based on statistical evidence that he recalled from past learning.

Sam certainly was not using process skills discretely or randomly. He combined the skills to serve his exploration, his curiosity about the lives of wild animals. Sam used these tools to make sense of the world before him and to construct new concepts based on current and past experience. Identifying and teaching these skills in isolation is not an easy or a productive process. Teachers of gifted students need to provide students with real life opportunities to weave and utilize process skills simultaneously, just as Sam did. It is through ongoing, guided opportunities to pose and investigate questions of interest to children that effective learning of both the skills and the content will take place.

Learning and Teaching through Inquiry

The Institute of Inquiry at San Francisco's Exploratorium is a great source of knowledge for those who teach gifted children. It offers rich understandings of the processing skills and hands-on explorations of scientific concepts and ideas. Its materials and workshops guide teachers and parents of gifted students into a greater understanding of the fundamentals of an inquiry-based approach to science. The Exploratorium is built on the "belief that human beings are natural inquirers and that inquiry is at the heart of all learning." (www.exploritorium.edu)

Gifted students have an advantage as they crave content and are very likely to remember the content that is meaningful to them. Teachers, however, must use an inquiry based hands-on approach that carefully interjects the process skills to encourage and sustain student's interest and curiosity about the world around them.

Pedagogical choices must be carefully matched with learning goals and objectives, planning backward from the desired outcomes. Teachers identify the process skills that will effectively support their students' investigations of the content. These decisions cannot be made by a guide or teacher's manual. A publisher does not know individual students' instructional strengths and needs. Only the observant and intentional teacher does.

All hands-on approaches to science are not alike. Some hands-on approaches require far more teacher direction than others. Remember, even within the circle of gifted education, students become proficient at skills with practice and over time. Desiring a high level of student independence does not mean that the teacher takes a hands- off approach. Different approaches call for various levels of direction from the teacher and knowledge of individual students.

Even inquiry-based process skills should be taught explicitly. Teacher modeling and guided practice are often required before students can be expected to effectively apply them independently. True differentiation occurs when teachers match the level and amount of support (teacher or peer) required for individual students to effectively use the skills successfully within the classroom and within the activity. Ultimately, teachers must weigh the type of instructional support learners' need to own the skill. They must determine the appropriate balance between self-direction and teacher direction, always a gradual release of responsibility.

Inquiry-based teaching cultivates student abilities to gradually take more responsibility for their own learning. This has been a long time goal in gifted education. In the classroom, the teacher of the gifted must keep in mind that the learning environment must always be responsive to the various needs of the learners. Cognitive activities that are planned for gifted students must be complex and challenging, but within each child's zone of proximal development.

Problem-based science units, such as those developed by the College of William and Mary, encourage students' thinking and the use of processing skills. Throughout, the exploration behavior must be monitored and directed in a positive manner. Teachers should continually ask themselves, "How much control does the learner have, and is that appropriate for the child, the activity and the outcome?"

A few years later, young Sam entered kindergarten early in a special program for gifted learners. Sam of course loved science for many years but the older he got, the less science was "real"; it became just another textbook driven course without real life connections. Sam does light up, however, when recalling a semester in seventh grade where again the investigative process came alive and they "did science"……. and it was not out of a textbook. "We explored the world of arachnids, that is spiders. The teacher taught us how to catch and handle Phidippus audax, a jumping spider." Sam was never involved in science again.

The lessons for the teacher of the gifted are never ending. Our pedagogy must align defensible programming with high expectations and student outcomes. We must not allow our students to wither on the vine but flourish with a love of learning, a love of science and keen understanding of the investigative tools that make it all possible. •

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Teaching Gifted Students STEM In An Antiscience Society

Shawn Lawrence Otto

A slipping grip

Literacy in STEM is critical to individual and national success in the twenty-first century, the century of science. Gifted students are in a position to make especially profound contributions to solving the world's major challenges and creating new economic opportunity. But modern American culture and the way we approach and value STEM education are both working against this outcome in ways that we are only beginning to fully understand and appreciate.

Some time during the last five decades, American students began to lose their grip on science. It's hard to determine precisely when this began to happen or what went wrong, but the change is remarkable for both gifted and non-gifted students alike. One need look no further than our public dialogue to see the transformation—and where public sentiment flows, so goes school funding and teaching priorities. Five decades ago, science was a national priority. Students in the 1960s were gathered together in school cafeterias to watch moon launches and landings on televisions wheeled in on carts. Breakthroughs in the 1970s created a vast new multitrillion dollar economy flowing over the internet that transformed how we communicate, treat patients, shop, entertain ourselves, pay bills, connect socially and do research. Biology and genetics breakthroughs based on evolution transformed health care and are poised to usher in a new era of personalized medicine that will be far more effective than anything we've had before. Science, in these decades, was a highly valued part of education and our national identity, and was the source of vast economic wealth. In fact, since World

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War II, science and technology have been responsible for more than half of all U.S. economic growth.

But somehow, U.S. students have over that same time span begun to fall behind their peers in other countries. A 1970 study of international student science performance ranked U.S. 15-year-olds 14th. But a recent comparison of 15-year-olds in 65 countries found that average science scores among U.S. students ranked 23rd, while average U.S. math scores ranked 31st. This is troubling in a century when STEM is starting to dominate and drive the world economy. The United States' major emerging economic competitor, China, was included in international rankings for the first time in 2010. Students in Shanghai took first place outranking all other countries in the world.

There is a lot that can be said about the teaching of STEM in the U.S. educational system that may be behind parts of this decline. One could point to how curriculum is set by some fifteen thousand independent school districts whose boards are made up of people mostly unknowledgeable in STEM. One could point to the absence of scientists from those school boards and our national dialogue to the point that most Americans cannot name a single living scientist, even though millions live and work in the United States. One could lay blame at the way we teach science in many districts as received wisdom instead of an exploration of nature and life, or to the fact that only a little over half of biology teachers and just a third of physical science teachers are teaching "in field," defined as teachers who have either a major or full certification in their main teaching field, or both.

But the problem isn't happening in a vacuum. Even more than the issues in our schools, parents must bear a large part of the responsibility for the decline. Parents set school budgets and priorities, and the public dialogue and national and state politics set school focus. Parents' attitudes at home play a critical part as well. Several studies, beginning with the Second International Science Study in the mid-1980s have shown that one of the single largest factors in a child's science performance in school is the child's parents. Good performers in science are more likely to have parents who work in the "professional/executive" class and who have a high degree of education themselves, suggesting that science, critical thinking, and education as a family value is an important predictor of student STEM performance. "Science education has been identified as a national priority, but science teachers can't do the job on their own. They need the help and support from key stakeholders, especially parents," says Francis Eberle, the executive director of the National Science Teachers Association. "We know that family involvement is important, and parents need help getting involved with their kids in a subject they may not feel comfortable with themselves. We must continue to find ways to break down the walls of the classroom and encourage learning together among families."

NSTA did some polling and found that many parents want this, but feel inadequately educated to support their children's science education, so family education is an important part of the larger STEM education discussion. Only thirty percent of us have a science class higher than high school. For most of us, what we know of science is what we learned in high school. But science is not static. It keeps changing. Therefore it's critical to teach and reteach the scientific approach to thinking and critical thinking and basing things on measurements and evidence of the real world.

The need for evidence

While a scientific view of the world and approach to problem-solving can come from education, education isn't the most important factor. This becomes clear when one considers how a 2009 PEW study found that thirty-one percent of non-college-educated Republicans believed the preponderance of the scientific evidence that anthropogenic global warming is real. But among college-educated Republicans, the number fell to just nineteen percent. Among Democrats, the revere was true. More college education correlated with an increase in belief in global warming, a position that is supported by science. Before you conclude that Democrats are more rational, consider what Seth Mnookin, author of *The Panic Virus*, frequently notes: vaccine refusers -- those who believe vaccines may cause autism -- are disproportionately represented among Whole Foods grocery store shoppers, who also tend to believe, against scientific evidence, that organic foods are more nutritious.

So if the acceptance of science by the adults in a student's life no longer increases with education, what is going on? It turns out that increased education tends to increase one's sense of entitlement to be skeptical of authority. This is not surprising, since it is a fundamental precept of many approaches to teaching critical thinking that were used beginning in the 1960s. What seems to be missing is that educators seem to be failing to connect the circle back to the need for evidence. It's not sufficient to simply question authority. Critical thinking alone is not enough. What we need, and appear to be failing to impart, is the necessity of evidence-based critical thinking.

STEM education and citizenship in a democracy

This matter of evidence is fundamental to the entirety of the enlightenment. In fact, it is what created the philosophy of empiricism that both modern science and American democracy are based on. Understanding the relationship between science, evidence and democracy is critical to solving the STEM education problem. John Locke defined the difference between knowledge and "but faith, or opinion" in *An Essay Concerning Human Understanding* in 1689, which would lay the foundation for empiricism. Locke watched all the various factions of Protestantism arguing with one another and with Catholics about who had the one true path to God. They can't all be right, Locke thought. This led him to propose that there had to be some method of establishing what is truth, and what is mere opinion. Many of the Protestant religions, like the Puritan sect, had two books: the book of revelation, which was the word of God in the Bible, and the book of nature, which one could study to discern God's laws. Study of the book of nature was called natural philosophy, and eventually became what we now know of as science. Locke developed a system for testing claims against observation of the world, and whatever claim fell short of these tests, he argued, "with what assurance soever embraced, is but faith, or opinion, but not knowledge, at least in all general truths."

Locke recommended "in all sorts of reasoning, every single Argument should be managed as a mathematical demonstration; where the connexion of ideas must be followed till the mind is brought to the source on which it bottoms." This idea that nature was knowable led inexorably to the idea of democracy some eighty-seven years later. Thomas Jefferson, who like Bacon was both a lawyer and a scientist, considered Locke one of his "trinity of three greatest men," along with Isaac Newton, the creator of physics, and Bacon, the creator of inductive reasoning. Using their thinking, Jefferson concluded that if anyone could discern the truth for him or herself using the tools of science and empiricism, then no one could lay a greater claim to the truth than anyone else. Therefore no king or pope—no one in authority—had the right to force his or her will on anyone else. The people themselves retained this inalienable right. Based on the principles of science and empiricism, government of, by and for the people was self-evident.

But Jefferson realized that there was also a weakness in democracy, and that weakness is what we are seeing today: democracy relies upon the well-informed voter or tyranny may soon again triumph. This is why Jefferson advocated for public education and a free and critical press.

Note to educators and journalists: there is such a thing as objective reality

The erosion in public acceptance of science can be traced to many sources, from the anti-regulatory interests of business aligned with the anti-reproductive science views of religious conservatives on the right to baby boomer distrust of science as an agent of "the man" on the left. But perhaps the most corrosive erosion can be traced to a philosophy that developed in academia itself, called postmodernism, which was developed in the 1960s and 1970s by philosophers who, like other humanities professors, were upset at how the sciences were supplanting the humanities in University budgets and esteem. At that time, science was viewed by many in the humanities as vaguely right-leaning, mechanistic, and jingoistic, largely because it was associated with the space race and the military-industrial complex.

These professors adopted ideas from cultural anthropology and the theory of relativity to argue that there is no such thing as objective truth. Science was just one of many ways of knowing; it was simply the way of knowing of Western white men. But it was no more worthwhile than the ways of knowing of Native Americans, African Americans, ancient Chinese, women, or other non-white-male political identity groups. This thinking meshed well with that of certain civil rights activists in the 1960s and 1970s as well as proponents of the New Age movement and became widely adopted in and outside of academia. The problem with the thinking is that it was false. It elevated political identity over evidence. There is such a thing as objectivity, and science is our best known tool to get at it. Using science we have doubled our life spans over the last century or so, and multiplied the productivity of our farms by some thirty-five times. The proof for objectivity lies in science's track record, which is all around us, influencing every aspect of life, for better or worse.

The thinking of postmodernism was quick to invade journalism schools, which began repeating the false mantra that "there is no such thing as objectivity." The phrase has now become endemic, infecting reporter guidelines at major publications, and is oft-repeated by senior Washington journalists and news editors. But it poses problems when reporting on public policy issues that, like most these days, have a large input from science. In those cases there really is an objective truth. We may not know all of it, but it is important that the press report what we do know, and not set up a false balance between knowledge, on the one hand, and whatever contrasting opinion they can find on the other. This is often hard for journalists, many of whom avoided science classes in college, and have been trained that the world is made up of people with varying views and the best way to get at the truth is to present opposing sides without exercising any judgment. But unless a journalist accepts that there is an independent means of verifying what is knowledge and what is "but faith, or opinion," and takes the responsibility to dig to really get at the truth, they can easily become tools of those who would seek to influence public policy by spreading sciency-sounding disinformation. Then, the ship of democracy is set adrift; its rudder of the well-informed voter is cut loose from the knowledge necessary to make evidence-based, and thus well-informed, public policy.

There is one other field beside journalism that postmodernism has made major inroads in, and that is the field of education. For the last three decades, teachers have been taught the false, politically motivated philosophy that they are simply a guide at the side, that their truth is no more valid that the many truths of their racially, genderly and orientationally diverse students. That political identity is the true arbiter of knowledge. But, as Allan Bloom pointed out in the classic *The Closing of the American Mind*, this leads away from evidence-based critical thinking and elevates not the factual or evidentiary value of truth, but the political value of tolerance, as the ultimate goal of an education. As soon as one does that, one can no longer appreciate the value of questioning claims and one's own personal assumptions to see if they really hold up. Once this view is adopted, we can toss any hope of an advance in STEM education out the window, and it becomes easy to see why all but the most science-oriented students began to slide in performance.

This thinking also leads to the political gridlock and extreme, dysfunctional partisanship we see today in government and political discourse. This happens because it undermines the precepts on which democracy and science alike were founded, and collapses us all the way back to the dark ages. Gone is the arbiter—knowledge—that can allow opposing sides in public policy disagreements to come to a consensus. Consensus itself has become a bad word. Instead we are left with endless warring opinions, where winner takes all, and extreme partisanship. Without knowledge it is the loudest voice, the most dominant personality, the most forceful bully, the wealthiest business, or the party in control, that comes to shape American public policy and the American national dialogue. By insisting on the uncritical acceptance of others and the equal validity of various "ways of knowing," postmodernism does not create tolerance, but tyranny.

Some solutions for educators in the cross hairs

In light of the general public sentiment about science it becomes easier to see how some students are slipping in the ranks. Blaming it all on teachers, as we are wont to do, is a red herring. That said, there are some things educators can do even while they spend their careers in the cross hairs of an increasingly unsupportive and antiscience national dialogue.

The first of these is a strategy that I share often with educators, and that is to use the political controversies around science issues as a means to raise the level of concern and make science relevant again in students' daily lives. The single best way to do this is by holding a student science debate. Science educators can team teach this unit with civics or rhetoric teachers, but it's not essential. The concept is very simple.

First, pick a politically contentious science topic. By doing this as an educator you are already opening up a conversation that intersects with students' lives. Second, state a preposition about that topic; ie, anthropogenic climate change is real. Then, announce the debate and tell students to research it. But here's the critical piece: don't tell them which side they are going to argue. They have to research both sides of the debate, and which side they argue will be determined by a coin toss on the day of the debate. In their research and in building the very best arguments they can on both sides, students begin to learn the difference between knowledge-based arguments and rhetoric. Educators can teach gifted students how to think without raising the hackles of antiscience parents because they are simply "teaching the controversy;" precisely what antiscience, ideologically motivated parents often argue for.

The second tool is one that takes more development but is well worth it. It is based on some stunning findings from the 2006 PISA, an international ranking of student performance published by the Organization of Economically Developed Countries (OECD). Ninety-three per cent of students surveyed reported that science was important for understanding the natural world, and 92% said that advances in science and technology usually improved people's living conditions, but only 57% said that science was very relevant to them personally. This is remarkable because science not only impacts every aspect of life, it lies at the center of our thorniest public policy problems, ranging from climate change to food to the internet. Clearly, we are failing to make the connection by not grounding science in the larger context. But even more importantly, we are failing to communicate how science lies at the center of all public policy in a democracy, and science educators can help reconnect the dots on this by team teaching with civics teachers the history of science and how it led to the birth of American democracy. Understanding how intertwined the concepts of democracy and knowledge are, and how Western science emerged from thinking about religion, gives students context on why both history and science are important in their daily lives, and gives them a reason to become curious and to value scientific thinking and the scientific process. I cover this extensively in my book, *Fool Me Twice: Fighting The Assault On Science In America*, because it is rarely taught anymore anywhere, but it is critical to living as a successful member of a scientifically advanced democracy.

A third approach is to have students research the responses of the candidates for president to the Top American Science Questions at www.sciencedebate.org. ScienceDebate.org is a nonprofit organization I cofounded in 2007 to help elevate discussion of science issues in our national public dialogue. Students can see and analyze the responses of President Obama and Senator McCain in 2008, and of President Obama and Governor Romney in 2012, and compare them to one another. Note how the political dialogue around science has changed in that time between and across parties. Analyze whether the candidates fully answered the questions and why or why not. Discuss the political controversies surrounding some of the questions and why they are controversial, and what science has to say versus other voices in our democracy. Assess whether the candidates' answers were grounded in science or were political rhetoric. Once again, these exercises seek to ground science back into the daily lives of students by finding the intersection point with the topics they hear being discussed in the rest of their world, and they work to give students valuable practice at understanding scientific thinking and how to apply it to problem solving.

Being a science teacher today is hard. There is a lot to navigate and there are limited resources and limited time. Teacher education and curriculum lets many science teachers down. Science could not be more critical to students' lives, and it has also never before been so broadly under attack in students' lives. Some of the most critical topics, such as the teaching of evolution, are openly challenged by antiscience students, parents, and legislators alike. Improving STEM performance among both gifted students and all students in that sort of climate takes lifting it out of the textbook, pulling it out of the lab, and reconnecting the dots about why science and evidence-based critical thinking is valuable in daily life. The most gifted scientists and engineers are the ones that can look at life, or at other fields beyond their own discipline, and make a connection that creates new knowledge or solves problems. They are as curious and creative as artists in their thinking, but they are artists who, as John Locke recommended, tie their thinking back into the physical world, taking the mind back to the place at which it bottoms. •

Resources

ScienceDebate.org
http://www.sciencedebate.org

First International Science Study (FISS)
http://www.iea.nl/fiss.html

International Mathematics and Science Assessment: What Have We Learned? (pdf)
http://nces.ed.gov/pubs92/92011.pdf

OECD Programme for International Student Assessment (PISA)
http://www.oecd.org/pisa/aboutpisa/

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World Economic Forum Global Competitiveness Report http://www.weforum.org/issues/global-competitiveness

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The Rise of Antiscience in our National Dialogue

Shawn Lawrence Otto

Note to readers: this bonus article was originally part of Shawn Lawrence Otto's previous article. The editors seperated it to give the original article an education focus but felt it important to include this information in the journal, particularly for those interested in political history behind current mindsets.

Considering the close link between family attitudes about science and student performance [see previous article for background on this], it is especially troubling that it has become increasingly acceptable in public dialogue, particularly in the "professional/executive" class, to be antiscience. This change is noticeable by watching the changing public expressions of U.S. politicians, who stake their careers on reflecting public sentiment back to voters. Public statements that would have ended a political career in shame and embarrassment a generation ago now may even bolster a sagging campaign.

This was available to witness during the 2012 Republican presidential primaries, where the candidates frequently stunned scientists and engineers with a seemingly endless parade of statements that can only be described as antiscience, ranging from the conspiracy theory that anthropogenic global warming is a hoax to the belief that human papillomavuris vaccine, which prevents the primary cause of cervical cancer, causes mental retardation, to how "absolutely not I don't believe in evolution," to how embryonic stem cell research is "killing children in order to get research material." These statements are not just uneducated, they are defiantly counter factual and were often made when candidates who knew better were slipping in the polls. Making them often gave candidates a bounce, leading to the inescapable conclusion that science itself has somehow become a partisan political football among Republican Party activists.

The problem became so pronounced that in a late 2011 debate, presidential candidate and former Utah governor Jon Huntsman was asked about a statement he had made that the Republican Party was becoming "the antiscience party."

“Listen,” Huntsman answered, “When you make comments that fly in the face of 98 out of 100 climate scientists, that call into question the science of evolution, all I am saying is that in order for the Republican Party to win, we can’t run from science. By making comments that basically don’t reflect the reality of the situation, we turn people off.” Republican primary voters apparently disagreed. Huntsman, the only GOP candidate to actively embrace science, fell in the polls after the comment, and finished last in the primaries.

The problem isn’t limited to Republicans. In 2011, the San Francisco board of supervisors, all Democrats, voted ten to one to require all cell phone shops in San Francisco to warn customers of the scientifically unsupported claim that their cell phones may cause brain cancer, a worry that is contradicted by basic high school physics. A microwave photon has about one millionth the energy necessary to damage DNA and cause cancer. And then there is the scientifically unfounded belief pushed by many celebrities and some politicians on the left that vaccines cause autism. This is more dangerous than the cell phone scare because vaccines don’t work by individual protection as much as they work by creating the collective protection epidemiologists call “herd immunity.” Depending on one’s genetics, some vaccines may be effective in only a portion of patients; but when the vast majority of the general population is vaccinated, enough people are protected that the virus cannot form a strong enough statistical base in the population to get a foothold, and so it does not spread. Parents who refuse immunizations place their own children at risk, but by eroding herd immunity they also endanger the children of others, as well as other vulnerable populations such as seniors and the immunodepressed. Communities with high levels of vaccine refusal, mostly liberal-leaning, are seeing rebounds of dangerous childhood diseases such as whooping cough and measles that were once thought to have been eradicated.

State legislators are getting into the antiscience act as well. In North Carolina this year legislators proposed House Bill No. 819, which prohibited local governments and state agencies from using science-based estimates of future sea-level rise (a predicted result of global warming) when planning roads and other development in low-lying and coastal areas of the state. Sounding not unlike Maoist China, the proposed law would have permitted local governments to only plan for a politically correct rise of eight inches, instead of the three to four feet that scientists predict the area will experience by 2100. Virginia Republicans passed a similar bill in June, in which they banned the use of the phrase “sea-level rise” from a government-commissioned study. Instead, they determined the study should use the politically correct words “recurrent flooding” because, as one legislator explained, “sea-level rise” is considered “a left-wing term.”

The battles over science in state legislatures aren’t limited to climate change.

Legislatures in Tennessee, South Dakota and Louisiana have also all recently passed legislation that encourages unwarranted criticisms of evolution to be taught in the states' public school science classes, even though evolution underlies all of biology and modern medicine. Evangelical "biblical literalist" state legislators and school board members mounted similar efforts this year in Oklahoma, Missouri, Kansas, Texas and Alabama.

The problem is also readily apparent in congress, where both economic and religious antiscience views wield significant influence over the nation's public policy debate. Ninety-four of one hundred new GOP legislators elected in 2010 have either said they believe climate change is a hoax, or have pledged to oppose efforts at mitigation. U.S. congressman Todd Akin caused a more recent national stir when he told an interviewer that a woman who is raped in unlikely to get pregnant. "From what I understand from doctors, that's really rare," Akin said. If the rape is "legitimate," he said, "the female body has ways to try to shut that whole thing down." Akin sits on the House Science, Space and Technology Committee, which oversees and funds much of the nation's science enterprise, so he should know what science actually says about key policy issues. But in fact, what science there is suggests that a woman may be up to twice as likely to become pregnant from rape, and that there is no biological means to "try to shut" pregnancy down in the case of rape. Akin's counter factual views appear to be drawn from propaganda on the web site Physicians for Life, an anti-abortion advocacy group. The antiscience belief is by no means unusual among abortion foes, who often minimize science to politically justify a no-exception antiabortion stance, even in cases of rape — a stance that has since become part of the 2012 national GOP party platform.

The confusion of "common sense" thinking

Any science can become politicized by opponents. In the early 1920s Weimar Republic, right-wing relativity deniers attacked Einstein's theory as a "hoax" and said Einstein was just in it for the money, charges quite similar to those leveled against climate scientists today. "This world is a strange madhouse," Einstein wrote a friend at the time. "Currently every coachman and every waiter is debating whether relativity theory is correct. Belief in this matter depends on political party affiliation." The politicization of the theory of relativity may sound silly today, but such politicization can occur over any science because we are all busy and don't have the luxury of time to read scientific papers and judge them for ourselves. So acceptance of science becomes a matter of belief, or faith in the integrity of the scientific process. And that makes it vulnerable to attack by those whose vested interests may be being challenged by the conclusions of a particular field of science. This means that what is important to successfully navigating the twenty-first century is what sources of information people choose to put their faith in—those based on received wisdom, or those based on evidence.

Often, instead, our conclusions are based on underlying assumptions. Democrat antiscience like the cell phone scare and the views of "antivaxers" tends to be based on unsupported suspicions of hidden dangers to health or the environment, usually caused, proponents often say they believe, by greedy corporations in league with corrupt government scientists or regulators. Republican antiscience, on the other hand, tends to focus on moral objections to control of the human reproductive cycle, or on economic objections to the environmental science that underlies many regulations that businesses would just as soon do without.

Of the two forms the current Republican version is the most caustic to student STEM performance and the future of the nation because it often seeks to override or cast doubt on science and education standards for all students in favor of politically correct positions. Consider the 2012 Republican Party platform in Texas, one of the largest text-book markets in the nation. It states that republicans will work to oppose "the teaching of ... critical thinking skills and similar programs that ... have the purpose of challenging the student's fixed beliefs and undermining parental authority."

But the entire purpose of STEM education, and indeed the whole thrust of science, is to challenge our fixed beliefs with observation, data, confirmation, and peer review. This is how we have been able to advance. These mechanisms were created precisely to guard against the conclusions of common sense and fixed beliefs, which the data show are often totally wrong.

Consider our common sense and fixed beliefs about fire. What is fire? It is the burning of wood. It's also the fire of the sun. It's the fire of lightning. It's the magical fire in a firefly's tail. But when we applied closer observation, this one concept was revealed to be four very different things. The burning of wood, we learned, is oxidation, much more akin to rusting than it is to the fusion going on in the sun. And the fusing of atoms is altogether different from the incandescence of lightning, which turns out to have nothing at all to do with the phosphorescence produced by the chemicals in a firefly's tail. What they have in common to our senses is that they appear bright. But science enabled us to see past the crudeness of common sense to the true nature of things, advancing our knowledge, and thus our power.

Francis Bacon, the scientist and attorney who created inductive reasoning, warned against the confusion of common sense in his classic Novum Organum. "The human understanding is no dry light," he said, "but receives an infusion from the will and affections; whence proceed sciences which may be called 'sciences as one would.' For what a man had rather were true he more readily believes. Therefore he rejects difficult things from impatience of research; sober things, because they narrow hope; the deeper things of nature, from superstition; the light of experience, from arrogance and pride; . . . things not commonly believed, out of deference to the opinion of the vulgar. Numberless, in short, are the ways, and sometimes imperceptible, in which the affections color and infect the understanding."

Being gifted is not a protection against confusion nor a predictor of reason. As a member of MENSA, I can attest that there is a significant number of very intelligent people who are confused by their affections to the point of being antiscience. Nor is being gifted a necessary prerequisite for science. Congressman Rush Holt, the only physicist in congress, often makes this point. "Scientists aren't smarter than other people," he says. "They just have a really smart method of asking questions that produce verifiable answers." The opportunity for gifted students to excel in STEM comes from their being exposed to this "really smart method" that sifts knowledge out from emotions and common sense by relying on evidence, and from learning to incorporate it into their everyday thinking. Those who can will excel in the century of science.

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Laughing at Chaos II

STEM?!?!

Jen Merrill

It's been almost a year since our son hit the academic wall, bounced, and rolled across my sanity to land in a ditch of anxiety and frustration. Fall 2011 will be forever known in the House of Chaos as The Season of Ugly and Scary Change. It was all kinds of fun, the kind of fun I wouldn't wish on my second worst enemy. My worst enemy would probably have it coming, but let's not talk about that. Also? I have no enemies...that I know of.

When homeschooling began to look like a real possibility, I had to start considering what kind of curricula would work best for my complex kid. I knew his strengths, acknowledged his challenges, but knew above all that if I didn't get him to buy in we'd be up a creek sooner rather than later. I have fallen in that creek regularly over the last decade; the ice cold rapids can really mess with your mojo and I wasn't keen on returning. So I took a deep breath and asked him.

Me: " A, if you were to be homeschooled, what would you like it to look like?"

A: "I want it to be quiet with no distractions (school is so loud, mom!), and not change every few minutes (I need more time to dive into things!), and it has to be STEM!!!"

Me: "Hm. That's a good idea." <I am so screwed>

My son has been an engineer since birth. He never asked WHY as a toddler, it was always HOW'S IT WORK? He figured out child-proofing at such a young age I considered hiring him out to new parents, to find the holes in their safety plan. When I took him to an Intro to Instruments class I designed, he ignored the piano instructor and crawled under the instrument to see how the foot pedals worked. So that he wanted a STEM-based home education was no big surprise. I just knew that I was well out of my element. I'm a musician. Need flute lessons? I'm your gal. Teaching anything more advanced than basic arithmetic or the scientific method and, well, I do a great impression of a dear in headlights.

But this was about him and his education, not me and my long-standing issues with math.

So to the internet I flew. With resources like Gifted Homeschoolers Forum, Hoagies, Living Math, Khan Academy, and good ole' Dr. Google, I have a pretty good handle on his STEM-focused education. It's not perfect, but with my son the second I start to think something is working perfectly is the second right before it all goes sideways. I'm learning to embrace imperfection; there are plenty of practice opportunities 'round these parts.

I'm also sneaking in bits and pieces of arts education as well. It's known as STEAM, but because I have to be judicious in its appearance, I think of it right now as STEaM. Important enough to be included, but not (yet) as important as the other areas. As a music educator, that kills me; as a homeschooling parent, I see it as how my son's education will evolve.

I'm glad I set up a STEM-centered education for my son. It's not exclusionary, simply the starting point for all subjects. He's able to see how science and religion and world history intertwine with one another, how technology and engineering are reflected in every part of today's society, and that some things make a lot more sense if you have exposure to literature and art. I'm able to divide fractions without hyperventilating. Win-win all around.

Now, if I could just get him to pick up an instrument... •

Jen Merrill *is a Chicago-based blogger and writer. After years of jamming her twice-exceptional son into various school settings that didn't quite fit, she's also now a new homeschooler and couldn't be happier. Jen is the author of* If This is a Gift, Can I Send it Back?: Surviving in the Land of Gifted and Twice-Exceptional *as well as her blog* Laughing at Chaos.

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Opportunities for 2X Students to Shine in STEM

Cheryl Franklin-Rohr

So often, we keep our twice-exceptional students toiling on basic skills where they have deficits (i.e. multiplication tables), and they never have the opportunity to use this information in a practical way. No wonder they don't want to spend time on this "boring" stuff since there are no connections to real life applications.

Twice-exceptional students can shine in the STEM fields because Science, Technology, Engineering and Math use higher levels of thinking skills like application, synthesis, creativity and evaluation. This doesn't mean that twice-exceptional students can jump over the acquisition phase of instruction; but it does mean that we can't hold these students back from studying more rigorous topics just because they haven't mastered the multiplication tables.

So what can parents and teachers do to open the STEM doors for twice-exceptional learners? First, at schools, we need to use math and science skills in order to solve real-life situations. There are so many resources and curriculum available to help us accomplish this goal. One of my favorites is the science and math curriculum created by the College of William & Mary. Through the science units, students experience the work of real science in applying data-handling skills, analyzing information, evaluating results, and learning to communicate their understanding to others. The math curriculum uses higher order thinking skills embedded in projects and problems that promote reasoning and problem solving. These units are created around problem-based learning, which emphasizes learner centered environment, the role of the teacher as a coach and evaluation through authentic assessment.

Second, there are resources that teachers can use in their classroom. One of the best is Project WILD, a widely used conservation and environmental education program for students in kindergarten through high school. One activity developed by Project Wild is "OH DEER!" which teaches students about predator/prey relationships in the environment. If you want to find out more about this exciting organization, check out the website at http://wildlife.state.co.us/Education/TeacherResources/ProjectWILD/Pages/ProjectWILD.aspx.

Third, schools can sponsor clubs and competitions that integrate the STEM content areas. In this way, twice-exceptional students won't be penalized for challenge areas. The students will designate tasks based on strength areas only. What a novel idea! Some clubs or competitions that schools can sponsor are: Robotics, MESA (Math Engineering Science Achievement), Math Counts, Science Olympiad, and Destination Imagination.

Fourth, parents can integrate math and science in many activities at home and through enrichment opportunities. My son's favorite places were those featuring math and science. We spent countless hours at the Museum of Nature and Science, the Zoo, the Botanic Gardens and the Butterfly Pavilion. They have so many summer enrichment opportunities that helped him grow in his knowledge of science, and he didn't get graded on his work. I found puzzles that helped him to memorize his basic math facts, and we played games to improve fluency. He developed a love of scientific inquiry by spending hundreds of hours creating science experiments in my kitchen sink. We checked out so many books from the library about science experiments, and Usborne Books had so many titles that kept him occupied for hours. In fact, even now at 19 years old, he is keeping several of these science books that he can't bear to give away.

We need to keep our twice-exceptional learners engaged in learning and introduce them early to Problem-Based Learning opportunities. In this way, we can create successful learning experiences in the STEM fields where so many jobs of the future will be created. •

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Science As a Candle in the Dark

Stephen Schroeder-Davis

"Anti-intellectualism has been a constant thread winding its way through our political and cultural life, nurtured by the false notion that democracy means that 'my ignorance is just as good as your knowledge.'"

-- Isaac Asimov

This is a somewhat daunting column to write, as my training and degrees are in language arts and educational leadership, so my domain-specific knowledge of STEM is, to put it generously, weak. I do, however, possess and advocate—as do those of you reading this—many of the hallmarks of scientific thinking. According to one of my heroes, Carl Sagan:

"Science has a built-in, error-correcting machinery at its very heart. Some may consider this an overbroad characterization, but to me every time we exercise self-criticism, every time we test our ideas against the outside world, we are doing science. When we are self-indulgent and uncritical, when we confuse hopes and facts, we slide into pseudoscience and superstition." (p. 27)

This column is about how teachers (whether in a STEM program or not) can best practice scientific (i.e., critical) thinking and therefore promote it in their students, despite the fact that there are powerful mechanisms in place to make such promotion difficult.

A Barrier to Critical Thinking in Science

A major impediment to fostering critical thinking in STEM programs is, ironically, state science standards. In 2012, the Thomas Fordham Foundation (Gross et al., 2012) completed a review of multiple aspects of US state science standards and determined states averaged a “C-” overall, with only six states earning an “A.” The full Foundation report can be downloaded at http://www.edexcellence.net/publications. According to Dr. Paul Gross (2012), an emeritus professor of life sciences at the University of Virginia and one of several coauthors of the Fordham report:

“There are . . . multiple reasons for the low marks. Among these, the saddest and least justifiable is what the authors call “Undermining Evolution.” Evolution is singled out in high-minded calls for “critical thinking,” for “strengths and weaknesses”—as though it were less reliable, less scientific, than the other (theories)!” (para. 2)

The “high-minded calls for critical thinking’” about evolution illustrate the heart of the critical thinking issue. In 2011, eight congressional bills in six states (with more pending this year) were introduced mandating that either creationism or “intelligent design” be taught as alternative scientific theories to evolution (Gross, 2012). Equating evolution and creationism reveals a fundamental misunderstanding of what constitutes a scientific theory, and, according to Gross (2012), is “ . . . intended to instill the belief that evolution is a highly controversial and hotly contested theory within the scientific community” (para. 9).

Wikipedia (Scientific theory, 2012) provides a nice, succinct summary of the five criteria any theory must meet in order to be considered a scientific theory. In brief, a scientific theory must be falsifiable; that is, it must make predictions that can be demonstrated through experimentation to be false. It must be supported by multiple, independent sources of evidence rather than by a single source. It must also accord with existing scientific theories and experimental results. Finally, a scientific theory must be modifiable to accommodate new evidence (which thereby improves the theory’s predictive validity), and it should provide the most logically parsimonious explanation for a given phenomenon, meaning it does not introduce unnecessary complexity to explain observations and experimental outcomes.

These criteria reveal that while there may be multiple theories available to explain a given body of observations, not all of them are necessarily scientific theories. Gross (2012) and many other knowledgeable scientists’ concern is that while intelligent design/creationism may be an explanatory idea, it does not meet the criteria for a scientific theory and therefore should not be taught as scientific theory.

The political activity surrounding the conflating of intelligent design and scientific theory, according to Gross (2012), is causing a chilling effect, as “teachers, understandably, fear controversy and potential attack by parents” (para. 8) and are therefore less likely to present evolution for what it is: the only scientific theory that presents evidence that the “earth is four billion years old and that life’s diversity emerged over eons in steps, usually small, driven by such (evolutionary) mechanisms as genetic change and natural selection.” (para. 9).

The consequences of this damaging "chilling effect," which is not limited to the teaching of evolution, can be overt, district-directed censorship of teachers' freedom to explore content, a more subtle internal or external (community) pressure to avoid controversial topics, or a combination of the two. In literature, the damage has been well documented by, among many others, the American Library Association [ALA] (1997-2012), specifically, their Office for Intellectual Freedom (http://www.ala.org/offices/oif), which celebrated the 30th anniversary of "Banned Books Week" during the first week in October. See http://www.ala.org/advocacy/banned/bannedbooksweek for details of my favorite week in October, as "Banned Books Week" draws attention to the absurdity of attempts to restrict what citizens—including students—can read.

I have experienced the chilling effect and the resultant self-censorship myself as a parent. When the first Harry Potter book was published, one of my daughter's teachers was using it as a read-aloud, as were many teachers in my district and surrounding districts. In a neighboring district, the book was "challenged," meaning that a formal, written complaint was submitted to the school requesting it be removed because of content or appropriateness (if the school complies, the material in question is thus "censored").

The Harry Potter challenge was reported in the local newspaper, and the next day my daughter's teacher stopped reading the book. My daughter was so disappointed that we immediately purchased the book—and all of the books in the series—and read them all together. Other students may not have been as fortunate, however, and were thus deprived of one of the most bibliophilic series of all time.

The chilling effect, and the self- and institutional censorship it can create are unfortunate when applied to Harry Potter, but when applied to the teaching of scientific theories, such as evolution, it becomes tragic, because censorship undermines the very basis of science: open inquiry that involves gathering data, forming a testable hypothesis, and empirically testing that hypothesis. By elevating criticisms of evolution ("intelligent design" and "scientific" creationism) to the level of theory, and stipulating they be taught alongside evolution to provide "balance," makes it appear as if every explanation is a scientific theory, which is tantamount to nothing being a scientific theory (similar to the common and debunked "all children are gifted in their own way" mythology).

As I will argue subsequently, I think "scientific" creationism and "intelligent design" should be taught in conjunction with evolution, not as "competitors" to evolution, but as examples of beliefs, which are not theories, proposed by legislators who do not understand science or scientific thinking and thus have no business dictating curriculum. The following example illustrates my point and is quoted from Tennessee House Bill 368 (2012):

(a) The general assembly finds that:

1) An important purpose of science education is to inform students about scientific evidence and to help students develop critical thinking skills necessary to becoming intelligent, productive, and scientifically informed citizens;

(2) The teaching of some scientific subjects, including, but not limited to, biological evolution, the chemical origins of life, global warming, and human cloning, can cause controversy . . .

This bill is ironic in the extreme in that evolution is not controversial in the scientific community; it is bills such as House Bill 368 that engender "controversy" because they can make the teaching of evolution—not the theory itself—controversial. Instead of making teaching evolution controversial, wouldn't it be better to develop students' "critical thinking skills necessary to becoming intelligent, productive, and . . . scientifically informed citizens" (Tennessee House Bill, 2012, p. 1) by having teachers not only present evolution as the only scientifically based explanation for the development of life on earth we have at present but also by encouraging their students to compare the reasoning and logic of the scientific theory to nonscientific competitive assertions? Gross (2012) ends his excellent essay with a reference to Asimov, who presented a superb analogy to the evolution "controversy":

"It was long believed . . . that the earth is flat. Accumulating evidence then showed that it must be a sphere. Centuries later, it was shown that Earth is not quite a perfect sphere. It bulges ever so slightly at the equator and flattens slightly at the poles. But it would obviously be absurd to think or teach that a spherical Earth is as wrong as a flat Earth. That would be dismissing reality with a triviality. Nibbling with trivial arguments at the heels of evolution is similarly absurd. But it does tend to undermine science education." (para. 10)

If legislators and misinformed others are going to "nibble" with nonscientific arguments, teachers can salvage the situation at least somewhat by using the "trivial arguments" as a springboard to teach critical thinking.

Embracing Controversy

What two things are true about the following three titles?

To Kill a Mockingbird, by Harper Lee (1960)

The Color Purple, by Alice Walker (1982)

Beloved, by Toni Morrison (1987)

The answer is that all three authors were awarded Pulitzers for their books, and all three titles are among the most challenged books in America. Other titles on the ALA's (1997-2012) most challenged list include *The Grapes of Wrath*, by John Steinbeck (1939), *Brave New World*, by Aldous Huxley (1932), *Song of Solomon*, by Toni Morrison (1977), and *Slaughterhouse Five*, by Kurt Vonnegut (1969).

A book does not have to be of substance and enduring value to be subjected to censorship attempts, but apparently it helps (ALA, 1997-2012). To pick one illustrative example, *To Kill a Mockingbird* was awarded the Pulitzer Prize in 1962 and won the Brotherhood Award form the National Conference of Christians and Jews and the Paperback of the Year award from Bestsellers magazine in the same year (ALA 1997-2012) In 1999, a Library Journal poll of the nation's librarians chose *To Kill a Mockingbird* as the best novel of the century, and Chicago's librarians selected the book as the city's first "Same Book at the Same Time" reading event in 2001 (ALA 1997-2012). Lee was awarded the Presidential Medal of Freedom in 2007 (ALA 1997-2012).

Given the book's transcendent quality, what could would-be censors find objectionable? According to the 2004 Banned Books Resource Guide, the most frequent protest involves the use of a racial slur, the same one used more than 200 times in Huckleberry Finn. The presence of this slur can enrage readers (and nonreaders), who then may challenge schoolteachers and/or building and district administrators to remove it wholesale from the curriculum, much to the consternation of others who find great value in teaching and reading the book, despite the presence of the word. *To Kill a Mockingbird* therefore provides a useful model through which we may examine how educators can embrace controversy over educational materials and practices and use it to teach students critical thinking skills.

There are at least three ways teachers can deal with controversies such as this:

1. Remove *To Kill a Mockingbird* from the curriculum,

2. "Sanitize" the book by removing whatever is causing the controversy, as has been suggested by Twain scholar Alan Gribben ("slave" appears instead of the racial slur in Gribben's version of Huckleberry Finn),

3. Confront the controversy through instruction. For example, students could read each chapter of the text and debate if the book's literary value outweighs what they or others find objectionable and whether everyone finds the same material objectionable. Further, students could examine the potential benefits and detriments of censorship, including governmental censorship. They could explore interesting questions such as whether Wikileaks editor Julian Assange is a hero or a villain, or the ethical implications of the actions of Daniel Ellsberg, who helped publish the Pentagon Papers, which "demonstrated, among other things, that the Johnson Administration had systematically lied, not only to the public but also to Congress, about a subject of transcendent national interest and significance" (Apple, 1996, para. 2).

The pivotal point is that controversy, especially controversy about big ideas, can be used to promote student thinking that transcends the knowledge and comprehension levels of cognition school curriculum far too frequently presents as the endpoint of education. To return to the issue of evolution, I think students would be well served if they had an opportunity to first understand clearly what a scientific theory requires to be considered valid. They then should be encouraged to evaluate evolution, "intelligent design," and "scientific creationism" against the rigors of what constitutes a scientific theory, thereby exercising critical thinking skills in the analysis of important "big ideas" that have serious real-world implications.

All content areas have potential for fascinating examinations of controversy, so long as teachers are prepared to teach both the content and the attendant controversy. The Rice Library Instructional Services [RLIS] (2012) compiled a list of topics for several content areas, demonstrating how prevalent controversy is in many domains of life, and thus implicitly emphasizing how important it is to teach students how to examine controversial issues carefully and rationally. The following is a severely abbreviated list of content areas and attendant potentially controversial issues from the RLIS offering:

Politics/law: "Treatment of Detainees," "Medical Marijuana," "Eminent Domain," and "Censorship."

Ethics: "Assisted Suicide," "Whistle Blowing," and "Ethics of War."

Education: "Standardized Testing," "Affirmative Action," and "Religion in Schools."

Other content areas covered by the RLIS include the economy, employment, religion, civil rights, science, and many more.

Controversy in the Classroom: The Democratic Power of Discussion

The section title above is taken from the book by the same name, written by Diana Hess, and dedicated to her parents, whom she credits as inspiring her interest in controversial issues resulting from the dinner table discussions she was exposed to as she grew up. I am similarly thankful to my parents, who provided constant intellectual forums in our home, including inviting several Sisters from the convent next door to discuss evolution and creationism! In Hess's (2009) introduction, the author asserts the premise of her text:

"Building on the central claim that schools should activate students' awareness and appreciation of the inherent link between authentic controversy and democracy, I argue that the single most important policy aim we should work toward is transforming schools into communities that honor and put to good use the advantages of diversity—especially the ideological differences that are so necessary for high-quality education." (p. xiii)

Rather than avoid or mute discussions of controversial subjects, Hess advocates making them the centerpiece of the curriculum, which I believe in turn would make education significantly more robust than the current centerpiece, which is the low-level knowledge assessed by the standardized tests students must frequently endure.

Organizing and managing discussions of controversial topics is beyond the scope of this article (help for that can be found in the "Making Connections" section), so I will close by emphasizing what I view as the central justifications for courting controversy in classrooms. As educators, we should not fear controversial subjects. Instead we should embrace and use controversy because we need:

To avoid what Elliot Eisner (1979) calls the "null curriculum," which is, "the options that students are not afforded, the perspectives they may never know about, much less be able to use, the concepts and skills that are not part of their intellectual repertoire" (p. 103).

To prepare students for college and engaged citizenry (Conley, 2005) which includes the ability to analytically read and discuss, write persuasively, draw inferences and conclusions from text(s), analyze conflicting source documents, support arguments with evidence, solve complex problems with no obvious solutions, and write multi page papers that support arguments with evidence.

To help students see democracy is not simply a set of slogans that politicians use to generate votes or an abstract set of principles that students are to learn for tests. Rather, democracy is a way of life . . . best learned in schools by engaging and practicing it. (Apple, 2009, p. xiii) •

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Making Connections

STEM Websites

NAGC information and resources on STEM

NGSS The Next Generation Science Standards website

LearningScience.org Science interactives and resources for teachers and students

Federal Resources for Educational Excellence Free resources for teachers on all subjects including STEM subjects

Steve Spangler Science Click on Experiments in the top menu for videos/explanations of science experiments across the science categories.

Science Daily The latest research news which can help spark questions and creativity in the classroom

TryEngineering.org Free lesson plans on engineering topics many complete with instructions, teacher materials and student handouts

Please see Suki Wessling's article for links to math websites.

Suggestions from Stephen Schroeder-Davis on managing conflicts that may occur when teaching controversial issues:

Managing Hot Moments in the Classroom
An online document by Lee Warren, Derek Bok Center for Teaching and Learning, Harvard University with strategies for turning "hot moments" in the classroom into learning opportunities for students.

Arizona State University Intergroup Relations Center
Under IRC Handouts are links to downloadable PDF files on such classroom management topics as conflict de-escalation strategies, discussion ground rules, and guidelines for constructive dialogue.

Handling Controversy in the Classroom
Tips for teachers from the Idaho Forest Products Commission on handling controversy.

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