# The MYTHS of Teaching Science and Their CONSEQUENCES

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When asked to explain why district students were struggling in science, the Superintendent admitted that "we don't have a strong science component in our curriculum" and went on to indicate that students needed to attain proficiency in the three R's – reading, writing and 'rithmetic - as a prerequisite to learning science.

This is the "standard model" used across the nation and thus at all levels across American education from kindergarten through college. I know this is true because for over eighteen years I have taught both high school and college chemistry. I know because I have heard colleagues and many other educators decry the lack of student proficiency in math as a prime reason for their lack of interest and success in science.

But, is the "standard model" accurate? Exactly what level of 3R proficiency is needed for a student to learn and to do science? How much math do actual working scientists use to conduct research, analyze data and understand experimental results?

Here are the facts. Children are natural born scientists. The accumulated evidence from decades of interdisciplinary research and just simple everyday anecdotal evidence shows this. Children endlessly ask questions, form and test hypotheses about themselves, their environments and social relationships and in language acquisition. This is how they learn. In some tasks children are actually better than adult scientists. They, for example, regularly "think outside the box" when confronted with a problem. This approach could lead to incredibly innovative and creative solutions. In fact, researchers working to develop advanced artificial intelligent systems are appropriating the Bayesian statistical models that are found to underlie children's learning and thinking processes.

The bottom line which defies the myth that learning science is difficult is a simple one. In our individual human development, we all behave as scientists long before we become proficient in reading, writing and arithmetic. The curiosity that is foundational to all learning, including the sciences, is what drives us to learn, is what drives us to read, write and count as a means of satisfying the basic human need for knowledge. We are wired at both the molecular genetic levels and biochemical levels, with genes and neurotransmitters, to facilitate this process.

The role of teachers and schooling should be to nurture and build upon our innate tendencies to be curious, to explore and to be scientists. This is generally not happening in science education and science classrooms across the United States, or indeed, across the globe. School often destroys our innate curiosity and then incredulously we wonder and anguish over why students are bored, frustrated, distracted and drop out" of class or of school entirely. Duh!!!!

***Marcus Purnell, a 7th grader from Benton Harbor International Academy, learns about vacuum filtration from Loren Simmons, 2013 graduate of Brandywine High School in Professor Desmond Murray's lab at Andrews University.***

Another myth is that most scientists are extraordinarily intelligent, really smart and very bright. How about they are simply curious? How about they love the dopamine rush that comes with exploring, understanding and discovering? They are not endowed with any superhuman powers. You don't believe me. How about Einstein, who said, "I have no special talent. I am only passionately curious." Bottom line scientists are just human equipped with the powers of innate curiosity like every other human. I am completely aware that within the human species, there is a huge range of variation in almost all complex traits, such as curiosity. Nevertheless, there is commonality, which is after all why they are in fact human traits.

So, our education system should be based on nurturing this common, intrinsic and invaluable human trait to the fullest individual potential. Unfortunately this has not been the case. This in my opinion is educational malpractice on a national, if not global scale. I count myself fortunate to have had mentors, Dwain Ford and Kim Albizati, at the BSc and PhD levels, respectively, who gave me the freedom to follow my curiosity, as well as the freedom to fail. I also pay high honor and due respect to my parents, Auldith and Hartwell Murray, who avidly nurtured my inward "jonesing" for knowledge.

Another myth is that all scientists are good at math and use advanced math in their every day work. This also is not true. You don't believe me. Listen to Harvard Professor Emeritus Dudley Herschbach, who received the 1986 Nobel Prize in Chemistry for the use of molecular beams to probe chemical reactions. In an interview for a YouTube video he said, "the fact is in most of science people don't use much more mathematics than a grocery store clerk." There it is.

As an active researcher in organic synthesis, one of the largest branches of chemistry, I know that to be true. Addition, subtraction, multiplication and division. That's it, folks. While I did a minor in math because I enjoyed it, I've never really had to rely on integrals, differential equations or matrices in the conduct of my PhD research or now as a university faculty member. This is not to say that all science and all scientists do not know and use advanced math to gain a deeper understanding of natural phenomena. In fact, as scientists, we recognize the power, beauty and poetry of a simple equation like E = mc2. Rather, it is to say, that the use of advanced math by scientists in their every day work is more the exception than the rule.

Another myth is that non-scientists do not use the scientific method and that all scientists do all the time. This is not true. Normal people, you, your neighbors, your plumber, your priest, all use the scientific method every day to diagnose and solve problems. Whether it is trying to figure out why your house lights are not working, to knowing how someone will react to your words, to wondering why there is no water in your faucet. We all begin with observations and hypothesis, test them and reflect upon the test results to help us change our hypothesis and eventually arrive at solutions. What we casually refer to as life experiences can be viewed as a series of experiments.

Further, the notion that the scientific method is some linear formulaic approach that all scientists use all the time is also incorrect. Like everyone else, we have hunches and we make guesses as we seek to "connect the dots," by laws, theories and equations, that our observations and experiments provide. This is the sort of recognition Einstein had when he famously said, "Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world."

Apart from the myths themselves I am even more concerned about their consequences on educational policy, classroom practice, and the "demographics" of the science, engineering and technology workforce. Some of the consequences of these myths include: (1) the unnecessary delay, pervasive in kindergarten through college, of fully engaging students in learning and practicing science, (2) the misguided lack of attention and investment of resources in science by school boards, administrators and teachers until 3R proficiency is attained, and (3) the negative effect on inclusion of demographic populations already underrepresented in US science: women, African-Americans, Hispanic-Americans, and Native Americans.

The bad news is it does not have to be this way. The good news is it does not have to be this way. I believe that if we challenge students to answer authentic questions of scientific interest to them, they will be much more motivated to acquire the knowledge and skills, including better reading comprehension skills and math skills in a "just-in-time" way needed to answer the questions posed. In fact, this "just-in-time" approach is one that I have adopted in facilitating high school students and "non-science" college majors, of varying GPA's, backgrounds and interests, to successfully conduct cutting edge organic synthesis research.

Students do not have to be put through an obstacle course of requirements before they are allowed to do science. Students do not have to be frustrated, bored and turned off by science. They don't need a PhD to do important research; they don't have to be a professional to be curious; they don't have to be a Nobel scientist to be observant and they surely don't have to be white, male and privileged to engage in the greatest adventure known to humankind. I invite you to view the following YouTube video by astrophysicist Neil deGrasse Tyson: http://www.youtube.com/watch?v=AIEJjpVlZu0

What we need is a cultural and educational revolution that privileges curiosity. This is going back to basics in the most fundamental way possible, since curiosity is the very foundation of all learning. It is more than just a hunger for knowledge or an appetite for information. It is this but it is more. It is our primal survival instinct in a world of incessant stimuli, some of which are harbingers of danger and even death. Curiosity is our hope as a human species for overcoming many of the technological, environmental, medical and security challenges we face globally.

We must debunk the myths that conventional science education has adopted and lay them alongside other relics of human history. Curiosity will keep us safe, alive and forever seeking. It will allow each of us to see our world with a thousand eyes.

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