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The Mystery in Science: A Neglected Tool for Science Education

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Of the many valuable tools available to science education, the mystery in science is the one that is the most ignored, underused, or misunderstood. Whenever it is used, it is only as mere entertainment or as an attention grabber. In a recent essay titled "Impedance Matching"[1] Robert P. Crease praises the efforts of his colleague Clifford Swartz, a physicist at Stony Brook, for his ability to use wonder and mystery in keeping students' interest in physics alive. But the mystery quality in science should do much more than that. Appropriately integrated in teaching, the mystery in science can improve student attitudes and generate a life-long interest in science. It may even prompt students to take a closer look at science as a possible career.

One of the most fascinating things about science is that its frontier is always in contact with an ocean of mystery that generates lots of questions, and it is filled with fascinating possibilities. Very often, this ocean of mystery is ignored in preference to what is securely known. Albert Einstein, however, regarded mystery as "*The fundamental emotion that stands at the cradle of true art and true science.*" In our ongoing efforts to seek more effective ways of improving science education, we are faced with the following questions. How can we best use this mystery in science towards our educational endeavors? Can our students fully understand what science really is, without the awareness of this ever-present mystery in science?

Most science educators would admit that they are uncomfortable with the mystery component, preferring to emphasize instead the success and certainty of science, just like science textbooks do. This, however, presents an inaccurate description of science. We know that much of what has been tried in the past in the name of science ended up as inconclusive or as "failure." It is these "failures," however, that constitute the bulk of the activity in science, yet we celebrate and talk only about the successful outcomes and the few surviving theories. We do not award medals or prizes for these "failures," no matter how valuable their "failed" outcome may have been in the long run. Albert Michelson, whose 1907 Nobel prize in physics was *"for his optical precision instruments, and the spectroscopic and metrological*

1. Critical Point Column, Physics World, August 2006, page 16.

investigations carried out with their aid" may be the exception. His Nobel Prize in physics was undoubtedly a subtle recognition of his "successful failed experiment" in his valiant efforts to detect the ether. Thomas Edison who tried hundreds of materials as filaments for his light bulb was keenly aware of "failures" being a part of the process of science. To that end, he is known for saying *"Good science is only five percent inspiration. Ninety five percent of it is sheer perspiration."* It can be unsettling that the image of science, as described in textbooks, is only one of glory and uninterrupted success. This clean-cut and glorified image is a lopsided portrayal of science, giving the wrong impression that science is perfect and infallible. Some educators choose, however, to present a more realistic image of science by going beyond the textbook. They do that by incorporating case studies from the history of science in their teaching of science. History of science not only adds a warm human element to an otherwise dry and mechanical discipline, but it also reminds us of the "failures," the ongoing mystery, and incompleteness of science. Encouraging students to ask relevant questions at the conclusion of each topic also helps. Even for a standard topic like Gravity, we can inform our students about the ongoing efforts to detect gravity waves and the discussions about Dark Energy, an "antigravity" force suggested recently by the discovery of an accelerating universe. The mystery associated with the antigravity qualities of Dark Energy should not deter us from referring to it in our teaching, even if we still have no clear idea as to what exactly Dark Energy is. We can make a similar reference to Dark Matter, whose existence is undisputed, yet its nature still elludes us. Each branch of science has its own share of cutting edge mystery and set of pending questions. We need to recognize that the mystery in science is an exciting part of science and it is of tremendous educational value, even if we have no answers to the questions it generates. Instead of shying away from the mystery in science, we should embrace and celebrate it in our teaching.

The borderline between what we know in science and the mystery beyond is one of the most fascinating places to visit. It generates feelings of awe, inspiration, excitement, and a sense of confidence mixed with pride for our many achievements since Galileo. I often take my students there, so that we can gaze and marvel at the ocean full of questions that lies ahead of us, while, at the same time, further appreciate the step-by-step discoveries and the scientific method that took us there. We know that in that ocean of mystery are tomorrow's discoveries and the answers to questions yet to be asked. We patiently unfold the mystery into knowledge by the systematic use of the scientific method of inquiry, although occasionally nature may reward us with the bonus of a serendipitous discovery. While we are all standing at that frontier of knowledge, I give my students also a fair warning, not to allow the mystery in science to create in their minds an exaggerated fantasy-wasteland that is totally devoid of any realistic projections of science. Such an abuse of the mystery in science remains a potential danger to the young minds. On the contrary, when the mystery in science is properly used, it can be the best nourishment for creative imagination.

Our matrix of education should be filled not only with knowledge that has been "certain and secure," but also with the many good questions that such knowledge can inspire. A truly educated person is one whose knowledge inspires him/her to generate as many meaningful questions as possible. Such questions may not only push the envelope of what is already known, but also strive to synthesize fragmented bits and pieces of knowledge into a more meaningful and comprehensive new picture. Unfortunately, asking questions has been treated poorly by our culture and by our educational system. Questions are often thought as expressions of ignorance and not as an essential path to knowledge. In some Asian countries, asking questions is even thought to be disrespectful, because they are seen as "challenging" one's teacher. We must abandon these cultural biases and rediscover the child-like joy and importance of questioning. Our need to ask questions is driven by curiosity and together with its twin sister, imagination, they have produced some of the most magnificent works of art and science. Einstein once said, *"Imagination is more important than Knowledge."* When students are taken to the edge of scientific knowledge, their imagination can help them frame creative questions about tomorrow's research efforts, whether these are about genetics or astrophysics. Such use of creative imagination gives student a taste of the thinking mode of research scientists and should be encouraged in the classroom. Children are the best-known natural explorers with so many questions, some of which can be at the cutting edge of science. My favorite example is from a sixteen-year-old, Albert Einstein, who asked: *"I wonder what the world would look like, if I were to ride on a beam of light."* In ten years time, that simple question gave birth to Relativity, a new theory that like an intellectual earthquake shook the foundations of classical physics.

"I wanted to know if God had any choice in the creation of the universe" is another one of Einstein's most popular quotes. It reflects his own fascination about the architecture of the universe and particularly about a handful of physical constants that he viewed as the main pillars of the structure of the cosmos. Why do these constants, such as the speed of light or the mass or charge of the electron, have the specific values that they do, and what will the cosmos look like if they had double or half of those values. New worlds built on distorted physical constants are described by George Gamow in his classic book *"Mr. Tompkins in Paperback."*[2] Taking trips through new worlds that are built on different value of physical constants is one of the best ways to practice a deep understanding of the fundamental concepts of modern physics. Another way is to remove a law or a constant from the universe and be able to see the full impact of such an act. Towards that end, I often invite my students to predict what would happen to the universe if, for example, the force of gravity were to suddenly stop. The inward pushing force of gravity is what slowly converts a huge cloud of interstellar gas into a shining star, with a core at millions of degrees generating energy by nuclear fusion. Gravity is also what keeps the star stable and in one piece by keeping it under pressure, and thus preventing it from exploding from its own internal pressure. Students learn through this very simple exercise that one of the first things that would happen to the universe, if there was no gravity, is that all stars will explode, even before their orbiting planets were to go astray in space.

An unexpected spin-off benefit that the mystery in science brings is the intellectual humility it can evoke. The Greek philosopher Socrates who preached learn-

2. Mr. Tompkins in Paperback, by George Gamow, Cambridge University Press.

ing by questioning (hence the *Socratic Method,*) often underlined humility with the statement *"I know of one thing, that I know nothing."* Only when we can become fully aware of the mystery in all knowledge can we develop intellectual humility, a quality we should highly respect and strive for. On the contrary, we should fear those who have no questions. Their mind is filled only with certainties, and it is often these kinds of minds that can breed fanaticism. Their thoughts and beliefs leave no room for doubt, questions, or alternative possibilities. History reminds us of the disasters that this kind of mindset can cause. Current events show that unfortunately our world continues to suffer from such a mode of thinking.

Even Isaac Newton, the most brilliant, yet one of the most unfriendly and egotistical scientists in history, exhibits a rare moment in humility and awe about the mystery in science when he wrote:[3]

> *I was like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.*

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Dr Pangratios Papacosta has a B.Sc. and Ph.D. degrees in Physics, followed by a M.Sc. in the History of Science, all from the University of London. He taught at universities in London and Florida before joining Columbia College Chicago in 1987. He is the author of numerous peer-reviewed articles on Physics, Science Education and History of Science. His book ***The Splendid Voyage: An Introduction to New Sciences and New Technologies*** (Prentice Hall, 1987) was translated in five languages including Chinese, Arabic and Spanish. He designed and is teaching physics courses that integrate the Humanities/Arts. In 1994 Papacosta was recognized by Columbia College Chicago as Teacher of the Year. In 2006 he was invited at the ***Oxford Round Table***, a week-long symposium at Oxford University about bridging the cultures of Science/Math with Humanities/Arts. (Reflecting on C. P. Snow's *Two Cultures.*) In 2007 he was one of the selected presenters at the ***Carnegie Academy*** for the Scholarship of Teaching and Learning. His presentation was titled ***"How Art can Reinforce Science."***

Humanizing science through its history and biography has always been Papacosta's philosophy and pedagogy. He served as Chair of a task force on Interdisciplinary Studies at Columbia College and he advocates the importance of interdisciplinary experiences for faculty and students. For his experience and expertise in this field he is often invited by American and European institutions and by major conferences to speak on the importance of ***"Bridging the Cultures of Science with those of the Humanities and Arts."*** The most recent event was an International Conference in Darmstadt Germany under the theme *Integrating Engineering and Humanities in Higher Education. The Bologna Process and Beyond.* His presentation was titled ***"Reinventing Prometheus: Humanities in the Education of Scientists and Engineers."***

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  The Florida Academy of Sciences (1986-87)
  The Chicago section of AAPT (American Association of Physics Teachers) (1993-94)
  The Illinois Section of AAUP (American Association of University Professors) (2002-05)

3. Brewster, Memoirs of Newton (1855), Vol. II, Ch. 27.