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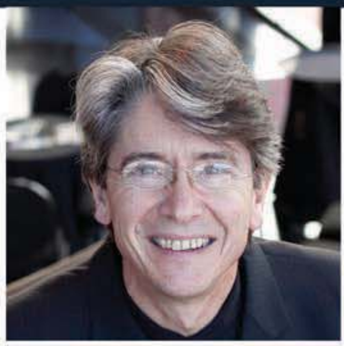

Mathematics and Science as Art in the Classroom

Grant Cooper, Artistic Director and Conductor
West Virginia Symphony Orchestra

Maestro Grant Cooper serves as conductor and artistic director of the West Virginia Symphony Orchestra. Previously, he taught for more than 20 years as a tenured professor in two upstate New York colleges, receiving awards both for his teaching and for creative activity. He taught a highly successful honors seminar titled "Music and Mathematics as Art."

A university graduate in pure mathematics, he is most often asked about the relationship between music and mathematics. Maestro Cooper was born and educated in New Zealand, and is a naturalized U.S. citizen.

It is evident to even a casual observer that the focus in education in our country, for the foreseeable future, will be on science and mathematics. Since these fields of study were the (narrow) focus of my own education, I would be the last person to argue against such a concept but, as with everything in life, there are some important, defining ideas to consider as we develop strategies for the design and implementation of any plan.

Is it an obvious conclusion that to teach our students to become better scientists, we need to teach them more science? Or to teach it more often? Do we advocate such an approach to training our sports teams, practicing and perfecting only those drills (and muscle groups) that will directly be used in the game?

From this simple analogy with sports, the obvious question must be asked: if our goal is to improve mathematics education, are we engaging in a fallacy of logic by equating the *avoidance* of teaching in non-mathematical areas as an effective strategy in the teaching of mathematics?

WEST VIRGINIA SYMPHONY ORCHESTRA

While this question can be addressed as an issue of balance in the curriculum, I would like to investigate a much more powerful idea that talks about the way we teach, rather than what we teach. Since my own field of study was mathematics, let me address that subject specifically: *how should we teach mathematics?*

In order to answer that, we must first establish what we mean when we use the word mathematics and, from there, perhaps understand why, nationwide, the United States seems to encourage "I am terrible at math" as a socially acceptable boast. This is not the case around the world, by the way, but that is the subject of another discussion.

Most people, when thinking of mathematics, think of numbers. Having a working knowledge

of how our number system works and being able to perform basic arithmetical operations (in our heads) is an essential skill for citizens of our time.

The same can be said of science, although the many branches of science are more readily acknowledged by non-scientists and so there is less of a tendency to construct an artificially narrowed definition of science, such as we do when we equate arithmetic with mathematics.

Understanding mathematics as something (much) more than arithmetic is important if we are to engage in a discussion that leads in a logical way from the conclusion that 21st century skills involve having a degree of comfort in mathematics, to decisions as to how we should actually *teach* mathematics.

Indeed, if we are to be intellectually honest with ourselves, we must confront an even more basic issue: are we concerned with students' ability in mathematics or are we concerned with the test scores our students get on standardized tests and how, in turn, these scores compare with students around the world?

It is well-accepted among educators that we teach kids in different ways, if our goal is to get those students to pass an exam (and different again if that exam is given in multiple-choice format). Quite recently, I was helping to coach our younger daughter as she prepared for the GRE exam. In reading the published books that purportedly help students in this quest, I was shocked by how blatantly the authors explained their methodology. They were completely uninterested in students learning the mathematical principles and applying them to solve a given problem! The strategy the authors were "teaching" was tightly focused on how to get to the right answer from among the four multiple-choice options. In fact, in as many words, they were advising their readers that trying to understand the basic principles was a waste of time and would probably lead to lower test scores. Ouch!!! What are we are trying to teach – the subject itself or good test-taking technique?

Is it possible to have a student who understands mathematics well, but who does not score well on tests? Ask the many mathematicians who have argued (wrongly) with a server about their change and you will hear a resounding "yes" to that question.

Successful students ask questions … Engaged students are curious about a subject – they want to know *more* than what will be on the test.

How do these people even call themselves mathematicians? What is going through their heads, if not a brain-powered super-calculator? And how does this relate to music and the arts?

Mathematics and music are both conceptual universes. In each "world," objects are identified and the most basic relationships between those objects are defined. These are the axioms of a mathematical system. From these basic relationships, other, higher-level relationships are deduced, often moving from the mundane to the highly conceptual.

Such a path in arithmetic might take us from the counting numbers (a highly intuitive and easily accepted first step) and then (after much thought, I might add), to the number zero. After zero, we add the concept of negative numbers (much squishier than the counting numbers on a "show-me-the-object" level) and, from there, the idea of the square root of negative 1, or *i*. How conceptual is *i*? "*i*" is totally made up and, in fact, in some arithmetical systems, *i* simply "doesn't exist." But the beauty and miracle of it all is that an enlarged number system behaves quite properly and elegantly, even with such imagined numbers in it.

In fact, mathematics starts to get interesting when our universes are allowed to come purely from the mind – the imagination – rather than from the real world (of balancing a checkbook).

A mathematical thinker is one who thinks in and explores conceptual universes. That is, one who thinks *creatively* about her/his subject. If we are to teach people to have meaningful relationships with mathematics, surely we realize that this does not mean creating ever higher percentages of our students who can perform routine mathematical tasks while lacking any *curiosity*, *inventiveness* or *passion* about and for mathematics.

In that last paragraph, I am implying quite explicitly that successful mathematicians (and scientists) are creative people. They are not automatons; they enjoy complexity and they welcome ambiguity. I cannot imagine any level of success in the teaching of the sciences if that teaching were attempted in a way that is devoid of any kind of artistic (creative) thinking.

I have focused on the sciences because the rest is easy. Are we to teach English and creative writing purely as a manipulation of everyday words (the equivalent of balancing a checkbook)? Can we fail to understand the value of exposure to the arts: reading Shakespeare aloud, applying paint to paper, making bowls from the clay of the earth, hearing a performance of a Beethoven symphony?

Successful students ask questions. The best educational outcomes occur when we observe students learning how to teach themselves. Engaged students are curious about a subject – they want to know *more* than what will be on the test.

None of this is theoretical. I believe it is self-evident.