The (Very) Human Nature of STEM: Truth, Beauty, and Mathematics

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At the 2017 joint meeting of the American Mathematics Society and the Mathematical Association of America, Francis Su delivered his final presidential address to a crowd of professional mathematicians, all working in what many consider a rarified and highly abstract field of study. His impassioned speech, "Mathematics for Human Flourishing," prompted long overdue self-reflection within the university mathematics community and beyond. Mathematics, he claimed, draws on "basic human desires" in order to "cultivate virtues that help people flourish."[1] In her essay, "STEM Education in the Age of 'Fake News': A John Stuart Mill Perspective," Guoping Zhao also describes a kind of human flourishing. Inspired by Mill's strikingly relevant rationale, she recognizes the power of STEM disciplines to cultivate the "art of thinking." This is crucial for "the proper functioning of a human being" and by extension the proper functioning of a democratic society.[2] To maintain a healthy skepticism is to flourish. To recognize fallacy is to flourish. To seek truth is to flourish. In fact, Francis Su identified "truth" as one of the human desires driving mathematical engagement, along with play, beauty, justice, and love. I suggest that all of these desires help to advance the project of democracy. At the risk of sounding a little more like Keats than Mill, truth and beauty are the two desires, the two drivers of inquiry that I wish to pursue more deeply today.

Zhao thoughtfully uses the term "truth-seeking," which is marked by action, by human endeavor. The verb "seeking" helps us in a few ways. It challenges the teleological view of mathematics as an adjudicator of truth and relocates agency to our hands and minds. We are sense-makers, modelers of our world. (And by "we," I include younger generations. They can and do critique the institutions that threaten to bankrupt them, the technology that both connects and divides them, and the societal injustices that haunt them.) "Seeking" also injects a degree of uncertainty that has a bearing on our character as well as our mathematical knowledge. We seek, yet we are not guaranteed a satisfactory result. How should we handle contradiction, dissent, or no resolution at all? Classroom vignettes, stories about children and problems, can be instructive here if we view the classroom as *of the world* rather than a simulacrum of it.

Last year, a second grade class debated whether a circle is a polygon with a great number of small sides or a shape with no sides at all. They used magnifying glasses to scrutinize the boundaries of printed circles, hand drawn circles, and the circular features of everyday objects. Some believed that as a circle grows larger, its many sides shrink to dimensionless points. Others argued that those points could *never* be tiny enough and would still constitute straight sides. Deadlocked, they decided to ask the most knowledgeable people they could think of: eighth graders. Most of the eighth graders reiterated their formal learning (that a circle is not a polygon and therefore has no sides), yet there were dissenting voices. A circle, a few claimed, may or may not have sides. As if channeling John Dewey himself they reasoned, "It depends."[3]

The circle question was characterized by children's curiosity, flexibility, inflexibility, capitulation, confusion, and surprise. Later, the children's parents visited the classroom and recorded their own responses on a community bulletin board. They too did not uniformly agree. Mathematically, it was an unresolved question. There was no terminus to this "road to truth," as Mill would say. But what *virtues* came from interminable circles? In his address Francis Su said, "The quest for truth predisposes the heart to the virtue of humility."[4] Considering an alternative viewpoint doesn't merely require humility, it engenders it. The late P.M. Forni, co-founder of the Civility Project at Johns Hopkins University, wrote that among the most "civil utterances" is the question "What do *you* think?"[5] I agree with Forni, as long as the question is asked in earnest and the reply keenly heard.

I turn now to another basic human desire named by Francis Su: beauty. While Su emphasized the beauty *of* mathematics, I am interested in how our human aesthetic sensibility helps us come to know mathematics. This is an important distinction: the beauty *of* mathematics eludes many, and touting the discipline's inherent elegance or aesthetic nature risks pointing to a character flaw of sorts, as if certain people do not or cannot understand math well enough to appreciate it. In so doing, mathematics becomes a secretive, exclusive domain, knowable only to some. Our aesthetic sensibility should do precisely the opposite and make mathematics more knowable, not less.

Here is another classroom story, this one about a group of second graders investigating odd and even numbers. Rather than ask students what makes numbers odd or even, the teacher asked, "Which do you prefer?" The students had strong feelings one way or another, as I expect many adults do. Katie said, "I like even numbers because it's fair and everybody's happy. If my brother found two pennies, it would be fair because my brother would get one, and the other person would get another. Or if it was four, it would be two and two." She did not generalize the *2n* structure of even numbers but instead stated why she prefers them. If the prompt had been, "What makes a number even?" Katie might have responded with the same social context but without the affective qualifier "happy." Her classmate Jason also preferred even numbers because "even numbers are more round, but odd numbers are more pointed." This was no synesthesia at work but rather his sensitivity to the reflection symmetries of regular polygons.[6] Preference and its complementary state, aversion, are strongly linked to our sense of "rightness" and "fit." It is not that feelings about shapes *lead to* mathematical thinking. Much in the way Dewey described, Jason is already engaged in mathematical thinking because he is interacting aesthetically with his environment. Mathematics entirely detached from aesthetic and affective domains is therefore mathematics detached from a critical human endowment. Children "think and learn through qualitative discriminations intended to achieve states of coherence with their environments and interactions."[7]

Beauty is more than a human desire. It is a right of children, a means of understanding the world, and a safeguard against indifference and inhumanity. Educator Vea Vecchi says that the aesthetic dimension "is a process of empathy relating the Self to things and things to each other. … It is an attitude of care and attention for the things we do, a desire for meaning."[8] If beauty is an activator of mathematical learning, rather than a mere property of mathematics to be

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unearthed, then the virtues cultivated are more complex than "transcendence and joy," as Su stated. As a safeguard against indifference, beauty can stimulate point of view and empathy.

Truth and beauty are words unlikely to appear in the "Engineering for Kids" website mentioned by Zhao. Furthermore, we are more likely to associate humility, viewpoint, and empathy with a social studies curriculum than with any letter of "STEM." This is more than a missed opportunity: it is contrary to human nature. The instrumental rhetoric of STEM deserves our attention and constant critique. We should even question what is meant by "preparation," because when we say we are helping students to *become* contributing members of a democratic society, it suggests we do not already view them as such. We are morally compelled to rethink our intentions around STEM with the objective of a more just society as our guide.

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1 Francis Edward Su, "Mathematics for Human Flourishing," *The American Mathematical Monthly* 124, no. 6 (2017): 483–493.
2 Guoping Zhao, "STEM Education in the Age of 'Fake News': A John Stuart Mill Perspective," *Philosophy of Education 2019*, ed. Kurt Stemhagen (Urbana, IL: Philosophy of Education Society, 2020).
3 They stated that "man made circles have sides" but "circles in theory" do not. This is surprisingly similar to a statement made by John Stuart Mill in *A System of Logic,* (New York: Harper Brothers, 1882): "It is not true that a circle exists, or can be described, which has all its radii exactly equal. Such accuracy is ideal only; it is not found in nature, still less can it be realized by art," 184.
4 Su, "Mathematics for Human Flourishing," 487.
5 Pier Massimo Forni, *Choosing Civility* (New York: St. Martin's Griffin, 2002), 80.
6 Regular polygons with an even number of sides have reflection symmetry lines that include segments with "like" endpoints (midpoint to midpoint, vertex to vertex). This feature was aesthetically pleasing to the students.
7 Nathalie Sinclair, *Mathematics and Beauty: Aesthetic Approaches to Teaching Children* (New York: Teachers College Press, 2006), 20.
8 Vea Vecchi, *Art and Creativity in Reggio Emilia: Exploring the Role and Potential of Ateliers in Early Childhood Education* (New York: Routledge, 2010), 5.