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Getting Real about the E in STEAM

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Abstract
STEM and STEAM are in the news. Researchers and educators in my field (cognition, art, and creativity) argue reasons for adding the A to STEM. While I visit this below, my focus is elsewhere. In this brief essay, I want to explore the meaning and importance of the E appearing in both STEM and STEAM. What's engineering doing in this mix? And what are some reasons for affirming the arts when the role of engineering is clarified?

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STEM and STEAM are in the news. Researchers and educators in my field (cognition, art, and creativity) argue reasons for adding the A to STEM. While I visit this below, my focus is elsewhere. In this brief essay, I want to explore the meaning and importance of the E appearing in both STEM and STEAM. What's engineering doing in this mix? And what are some reasons for affirming the arts when the role of engineering is clarified?

It can't be news to the readers of this journal that enhanced science, technology, engineering, and mathematics education, or STEM for short, is widely considered a path to a revitalized United States. Witness the geometric growth of STEM-related programs in the nation, and the reverence conferred on these programs by politicians and business leaders wanting to say something important and hopeful about American schools. Norm Augustine, retired Lockheed CEO was exemplary in October 2012 when he called upon:

> *"... industry and government to promote more STEM education in the U.S. 'Failure to do so... will undermine the U.S. economy, security and place as a world leader.' Competing with knowledge-based resources will be one way that the U.S. can recover and retain primacy in the global marketplace"* (Twittweb, 2012).

A billboard for the *Los Angeles Fund for Education* glares out over Burbank, California: "*Support Los Angeles Schools*" in 8-inch letters, and in 8-foot letters "*or FACE CATASTROPHE*." A possible reference to technological obliteration?

More than a decade ago, state school boards and legislatures practically gave up suggesting or dictating changes in what schools taught in favor of testing students to be sure they were learning. Assessment and accountability trumped educational ideas. Education oversight became a matter of deciding what to test and how to reward and punish schools and districts based on student performance.

STEM is defying this cycle. STEM ideas have attracted a diverse and powerful crowd excited to see schools deliver when it comes to the sciences, mathematics, and technology. Once again, resources are concentrating on a cluster of learning objectives considered poorly served, goals that are perceived to succeed mainly in the education systems of our economic competitors.

The advent of STEAM. A revisionist delegation recently sidled up to STEM. Here were educators convinced that the Arts had a legitimate place in science and technology education. The point was NOT that you couldn't teach physics or mathematics without the arts, but that artistic expression and principles could assist learners in structuring and organizing ideas, exploring disciplinary and cross-disciplinary connections, and solving scientific problems. Furthermore, the STEAMers contended, creative practice in the arts might boost capacity and dispositions to think creatively in the sciences. A drawing or model of chemical bonds could be both practical and aesthetic -- and perhaps through its visual charm, all the more engaging to learners. To some, STEM should be STEAM.

While STEM programs haven't rushed to embrace the arts, a movement was born. *RISD*, the Rhode Island School of Design, quickly took a leading role in STEAM education leadership:

"STEM to STEAM is a RISD-led initiative to add Art and Design to the national agenda of STEM (Science, Technology, Engineering, Math) education and research in America. STEM + Art = STEAM. The goal is to foster the true innovation that comes with combining the mind of a scientist or technologist with that of an artist or designer. RISD President

John Maeda and other members of the community have been championing the idea that STEM expands into STEAM when art is part of the equation" (RISD, n.d.).

And the advocacy group *STEAM-not STEM* has argued:

"Much research and data shows that activities like Arts, which use the right side of the brain, supports and fosters creativity, which is essential to innovation. Clearly the combination of superior STEM education combined with Arts education (STEAM) should provide us with the education system that offers us the best chance for regaining the innovation leadership essential to the new economy" (STEAM, n.d.).

Evidence supporting the A in STEAM. The cognitive research community has explored roles of the arts in science and mathematics learning in recent years, with positive results in individual studies investigating such things as music learning and spatial reasoning (Catterall & Rauscher, 2008). Neuroscientists, for example Professor Nina Kraus at Northwestern University's Auditory Neuroscience Laboratory, are reporting a wide array of effects of music experience on neurobiology, brain function, and brain structure (Kraus, 2012).

Based on accumulated individual studies, it is fair to say that we understand a great deal about how various visual and performing arts experiences impact diverse areas of understanding (Deasy, 2002). The STEAM team has a substantial research-based case for the potential roles of the arts in science and technology learning. The practical challenge is devising instructional and curricular applications and ways to bring arts-infused science and mathematics learning to today's classrooms, and bringing the whole operation to a scale that could bring pervasive impacts to American science and industry. This is no easy prospect. The world of STEAM is beginning to sort these questions out.

What about the E? STEAM is a natural. Science, technology, engineering, arts, and mathematics education go hand in hand – there are elements of all five domains in each of them, at least some of the time. Science needs ever-better measurement instruments (technologies) to advance. The design and calibration of instruments require mathematics. And artistic ways of representing and understanding scientific concepts are commonly accepted, perhaps most widely by scientists themselves. When engineering is included as the practical application of science and technology to the creation of processes and devices, the cluster is complete.

But is it? The E for engineering takes on something of an outsider role in what STEM and STEAM actually mean. We teach science in the schools; we teach mathematics; and we teach the arts. We also use technologies in the schools and think about their connections to science and mathematics. Think of the wave tank in physics, the microscope, the analytical balance in chemistry, and even the chromatograph in biology.

But engineering is not present in the school curriculum. Engineering is for later. Engineering is a college major, an applied science career bringing us better materials, processes, and products; or it is a means to land a Rover on Mars, organize flows of traffic, deliver drug therapies more effectively, and to solve myriad real-world problems in between.

The high school curriculum is a precursor to the practice of engineering. The original STEM movement surely included the E because science and mathematics training was a known foundation of engineering. If the impetus for STEM education was innovation and competitiveness in business, the largest portal to success is through our engineers. But “STM for E” lacks elegance as an acronym.

A and E. The Arts and Engineering. It would be nit-picking to fault the inventors of STEM for misapplying engineering on their banner. But the case described above provides good reason to give STEM and STEAM a little additional thought right now. It would be a good idea to clarify and reinforce the place of engineering in these initiatives. When schools or systems enact these programs, emphases gravitate to science, mathematics, and technology. We don't have high school engineering textbooks. We could say we don't have technology courses either, but technology is so pervasive in our lives and so integral to the worlds of science, that bringing technology to the core of STEM seems reasonable. Where engineering is concerned, the tacit assumption of STEM and STEAM seems to be that participating schools prepare students for successful careers in engineering. But students are not typically exposed in either STEM or STEAM initiatives to what engineering is about.

Design Education. Right here, the arts could reenter the discussion and help to bind STEAM into a coherent whole. Simply put, schools could elevate *design* education in the curriculum. Yes, pursuits in the visual and performing arts generally, and the integration of ideas from the arts into science and mathematics specifically, are important to STEAM. But design and engineering go hand in hand, and a basic course in design is developmentally and *curricularly* appropriate when it comes to a comprehensive STEAM-focused education. Design begins by recognizing needs for processes and technologies, thinking, sketching and modifying ideas, organizing learning around what the task and design solutions require, revising, learning more, collaborating, and getting feedback. Design processes can relate science and technology understanding to what's being designed. Mental imagery and artistic 2D and 3D sketches and models – and of course CAD, computer assisted design, are core parts of designing. The following comments (Bizcommunity, n.d.) suggest the flavor of learning in design:

"Every contrivance of man, every tool, every instrument, every utensil, every article designed for use, of each and every kind, evolved from very simple beginnings" Robert Collier.

"Having an idea in the first place is just the start; bringing that idea to life in a way that inspires others to help it grow can mean the difference between an abandoned sketch on a notepad and a successful finished product in a customer's hands" Lucy Blakemore.

If elementary and secondary students in STEAM programs were offered instruction, challenge, and opportunity in design, they may better understand, and personally integrate, science, mathematics and technology ideas in their views of the world and its problems. They might even aspire to engineering careers with a clearer sense of what they could contribute to society and to their own lives by doing so.

Just how design education could interface with STEAM programs is a design problem of serious magnitude, one that some programs are surely working on. Nonetheless, an overarching goal might be the cultivation of a design identity in STEAM education that propels how students learn and solve problems in the arts and sciences. The *student as designer* may go as far as any vision to realize what STEAM is all about.

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