

Exploring STEAM: Science, Technology, Engineering, Arts, and Mathematics

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“The game is changing. It isn't just about math and science anymore. It's about creativity, imagination, and, above all, innovation.” –Business Week Magazine

Or, maybe it has always been this way, and we are simply realizing it anew...

Leonardo Da Vinci: *“Art is the queen of all sciences communicating knowledge to all the generations of the world.”*

The value of including art and innovation as part of our national effort to encourage careers in science, technology, engineering, and mathematics (STEM) is multifaceted. Foremost is the need for creativity and innovation in STEM fields, particularly given the United States' role in the global economy. A significant body of research also documents the relationship between involvement in the arts and superb science: great scientists are far more likely than the general public to practice or appreciate art, and research increasingly demonstrates how art education may benefit students more broadly.

The Rhode Island School of Design spearheaded the initiative to turn “STEM to STEAM” by adding elements of art (“A”) and design to STEM: “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...Art and design education teaches the flexible thinking, risk-taking and creative problem solving needed to solve today's most complex and pressing challenges—from healthcare to urban revitalization to global warming” (RISD 2014).

The following pages explore the evidence in support of adding arts and innovation to our national effort to encourage STEM education and careers.

STEAM and the Economy

“To remain competitive in the global economy, America needs to reinvigorate the kind of creativity and innovation that has made this country great. To do so, we must nourish our children's creative skills. In addition to giving our children the science and math skills they need to compete in the new global context, we should also encourage the ability to think creatively that comes from a meaningful arts education.” –President Obama (Eger 2011b)

It may well be a key moment to turn STEM to STEAM, as “America is beginning to see the outlines of yet another out-migration of American jobs. Unlike the earlier shift of manufacturing jobs to less developed East Asian countries, the loss of the latest round of high-tech software and service jobs will have dramatic, some say devastating, impacts on America's economic wealth and well-being. Today, the demand for creativity has outpaced our nation's ability to create enough workers simply to meet our needs. Our schools and our businesses need to rethink the needs of the nation, and rethink the important roles of creativity and innovation” (Eger 2011a).

Indeed, there is striking evidence of the demand for more creativity and innovation in the American economy. A diverse team of organizations (the Conference Board, Corporate Voices for Working Families, the Partnership for Twenty-first Century Skills, and the Society for Human Resource Management) partnered to survey over four hundred employers about their experiences with high school, some-college, and bachelor’s educated students to learn about how well they are prepared for work. They found that employers significantly value creativity and innovation (defined as the ability to “demonstrate originality and inventiveness in work; communicate new ideas to others; integrate knowledge across different disciplines”), and expect its importance to increase over time. However, a majority of employers found high school graduates to be “deficient” when it comes to creativity and innovation, and a somewhat meager 4 and 22 percent of employers considered two- and four-year college students (respectively) to be “excellent” in creativity and innovation (CB/CVWF/P21CS/SHRM 2006).

Another report released by the Conference Board and Americans for the Arts, in partnership with the American Association of School Administrators, found that “both the superintendents who educate future workers and the employers who hire them agree that creativity is increasingly important in U.S. workplaces, yet...85 percent of employers concerned with hiring creative people say they can't find the applicants they seek” (Woock et al, 2007).

Likewise, according to the IBM 2010 Global CEO Study “the ability to embody creative leadership is among the most sought-after attributes,” yet “69 percent of human-resource managers said they are having trouble developing future leaders.” Illustrating this, the company Twitter specifically hires engineers with backgrounds in the arts, believing in the value of technology that is done “in a very simple and artful way that people can intuit” (quote from Twitter cofounder Jack Dorsey; Fournier 2013).

Incorporating the arts into STEM education may result in the development of easier-to-use, more aesthetically and emotionally appealing products and services (Jana 2012). History shows us the value of easy and aesthetically appealing product design: arguably, advances in American invention like the auto industry and Apple Computers succeeded by adding art to technology—that is, by transforming a functional invention into something broadly desirable (Kamen and Maeda 2012).

Thus, both in looking backward to STEM successes in recent history, and in looking forward to what educators and employers see ahead, a convincing case can be made for the value of arts and innovation alongside strong STEM education.

Arts and the Brain

“For those of us involved in either [art or science]...we know that the similarities between how artists and scientists work far outweigh their stereotypical differences. Both are dedicated to asking the big questions placed before us: ‘What is true? Why does it matter? How can we move society forward?’ Both search deeply, and often wanderingly, for these answers. We know that the scientist’s laboratory and the artist’s studio are two of the last places reserved for open-ended inquiry, for failure to be a welcome part of the process, for learning to occur by a continuous feedback loop between thinking and doing.’”

–John Maeda, President of the Rhode Island School of Design (2013)

The arts may not lie as far from the fields of science, technology, engineering, and mathematics as they seem to in today’s siloed education system. Both art and science are driven by observation, experimentation, discovery, collaboration, and innovation (Beal 2013). Indeed, a recent study out of Michigan State University found that Nobel laureates in the sciences are “25 times as likely as the average scientist to sing, dance, or act; 17 times as likely to be artists; 12 times more likely to write poetry and literature; and eight times more likely to do woodworking or some other craft” (Fournier 2013).

It is not difficult to imagine how arts education might facilitate success in STEM fields. People can learn many things from the arts that can also be valuable for succeeding in STEM, such as the *creativity* to “think outside the box” and approach projects from diverse perspectives, the *confidence* to step outside one’s comfort zone and learn from one’s mistakes and move on, and the *perseverance* to master an art such as music which involves practicing a complex skill until it becomes something simple you can build upon” (Strauss 2013).

In support of the proposed value of the arts for education in general, over three hundred educators, scientists, school administrators, and policy makers recently gathered at Johns

Hopkins University to explore the relationship between the arts, learning, and neuroscience. Several striking studies were discussed, including work demonstrating that children randomly assigned to receive regular music instruction also improved related skills such as fine motor control; furthermore “changes occurred in certain brain structures” for the children receiving music instruction compared to the children who did not. Another study that was discussed “gave two groups of children a prompt about Ancient Egypt. One group drew and then wrote in response to the prompt; the other group just wrote. The students who drew and then wrote had better organized and more detailed written responses. This was particularly true of students with limited English proficiency.” Likewise, research reveals that “in children who are open to, interested in, and motivated to practice a specific art form, training focuses their attention and strengthens the executive attention [neural] network.” While the relationship between arts, learning, and neuroscience is still a developing field, there is clearly research demonstrating an existent, and potentially powerful, relationship (Hardiman et al 2009).

Furthering this line of inquiry, President Obama’s Committee on the Arts and the Humanities (PCAH) recently released a report titled “Reinvesting in Arts Education: Winning America's Future Through Creative Schools.” This report was the culmination of a year-and-a-half of research review, school visits, and interviews with stakeholders nationwide (PCAH 2011). It identified striking linkages between the arts and STEM education. For example, “music training is closely correlated with the development of phonological awareness—one of the most important predictors of early reading skills”; “children who practiced a specific art form developed improved attention skills and improved general intelligence”; and techniques that “use multiple senses to repeat information cause more information to be stored in long-term—as opposed to short-term—memory, and may actually change the structure of the neurons” (PCAH 2011).

Additional research demonstrates that, compared to low-income students without arts education, those who participate in arts education are four times as likely to demonstrate high academic achievement, three times as likely to have high attendance, and more likely to participate in a math or science fair or to be elected to class office. By their mid-

twenties, these “arts-engaged low-income students are more likely than their non-arts-engaged peers to have attended and done well in college, built careers, volunteered in their communities and participated in the political process by voting” (PCAH 2011).

Supporting learning through the arts also appears to strengthen student and teacher morale. As the PCAH report argues, “there’s a pride and a collegiality in an arts integrated school. Learning seems more fun; students and teachers are more engaged, and the whole school seems like a more creative place” (PCAH 2011).

In a similar vein, a recent report from the National Endowment for the Arts (NEA) analyzed nationally representative data to examine the relationship between students’ level of engagement with the arts and their academic and civic outcomes (NEA 2012). While the report presents correlations rather than evidence indicating that arts engagement necessarily *causes* positive academic and civic behaviors, findings are striking, including:

- Low income “eighth graders who had high levels of arts engagement from kindergarten through elementary school showed higher test scores in science and writing than did students who had lower levels of arts engagement over the same period” (NEA 2012).
- Low income “students who had arts-rich experiences in high school were more likely than students without those experiences to complete a calculus course” (NEA 2012).
- Low income “students who had arts-rich experiences in high school [and who took arts courses in high school] showed higher overall GPAs than did students who lacked those experiences” (NEA 2012).
- Low income “high school students who earned few or no arts credits were five times more likely not to have graduated than students who earned many arts credits” (NEA 2012).

- Low income “8th-grade and high school students who had high levels of arts engagement were more likely to aspire to college than were students with less arts engagement” (NEA 2012).
- Low income “arts-engaged high school students enrolled in competitive colleges—and in four-year colleges in general—at higher rates than did low-arts-engaged students” (NEA 2012).
- Low income “students who had intensive arts experiences in high school were three times more likely than students who lacked those experiences to earn a bachelor’s degree. They also were more likely to earn ‘mostly A’s’ in college” (NEA 2012).
- “Young adults who had intensive arts experiences in high school are more likely to show civic-minded behavior than young adults who did not. They take an interest in current affairs, as evidenced by comparatively high levels of volunteering, voting, and engagement with local or school politics” (NEA 2012).

In addition to the value of engaging students in the arts in general, it is also possible to specifically combine arts and STEM education. What exactly does this look like? While STEAM education can take myriad forms, examples include a third grade math class where students built “Calder mobiles out of coat hangers and buttons to understand the concept of linear equations, in which one set of buttons were balanced by a different but equal number on the other side,” or a fifth grade science class preceded by a dance class that served to illustrate the new vocabulary students were developing: “Use your momentum to get you into the turn” “What slows our arms down here? Inertia!” “Now focus on lowering your center of gravity” (PCAH 2011).

Looking forward

It is a key moment to understand and respond to evidence identifying the value of art and innovation alongside STEM education: While STEM education funding flourishes, education budgets nation-wide are placing arts programs among the first to go. This prioritization may in some ways be “robbing Peter to pay Paul”—that is, this redistribution towards STEM education and away from the arts may actually harm aspects of the STEM economy by losing sight of the importance of creativity and innovation in the success of the STEM economy (Pomeroy 2012).

Fortunately, momentum is building to turn “STEM TO STEAM,” including a new bipartisan STEAM caucus in Congress. As this paper began: The game *is* changing. Today’s economy requires creativity, imagination, and above all innovation. And both evidence from the past and inklings of the future suggest that art and innovation may indeed lead the way for science, technology, engineering, and math, generating and communicating new knowledge for today’s world.

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