A Review of ACD-STEMM Integration

Part 1: A Taxonomy of Integrated Bridges

Robert Root-Bernstein, Ania Pathak
and Michele Root-Bernstein

This is Part 1 of a three-part analysis of studies concerning useful ways in which visual, plastic, musical and performing arts; crafts; and design (referred to for simplicity as arts-crafts-design, or ACD) may be used to improve learning of science, technology, engineering, mathematics and medicine (STEMM) and increase professional success in these subjects. We address the following questions: (1) What are the ways in which ACD and STEMM can interact fruitfully? (2) Which of these ways of interacting have been explored using well-devised studies and what do those studies tell us about efficacy? (3) Where are the gaps (and therefore the opportunities) that can readily be addressed by new studies? and (4) What kinds of methods can be used to generate reliable data about effective ACD-STEMM integration?

Part 1 summarizes studies demonstrating that ACD are valuable to STEMM professionals, providing a taxonomy of eight connecting "bridges" that STEMM professionals say they employ to connect arts and science into "integrated networks of enterprise." We demonstrate that STEMM professionals utilizing these bridges are significantly more likely to achieve success than those who do not. These findings make the issue of near and far transfer between ACD and STEMM disciplines irrelevant: The question of far transfer reduces to whether specific links between the two can be found that create direct "near-transfer bridges" between "far-apart" subjects.

To elaborate, we review studies that demonstrate a strong correlation between success in STEMM careers and serious, persistent avocational participation in ACD over a lifetime. These studies range from personal accounts of how ACD skills, knowledge, materials, techniques and inventions have inspired STEMM work to large-scale statistical studies in which scientists, engineers and mathematicians correlate ACD activities with various measures of STEMM success, such as winning a Nobel prize, becoming a member of a National Academy, filing patents or starting new companies.

Correlations are not, of course, causation. What one would like to see are interventions demonstrating not only that ACD can improve STEMM learning and performance but also how they can do so. The second and third parts of this extended abstract provide such evidence. Here we provide a necessary framework for analyzing interventional studies by examining the kinds of connections one might reasonably expect to find between ACD and STEMM. Such a framework, generated from anecdotal and correlational studies described above, utilizes connections between ACD and STEMM that STEMM practitioners themselves believe to be functional.

The ACD-STEMM framework we propose consists of eight types of connections or "bridges":

Bridge 1. Transdisciplinary tools for thinking. In *Sparks of Genius* (1999), Root-Bernstein and Root-Bernstein previously investigated creative practice among hundreds of individuals drawn from ACD, STEMM, humanities and literary professions to derive a set of cognitive skills of universal utility. These "thinking tools"—observing, imaging, abstracting, pattern recognition, pattern-forming, analogizing, modeling, dimensional thinking, empathizing or play-acting, kinesthetic or body thinking, playing, transforming and synthesizing—form process connections across disciplines.

Bridge 2. ACD implements, methods and materials. Bridge 2 focuses on physical implements, methods of using them and materials to which they are applied as useful connectors between ACD and STEMM practices.

Bridge 3. ACD-generated phenomena. Sometimes artists, working as artists, discover or invent new phenomena that STEMM professionals have never encountered before, which then become the focus of STEMM research.

Bridge 4. ACD principles and structures. Artists sometimes discover new principles governing natural phenomena or invent new kinds of structures that have STEMM applications.

Bridge 5. Experience with the creative process. ACD and STEMM professionals often assert that the creative process of defining new challenges, developing relevant skills, exploring and testing possibilities, and conveying the results to a public audience is universal across disciplines. Process skills learned in ACD transfer to STEMM.

Bridge 6. Transdisciplinary aesthetic principles. STEMM professionals often identify aesthetics as a motivation for their work and as valid criteria for the development and analysis of STEMM research and results. By aesthetics, they mean the same thing ACD professionals mean: a synthetic melding of sense and sensibility, of technique and passion, of content and form, leading to an experience of beauty.

Bridge 7. Mnemonic devices; recording and communication techniques. Remembering, recording and communicating information are essential elements of STEMM expertise that ACD can stimulate and enhance.

Bridge 8. Recreation leading to re-creation. Recreation refers to the act of getting away from one's work to recharge energy and reclaim motivation. When it includes play (one of the thinking tools described in Bridge 1), ACD recreation may involve exploring new ideas, skills, materials, techniques and/or problems of practical or inspirational use in STEMM.

Robert Root-Bernstein* (educator), Department of Physiology, 567 Wilson Road, Room 2201, Michigan State University, East Lansing, MI 48824, U.S.A.
Email: rootbern@msu.edu.

Ania Pathak (researcher), Michigan State University Neuroscience Graduate Program, Giltner Hall, 293 Farm Lane, Room 108, Michigan State University, East Lansing, MI 48824, U.S.A.; Michigan State University College of Osteopathic Medicine, East Fee Hall, 965 Fee Road, Room A136, East Lansing, MI 48824, U.S.A.
Email: pathakan@msu.edu.

Michele Root-Bernstein (educator), Department of Theatre, Michigan State University, East Lansing, MI 48824, U.S.A. Email: rootber3@msu.edu.

*Author to whom correspondence should be addressed

Supplemental files associated with this issue are available at www.mitpressjournals.org/toc/leon/52/5.

 https://doi.org/10.1162/leon_a_01579

In such a case, ACD recreation can lead to STEMM recreation.

In light of the specific and varied ways in which STEMM professionals have utilized ACD, it becomes clear that an enlightened approach to curricular integration requires two things: (1) breaking down the specific types of skills or knowledge developed in any particular ACD project and (2) ascertaining how these may overlap with skills and knowledge required in a STEMM subject. Hypotheses that "the arts will make STEMM professionals more creative" are simply too broad and amorphous to be testable or implementable and have no empirical basis. Equally important, since different STEMM professionals use different aspects of ACD for different reasons, there can be no "one-size-fits-all" approach to ACD-STEMM integration. Integration must be discipline-appropriate and, ultimately, individual-appropriate.

Finally, we argue that the bridges framework makes the ongoing debate about near and far transfer irrelevant to understanding ACD-STEMM integration. The issue concerns whether skill and knowledge transfer can be successfully achieved between disciplines as apparently disparate as, say, mathematics and poetry or music and biology, as it clearly can be between closely related areas such as still-life drawing and industrial drawing. In the absence of defined bridges between subjects, we argue that "far transfer" is impossible. STEMM professionals almost always point to specific ways in which their ACD and STEMM practices connect through one of the eight types of bridges. Bridges create links that draw "far" disciplines into "near" proximity.

Manuscript received 31 March 2016.