Routledge
Taylor & Francis Group

Arts Education Policy Review

ISSN: 1063-2913 (Print) 1940-4395 (Online) Journal homepage: https://www.tandfonline.com/loi/vaep20

STEAM by another name: Transdisciplinary practice in art and design education

Tracie Costantino

ARTS EDUCATION POLICY REVIEW
2018, VOL. 119, NO. 2, 100–106
https://doi.org/10.1080/10632913.2017.1292973

STEAM by another name: Transdisciplinary practice in art and design education

Tracie Costantino

Rhode Island School of Design, Providence, Rhode Island, USA

ABSTRACT
The recent movement to include art and design in Science, Technology, Engineering, and Mathematics (STEM) education has made Science, Technology, Engineering, Arts, and Mathematics (STEAM) an increasingly common acronym in the education lexicon. The STEAM movement builds on existing models of interdisciplinary curriculum, but what makes the union of art and design with the STEM disciplines so persuasive? In this article, I draw from research on interdisciplinary curricular projects that fit into the category of STEAM, but may also be considered inquiries into the role of art and design in the creative inquiry process, in order to sketch a transdisciplinary curriculum model that may be applied across disciplines.

KEYWORDS
Creative inquiry; STEAM; transdisciplinary

Over the past decade, a movement to include art and design in Science, Technology, Engineering, and Mathematics (STEM) education has gained momentum, making Science, Technology, Engineering, Arts, and Mathematics (STEAM) an increasingly common acronym in the education lexicon. STEAM schools and programs are being initiated around the United States (e.g., Double Helix STEAM School), and the reauthorization of the Elementary and Secondary Education Act (titled Every Student Succeeds Act [ESSA], 2015) includes art and music education as eligible subjects for the Student Support and Academic Enrichment Grants (SSAE) (as well as improved programming in STEM education). The STEAM movement builds on existing models of interdisciplinary curriculum but what makes the union of art and design with the STEM disciplines so persuasive?

In this article, I will draw from research on interdisciplinary curricular projects that now fit into the category of STEAM, but initially—and presently—may also be considered inquiries into the role of art and design in the creative inquiry process (Costantino, 2015) in order to sketch a transdisciplinary curriculum model that may be applied across disciplines. The model is constructed from my prior work in art and engineering interdisciplinary/transdisciplinary curriculum projects (see Costantino, Guyotte, Kellam, & Walther, 2014; Guyotte, Sochacka, Costantino, Walther, & Kellam, 2014; Kellam, Walther, Costantino, & Cramond, 2013) and the productive collaborations between art, design and science at the Rhode Island School of Design (RISD) (see Stem to Steam, 2017). Essential to this model, which may be adapted to secondary and postsecondary school contexts, is its foundation in the signature pedagogies of art and design education.

This special issue is focused on exploring the notion of STEAM as a compelling educational approach. This article may be considered an attempt to unpack what may be foundational to its appeal with the aim of highlighting the intrinsic value of an arts and design education, regardless of its association with the STEM disciplines. I begin with a brief engagement with key rationales for STEAM, which leads to a discussion of the challenges and opportunities of interdisciplinary or transdisciplinary curriculum on which the rationales are often based. I then focus on a description of the signature pedagogies of art education and how these pedagogies inform the creative inquiry curricular model, which is animated with an example from the art and engineering project referenced above.

Rationalizing STEAM

Much of the literature directly focused on STEAM (with STEAM in the title or called out in the abstract) aims to theorize or present rationales for the integration of art and design with the STEM fields. On its front page, the *STEAM Journal* explains:

> Although there is a long history of the interaction of the sciences with the arts, STEAM is a new acronym that

CONTACT Tracie Costantino tcostant@risd.edu Rhode Island School of Design, Two College Street, Providence, RI 02903-2784, USA.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/vaep.

> has emerged over the last decade and has a multitude of definitions and approaches. Some of the main themes of STEAM are fostering innovation, the need for twenty-first century skills, and divergent and convergent thinking. (Retrieved from http://scholarship.claremont.edu/steam/)

In the *STEAM Journal*'s inaugural issue, John Maeda, past president of RISD and leading architect of the STEAM movement, provides this rationale, "Design creates the innovative products and solutions that will propel our economy forward, and artists ask the deep questions about humanity that reveal which way forward actually is" (2013, n.p.).

Seeking to provide resources for current trends in art education, in response to the rapidly advancing interest in STEAM, a recent issue of *Art Education* was devoted to articles exploring the potential of STEAM (volume 69, issue 4). In his editorial for the issue, Rolling provides a justification situated in creativity for social responsibility rather than Maeda's rationale focused on economic advancement. Rolling (2016) asserts:

> STEAM matters because we are more than just instructors of art and art education. While most of our students year in and year out will not become professional artists, we are nevertheless arguably the primary teachers of creativity our students will ever have throughout their education. Fundamentally, our job is to instigate and foster arts practice and design thinking as a means for individual learning, social responsibility, and creative problem solving—mediating ideas and materials toward meaningful and enduring solutions. (p. 4)

Kylie Peppler (e.g., see this issue; 2013) has conducted persuasive research about a STEAM approach for involving more female and minority students in technology-related disciplines (such as computer education). In an article about her work with e-textiles, Peppler (2013) makes a strong argument for the role of cross-disciplinary learning such as in a STEAM model:

> The creative problem solving, flexible thinking, and risk taking integral to e-textile design are ideal by- products of a STEAM-powered approach to education, which aims to balance technical expertise with artistic vision. By appealing especially to young girls and women, e-textiles offer a compelling medium to broaden participation in computing. (p. 39)

Bequette and Bequette (2012) encourage "savvy art educators" (p. 40) to leverage their disciplinary foundation in design, aesthetic, and creative thinking with a STEM focus, making connections especially with the problem-solving process in engineering. They take an understandably pragmatic approach in providing a rationale for art and design in STEM curricula being rolled out in K-12 schools as a way to advocate for the particular relevancy of the arts in 21st-century education.

Advocates for STEM education, however, express caution about inserting an A in STEM. Gary May, dean of Engineering at Georgia Tech, states, "The clear value of the arts would seem to make adding *A* to STEM a no-brainer. But when taken too far, this leads to the generic idea of a well-rounded education, which dilutes the essential need and focus for STEM" (2015, n.p.). In his article, May goes on to emphasize that the STEM disciplines, undiluted, are essential to driving innovation in the U.S. economy.

These justifications recall the debate at the turn of the 21st century in the pages of *Art Education* (volume 51, issue 4; volume 54, issue 5) between James Catterall and Elliot Eisner for an instrumental versus intrinsic justification for arts education. While Eisner recognized the longstanding relationship between the arts and other disciplines, and the value of not segmenting learning according to the constraints of formal disciplines, he was concerned about the pressure to find causal evidence for the impact of arts learning on learning in non-arts disciplines. Instead, he focused his book *Arts and the Creation of Mind* (2002) on articulating the inherent value of the arts for education. Since this debate, James Catterall (2009) also further developed his justification for an instrumental value to arts education with correlational research documenting promising relationships between arts learning and academic and social outcomes such as increased graduation rates and greater participation in activities for civic good, such as volunteering. The STEAM discussion may be considered the latest iteration of this debate, but it is also an opportunity to explore if there is something both inherently and instrumentally valuable to the relationship between art and design and the STEM disciplines. One avenue of exploration is the merits and challenges of interdisciplinary or transdisciplinary curriculum.

Interdisciplinarity–transdisciplinarity: Opportunities and challenges

In higher education (with analogous issues in K-12), interdisciplinary collaboration poses both logistical and intellectual challenges. Logistically, it can be difficult to find common planning time, and complicated to schedule co-taught classes so that they count both for teaching load requirements and within a student's program of study. There is also the need to negotiate a location for the class that may be conducive to interdisciplinary learning, as well as the time and days that will fit into faculty and student schedules from the varied disciplines.

Intellectually, despite the ideal that an educational institution would be the seat for cross-fertilization of ideas, faculty members are disciplinary experts contained within departments that often function as silos. Without institutional structures in place to facilitate faculty collaboration it can be a challenge to even meet faculty from a different department with whom one may wish to collaborate (see Lattuca, 2002 for a discussion of interdisciplinarity and faculty development). Once faculty members do meet, they may find that the different terms, methods of inquiry, and domains of knowledge from their disciplines make collaboration complicated. These unique disciplinary qualities must be mastered by students, therefore teaching within the disciplines is important (Donald, 2009), but "rather than envisaging boundaries between disciplines, we could promote the concept that disciplines provide homes within the larger learning community" (p. 48). It is within this learning community that disciplinary knowledge can be brought in to inform the collaborative work of interdisciplinary or transdisciplinary curriculum.

The barriers to interdisciplinary teaching may explain why it is infrequently done, although there is a significant body of literature supporting the value of interdisciplinary curriculum. Much of this literature has been focused on elementary and secondary school contexts (e.g., Beane, 1995, 1997), although there is recognition that an interdisciplinary curriculum structure can facilitate university students' abilities to apply knowledge to real-world contexts (Davis, 1995; Lattuca, Voigt, & Fath, 2004). Kreber (2009) emphasized the urgency of this: "The implication for higher education is that unless institutions pay closer attention also to 'Mode 2' [transdisciplinary] knowledge production, students may not be adequately prepared for the demands of the modern knowledge society" (p. 25). Kreber defined transdisciplinary inquiry as "research that is directed at problems that go beyond, or transcend, the boundaries of particular disciplines" (p. 25). Donald (2009) identified common thinking processes across disciplines that can support students' development of transdisciplinary thinking, including recognizing organizing principles, the ability to change perspective, and most importantly, being able to identify the context of the problem or question under investigation. Lattuca (2001) defined transdisciplinarity as "the application of theories, concepts, or methods across disciplines with the intent of developing an overarching synthesis" (p. 83). Transdisciplinary approaches to curriculum are valued especially for the development of multiple perspectives that inform deliberation on a problem that is relevant to a real-world context, sometimes called "wicked problems" (Brown, Harris, & Russell, 2010). Integrated with the signature pedagogies of art and design education, a problem-based or issues-based transdisciplinary curricular model may be what is the basis for the compelling interest in STEAM.

Signature pedagogies in art and design

The "signature pedagogy" in art and design education, what Shulman defined as "characteristic forms of teaching and learning" in a profession (Shulman, 2005, p. 52) encompasses three essential areas: critical making and object-based learning (Somerson & Hermano, 2013), critique, and exhibition. While Hetland, Winner, Veneema, and Sheridan (2013) identified four primary learning structures in visual art education (demonstration-lecture, students-at-work, critique, and exhibition) I find the framework of signature pedagogies honed to the three identified above as a productive model for the transdisciplinary STEAM context. Demonstration-lecture and students-at-work are implied in critical making, but the emphasis is on thinking through the critical and reflexive manipulation of materials.

Critical making

Critical making is the hands-on mode of inquiry and knowing prevalent in the visual arts. It draws on theories of embodied cognition that assert the nondualistic nature of human cognition in which the body-mind builds knowledge, understanding, and insight through human–environment interaction (Johnson, 2008). Importantly, this knowing through making is multimodal and relies on critical reflection. Johnson, building on John Dewey, explains:

> An embodied view of meaning looks for the origins and structures of meaning in the organic activities of embodied creatures to interact with their changing environments. It sees meaning and all our higher functioning as growing out of and shaped by our abilities to perceive things, manipulate objects, move our bodies in space, and evaluate our situation. (2007, p. 11)

Object-based learning

Object-based learning relates to both the process-product outcomes of critical making and the importance of contextual understanding developed through the study of aesthetic objects as in the disciplines of art history and aesthetic education. The study of aesthetic objects through observation, whether careful looking or observational drawing, paired with knowledge and understanding of the sociohistorical context of an object, what Dewey (1934) called the *genius loci* of a work of art, and the mediating role of its contemporary presentation (see

Paris, 2002) is especially compatible to an interdisciplinary, or transdisciplinary approach to curriculum.

An example of this approach at the middle grades level is found on PBS Learning Media (2015) in two lessons with art objects and natural history objects at the center of inquiry to explore the concepts of "Discovery through Juxtaposition" and "Attention and Perception." Developed collaboratively by leaders in RISD's Nature Lab, Museum, and Academic Affairs these lessons are transdisciplinary in that they explore abstract concepts through the shared and unique ways of inquiry in the sciences and art and design with the intended learning outcome that students will see the value in multiple ways of looking at a problem:

> Problem solving is often guided by disciplinary frames of reference, which can restrict our ability to see other possibilities. These exercises use object-based learning to underscore the idea that there is more than one way of analyzing and knowing the world, and that through multiple ways of knowing, we develop more complex understandings and new solutions. Through the process of critique, an essential part of visual-arts pedagogy, students practice analyzing and reflecting both individually and in groups.

Students use creative thinking skills (Root-Bernstein & Root-Bernstein, 1999) such as observation, analysis, synthesis, and transformation to represent their understanding through creating an exhibition of objects that reflects their system of classification and aesthetic relationships and exploring how perception influences meaning in a series of objective and subjective drawings of organic and inorganic specimens. In these lessons, students will also experience critique as a type of formative assessment.

Critique and exhibition

Critique and exhibition may be considered representative examples of assessment in art and design education. Critiques may be whole group—for example with artworks displayed along a critique wall—or conducted one-on-one between the student and instructor (also called desk crits). Often the critique serves as a summative assessment at the end of a project or course, and resembles a formal presentation in which the artist shares his or her intent and process. When a critique is done well, an instructor uses various strategies to help the student identify areas of weakness and strength in their work and offers suggestions for improvement in a constructive and supportive tone. The instructor might employ the Socratic method, asking a series of questions to help the student articulate his or her intent, or the instructor might engage classroom peers as critique partners. The critique can be an especially powerful learning tool when it is used formatively, as with the in-process critique occurring in the midst of a project, instead of occurring at a project's conclusion (Costantino, 2015).

The exhibition serves as an authentic performance assessment in which students represent their learning and development through aesthetic objects often accompanied by statements of artistic intent. Exhibitions may also be in the form of didactic installations or documentation of community engagement or interventions more akin to social practice (e.g., see Guyotte et al., 2014). They are typically summative assessments that chronicle the processes and products of a sustained problem-based inquiry that is central to a transdisciplinary approach.

Creative inquiry model for transdisciplinary curriculum

Figure 1 presents a model for what creative inquiry framed through the signature pedagogies of art and design might look like (Costantino, 2015). It forms a robust model that is iterative, focused on problem definition and refinement, recurring multimodal and material exploration/critical making and presentation of ideas with in-process critique occurring at multiple points in the inquiry process and exhibition as a point in the cycle that may also generate a reframing of the problem and stimulate further inquiry.

This model is informed by a collaborative curricular research project funded by the National Science Foundation and my application of Shulman's theory of signature pedagogies to art and design education. I will animate the various components of the model through the example of this curricular research project, the Synthesis of Engineering and Art (SEA).

SEA was based on a Synthesis and Design Studio (Kellam et al, 2013; Walther, Kellam, Costantino, & Cramond, 2010). It included nine environmental engineering undergraduate students and 10 art students (studio art and art education majors) and was co-taught by two engineering education and one art education faculty. The primary objective of the Studio was for students to develop an understanding of how to analyze, frame, and model problems within a complex, real-world context, utilizing diverse perspectives and ways of thinking. In order to meet this objective, the Studio focused on observing, abstracting, and modeling energy use within complex sociotechnical systems. We used the book *Sparks of Genius: The Thirteen Thinking Tools of the World's Most Creative People* (Root-Bernstein & Root-Bernstein, 1999) as a conceptual and curricular organizing framework for the course, focusing on one thinking tool per

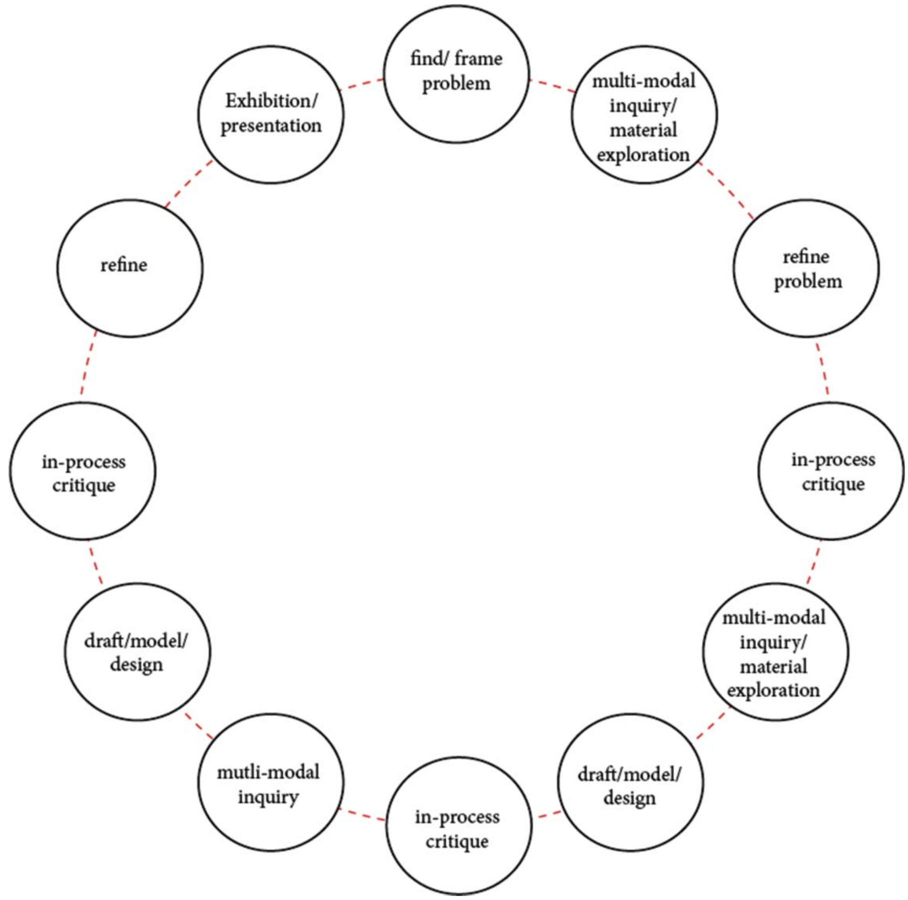

Figure 1. Creative inquiry process (Costantino, 2015). Graphic design by Laura Bejarano.

week over a 13-week period. The 13 thinking tools are: observing, imaging, abstracting, recognizing patterns, forming patterns, analogizing, body thinking, empathizing, dimensional thinking, modeling, playing, transforming, and synthesizing. These tools were not taught in isolation, but applied as ways of thinking about problems related to energy in various sectors, which reflects the environmental engineering emphasis of the course.

To synthesize their learning in this class, students worked in interdisciplinary teams on a semester-long design challenge focused on energy use within the local community as manifested in the following sociotechnical sectors: food, transportation, industry/commerce, residence/domestic, ecosystem, and infrastructure. The design challenge was for students to frame a problem related to energy in their assigned sector, which they identified through observation and modeling of their sector, and then to create an initiative to raise awareness about the problem. The design challenge was supported by workshops and activities to foster higher order thinking skills through hands-on applications, whether drawing concept maps, artmaking, or other creative explorations structured around the 13 thinking tools (Root-Bernstein & Root-Bernstein, 1999). The thinking tools were explored through ways of working, processes and strategies typical in engineering and or art. For example, when exploring body thinking, students constructed group body sculptures expressing energy flow in their selected sector. The students in the audience for these sculptures had to articulate a metaphor for the representation of energy. Through this bodily, visual, and metaphoric thinking, students gained greater insight into the issues related to energy consumption in a particular sector, helping them in the problem framing process. For abstraction, students created clay sculptures representing an abstraction of how energy is manifested in their selected system. An engineering student working in the ecosystem sector created a clay sculpture of the water cycle. While this was an artistic exploration of abstraction related to environmental engineering content, students also created energy flow diagrams for their system, which is an important strategy used in engineering design, taking into account sociocultural factors as well as technical. As another example for abstraction, students worked with the AutoCad drawing program typically used in engineering to create a map of a waste removal system in the engineering department.

Guest speakers from engineering, studio art, and educational psychology gave presentations to students, modeling ways of thinking and significant inquiry problems in their respective disciplines, as well as serving as consultants on the students' design challenge projects. In these ways, both art and engineering students experienced different ways of thinking and representing knowledge characteristic of each discipline, while also seeing the compatibility of the 13 thinking tools (Root-Bernstein & Root-Bernstein, 1999) across disciplinary boundaries.

At the end of the semester, samples of student work from class activities, reflections, and team design challenges were presented in an exhibition at the university's art school. The majority of the exhibition was made up of students' representations of the problem they framed in the form of an initiative to raise public awareness. Students used diverse media in their exhibition installations, including video, sculpture, photography, and printmaking. The final projects included a common element of design, but each group representation reflected a synthesis of content, tools, and thinking dispositions from both disciplines that resulted in something other than an art presentation or an engineering report, revealing instead a third space in what became an example of *transdisciplinary* curriculum that was a hybrid of content and ways of thinking characteristic for engineering and art.

Implications

With STEM curriculum emphasizing problem-based, inquiry-based, and hands-on learning (as in the Engineering/Art example discussed above), this creative inquiry model demonstrates a mutually engaged transdisciplinary approach for STEAM learning that intrinsically values the signature pedagogies of art and design education in synergistic relationship with one or more STEM disciplines. While promising, the effectiveness of this model needs further investigation through research on its application in diverse settings. Funding streams through the ESSA, such as the Student Support and Academic Enrichment grants, may provide opportunities for K–12 and higher education partnerships around STEAM curriculum implementation employing this model.

Funding

This material is based on work supported by the U.S. National Science Foundation under Grant No. 0837173. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

Beane, J. A. (1995). Curriculum integration and the disciplines of knowledge. *Phi Delta Kappan*, *76*(8), 616–212.

Beane, J. A. (1997). *Curriculum integration: Designing the core of democratic education*. New York, NY: Teachers College Press.

Bequette, J. W., & Bequette, M. B. (2012). A place for art and design education in the STEM conversation. *Art Education*, *65*(2), 40–47.

Brown, V. A., Harris, J. A., & Russell, J. Y. (2010). *Tackling wicked problems through the transdisciplinary imagination*. London, UK and Washington, DC: Earthscan.

Catterall, J. S. (2009). *Doing well and doing good by doing art: A 12-year national study of education in the visual and performing arts: Effects on the achievements and values of young adults*. Los Angeles, CA: Imagination Group/I-Group Books.

Costantino, T. (2015). Lessons from art and design education: The role of in-process critique in the creative inquiry process. *Psychology of Aesthetics, Creativity & the Arts*, *9*(2), 118–121.

Costantino, T., Guyotte, K., Kellam, N., & Walther, J. (2014). Seeing experiences of interdisciplinarity through student artwork: Exploring different approaches to analysis. *International Review of Qualitative Research*, *7*(2), 217–235.

Davis, J. R. (1995). *Interdisciplinary courses and team teaching: New arrangements for learning*. Phoenix, AZ: American Council on Education and the Oryx Press.

Dewey, J. (1934). *Art as experience*. New York, NY: Minton, Balch & Co.

Donald, J. G. (2009). The commons: Disciplinary and interdisciplinary encounters. In C. Kreber (Ed.), *The university and its disciplines: Teaching and learning within and beyond disciplinary boundaries* (pp. 35–49). New York, NY and London, UK: Routledge.

Eisner, E. W. (2002). *The arts and the creation of mind*. New Haven, CT: Yale University Press.

Guyotte, K. W., Sochacka, N. W., Costantino, T. E., Walther, J., & Kellam, N. (2014). Steam as social practice: Cultivating creativity in transdisciplinary spaces. *Art Education*, *67*(6), 12–19.

Hetland, L., Winner, E., Veneema, S., & Sheridan, K. M. (2013). *Studio thinking 2: The real benefits of visual arts education*. New York, NY: Teachers College Press.

Johnson, M. (2008). *The meaning of the body: Aesthetics of human understanding*. Chicago, IL: University of Chicago Press.

Kellam, N., Walther, J., Costantino, T., & Cramond, B. (2013). Integrating the engineering curriculum through the synthesis and design studio. *Advances in Engineering Education*, *3* (3), 256–270.

Kreber, C. (2009). The modern research university and its disciplines: The interplay between contextual and context-transcendent influences on teaching. In C. Kreber (Ed.), *The university and its disciplines: Teaching and learning within and beyond disciplinary boundaries* (pp. 19–31). New York, NY and London, UK: Routledge.

Lattuca, L. R. (2001). *Creating interdisciplinarity: Interdisciplinary research and teaching among college and university faculty*. Nashville, TN: Vanderbilt University Press.

Lattuca, L. R. (2002). Learning interdisciplinarity: Sociocultural perspectives on academic work. *The Journal of Higher Education*, *73*(6), 711–739.

Lattuca, L. R., Voigt, L. J., & Fath, K. Q. (2004). Does interdisciplinarity promote learning?: Theoretical support and researchable questions. *Review of Higher Education*, *28*(1), 23–48.

Maeda, J. (2013). STEM + Art = STEAM. *The STEAM Journal*, *1*(1), Article 34. doi:10.5642/steam.201301.34.

May, G. S. (2015, March 30). STEM, not STEAM. *Inside Higher Ed*. https://www.insidehighered.com/views/2015/03/30/essay-criticizes-idea-adding-arts-push-stem-education

Paris, S. G. (Ed.). (2002). *Perspectives on object-based learning in museums*. Mahwah, NJ: Lawrence Erlbaum.

Peppler, K. (2013). STEAM-powered computing education: Using e-textiles to integrate the arts and STEM. *Computer*, *9*, 38–43.

PBS Learning Media. (2015). *RISD STEAM lesson plans*. Retrieved from http://www.pbslearningmedia.org/collection/risd-steam.

Rolling, J. H. (2016). Reinventing the STEAM engine for art + design education. *Art Education*, *69*(4), 4–7.

Root-Bernstein, R. S., & Root-Bernstein, M. (1999). *Sparks of genius: The thirteen thinking tools of the world's most creative people*. Boston: Houghton Mifflin.

Shulman, L. S. (2005). Signature pedagogies in the professions. *Daedalus*, *2005*, 52–59.

Somerson, R., Hermano, M. L., & Maeda, J. (2013). *The art of critical making: Rhode Island School of Design on creative practice*. Hoboken, NJ: John Wiley & Sons.

Stem to Steam. (2017). *What is STEAM?* Retrieved from http://stemtosteam.org..

Walther, J., Kellam, N., Costantino, T., & Cramond, B. (2010). Integrative learning in a synthesis and design studio: A phenomenological inquiry. In *2010 IEEE Frontiers In Education Conference (FIE 2010)*. IEEE. doi:10.1109/FIE.2010.5673434