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## **Art and Science: Utilizing Steam Education to Promote Empathetic Scientific Literacy and Global Citizenship**

Ali Orsi Davis

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ART AND SCIENCE: UTILIZING STEAM EDUCATION TO PROMOTE EMPATHETIC  
SCIENTIFIC LITERACY AND GLOBAL CITIZENSHIP

by

ALI ORSI DAVIS

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SYNTHESIS\*

MASTER OF ARTS

CRITICAL AND CREATIVE THINKING

UNIVERSITY OF MASSACHUSETTS BOSTON

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Advisor: Robert Ricketts

\* The Synthesis can take a variety of forms, from a position paper to curriculum or professional development workshop to an original contribution in the creative arts or writing. The expectation is that students use their Synthesis to show how they have integrated knowledge, tools, experience, and support gained in the program so as to prepare themselves to be constructive, reflective agents of change in work, education, social movements, science, creative arts, or other endeavors.

## ABSTRACT

This research expounds on the history of, hurdles facing, and future goals and possibilities for STEAM (science, technology, engineering, art, mathematics) education, including how it can create empathetic, scientifically literate global citizens. Reasons for the cultivation of empathy, scientific literacy, and global citizenship in the classroom are numerous; escalating worldwide nationalism, accelerated climate change, and the increased need to address sustainable development and poverty have produced particular urgency for such student development. Science educators today rarely prioritize the “art” in STEAM education, despite a panoply of cognitive benefits including perspective-taking, critical thinking, and increased personal connection to scientific content. Development of such skills is needed to ensure that well-informed democratic participation and scientific innovation can be relied upon to create an equitable and sustainable future for the planet and humanity. In addition to providing an analysis of piloted STEAM lessons, this paper urges a more robust understanding of effective STEAM education, including explicit emphasis on art, in order to prepare humankind to confront our most pressing issues.

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Afloat in the darkness before my eyes, the watery planet blueely glows  
How strong is my affection for that ancient home of ours,  
how deep my gratitude for the gift of life  
Tomorrow, I will dare the blue sky and open up worlds unknown  
for there we have our dreams

-Wakata Koichi  
*Japan Aerospace Exploration Agency*  
*International Space Poem Chain*<sup>1</sup>

## Where We Find Ourselves Today

The Bahamas often conjure images of palm trees swaying before a bright blue sky, with perhaps some honeymooning figures, drinks in hand, silhouetted against the white sand. September 1, 2019, drew a different picture. Hurricane Dorian, unlike previous tropical storms, spared no force in making its unexpectedly damaging landfall. From afar, those who tried to bridge the paradisiacal images with the reality of the most powerful hurricane to hit the shores of the Atlantic were left with furrowed brows, murmuring “climate change.”

Later that month, the United Nations vocalized its own murmurs when US President Donald Trump addressed the General Assembly. To a panel deemed “the world’s only truly universal global organization [that] has become the foremost forum to address issues that transcend national boundaries and cannot be resolved by any one country acting alone,”<sup>2</sup> Trump proclaimed, “The future does not belong to globalists. The future belongs to patriots.”<sup>3</sup> These

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<sup>1</sup>“Space Poem Chain, Vol 3, ” JAXA Space Environment Utilization Center, JAXA Japan Aerospace Exploration Agency, published March 19, 2010, [https://iss.jaxa.jp/utiliz/renshi/index\\_e.html](https://iss.jaxa.jp/utiliz/renshi/index_e.html).

<sup>2</sup> “About the UN,” United Nations, accessed February 15, 2020, <https://www.un.org/en/about-un/>.

<sup>3</sup> “Remarks by President Trump to the 74th Session of the United Nations General Assembly,” The White House, published September 25, 2019, [https://www.whitehouse.gov/briefings-statements/remarks-president-trump-74th-session-united-nations-general-assembly/](https://www.whitehouse.gov/briefings-statements/remarks-president-trump-74th-session-74th-session-united-nations-general-assembly/).

words were spoken as energy giant Pacific Gas and Electric debated whether to shut off power to Californians in order to reduce the chance of sparking fires that had, for the previous two years, exposed Californians to “the largest, most destructive and deadliest blazes recorded in the state’s long history of wildfires.”<sup>4</sup> Unfortunately, the eventual termination of power did not provide immunity to the most catastrophic of the 2019 California fires, which were still a month away. Meanwhile, Mexico City was experiencing escalating perils of drought and overdrawing of groundwater, causing portions of the city to sink into the Earth.”<sup>5</sup>

This unexhaustive catalogue of economic, environmental, and political events plucked from a random month last year alludes to larger issues beyond North America and September 2019. One of the most laudable collaborations of scientists worldwide striving constantly to take global issues into account is the Intergovernmental Panel on Climate Change (IPCC). Established in 1988 by the United Nations Environment Programme and the World Meteorological Organization, the IPCC is consistently relied upon by governments, policymakers, and scientists alike to provide robust assessments regarding the state of “climate change, its impacts and future risks, and options for adaptation and mitigation.”<sup>6</sup> With 195 member countries, the IPCC does not produce its own research; rather, it relies on scrutinizing internationally peer-reviewed literature.<sup>7</sup> It is common for hundreds of scientists from upwards

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<sup>4</sup> Tim Arango, Jose A. Del, and Ivan Penn, “5 Lessons We Learned From the California Wildfires,” *New York Times*, November 4, 2019, <https://www.nytimes.com/2019/11/04/us/fires-california.html>.

<sup>5</sup> Somini Sengupta and Weiyi Cai, “A Quarter of Humanity Faces Looming Water Crises,” *New York Times*, August 6, 2019, <https://www.nytimes.com/interactive/2019/08/06/climate/world-water-stress.html>.

<sup>6</sup> “IPCC Factsheet: What is the IPCC?” IPCC Secretariat, Intergovernmental Panel on Climate Change, August 30, 2013, [https://atmos.washington.edu/~david/Overview\\_of\\_the\\_IPCC.pdf](https://atmos.washington.edu/~david/Overview_of_the_IPCC.pdf).

<sup>7</sup> IPCC Secretariat, “Factsheet.”

of 100 countries to contribute to published IPCC assessments, and when a publication occurs, it often demands attention. For example, according to the IPCC's 2018 report, we have less than ten years to prevent catastrophic climate change.<sup>8</sup>

If the IPCC's prediction, backed by hundreds of scientists, is correct, the sustainability and habitability of our planet rests not only with democratic participation in policy decisions, but also with tailored scientific innovation. Yet, add to this the continued friction between increasingly weaponized (including through cyber armaments) and hostile interactions between governments and it is no surprise the Bulletin of the Atomic Scientists, founded in 1945 and consisting of, among other board members, 13 Nobel laureates, claimed in January of this year that we are "100 seconds to midnight" on the Doomsday Clock. Their 2020 statement bares:

...over the last two years, we have seen influential leaders denigrate and discard the most effective methods for addressing complex threats—international agreements with strong verification regimes—in favor of their own narrow interests and domestic political gain. By undermining cooperative, science- and law-based approaches to managing the most urgent threats to humanity, these leaders have helped to create a situation that will, if unaddressed, lead to catastrophe, sooner rather than later.<sup>9</sup>

Nobel laureates are not the only advocates for the Bulletin of the Atomic Scientists' assessment. Awareness efforts spearheaded by former United Nations secretary-general Ban Ki-moon, former president of Ireland Mary Robinson, former governor of California Jerry Brown, and former US secretary of defense William J. Perry proclaim bluntly, "We are in humanity's moment of greatest peril."<sup>10</sup>

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<sup>8</sup> "Summary for Policymakers," in *Global Warming of 1.5°C*, ed. V. Masson-Delmotte et al. (IPCC, 2018).

<sup>9</sup> John Mecklin, "2020 Doomsday Clock Statement," Bulletin of the Atomic Scientists, published on January 23, 2020, <https://thebulletin.org/doomsday-clock/current-time/>.

<sup>10</sup> Ban Ki-Moon et al, "Why the World Is Closer than Ever to Doomsday," CNN Opinion, *CNN*, January 24, 2020, <https://www.cnn.com/2020/01/24/opinions/doomsday-clock-emergency-moon-robinson-brown-perry/index.html>.

As global leaders continue to espouse nationalistic sentiments, the opportunity for effective, collaborative problem solving for our future diminishes. If we are going to sincerely consider prioritizing any goals the IPCC has carefully chosen to declare—“strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty”<sup>11</sup>—we as a species need more than the ability to reiterate facts. If science is viewed and taught to current and future generations as a neutral, unemotional subject that remains out of context with global realities and limited by national interests, science education will be insufficient to alter humanity’s current debilitating trajectory. The scale of scientifically literate democratic participation and innovation needed to derail the “catastrophic” disaster predicted by the IPCC is considerably more than what presently exists because we have not synthesized solutions thus far. Yet the future still holds hope.

Currently this hope takes many shapes. Some insist a political administration or global alliance will ensure humanity’s stable future. Other pathways include a future “unicorn” or two from Silicon Valley. Instead, I propose an idea not reliant on political cohesiveness or Series A, B, and C funding. Through art, science teachers can promote accessible scientific understanding along with empathy to equip future generations with the ability to recognize, identify with, and solve issues threatening our planet’s future.

While often understated, the effect teachers have on the cultivation of student potential, and in turn our world’s future, is immense. The pinpointed IPCC goals highlighting climate change, sustainability, and poverty each require the public to become both versed in scientific knowledge and experienced in perspective-taking, or empathetically putting oneself in another’s

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<sup>11</sup> Masson-Delmotte, “Summary.”



shoes.<sup>1213</sup> Emphasizing art in conjunction with science is proven to enhance students' abilities in areas such as "conveying meaning through self-expression... verbal and non-verbal communication skills, openness to others' perceptions, understanding of sociocultural dynamics, self-understanding through reflection, communication skills, listening, interpretation, reasoning, and learning through feedback," all of which run counter to many of the current *modi operandi* seen in transnational accord withdrawals and policies driven by nationalism.<sup>14</sup> However, these vital educational results from transdisciplinary art and science implementation in the classroom are rarely prioritized.

With recent pedagogy shifts from STEM education (science, technology, engineering, and mathematics) to STEAM education (science, technology, engineering, art, and mathematics), a panoply of positive effects specifically regarding students' subjective understanding have already been observed.<sup>15</sup> Art, including "visual art, music, moving image, creative writing and performance,"<sup>16</sup> provides avenues for transcendent "ways of thinking"<sup>17</sup> about science and its relationship to the world, especially for those who "may not traditionally be interested"<sup>18</sup> or lack

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<sup>12</sup> Adam M. Grant and James W. Berry, "The Necessity of Others is the Mother of Invention: Intrinsic and Prosocial Motivations, Perspective Taking, and Creativity," *Academy of Management Journal* 54, no. 1 (2011): 73-96.

<sup>13</sup> Michelle D. Harwood and M. Jeffrey Farrar, "Conflicting Emotions: The Connection Between Affective Perspective Taking and Theory of Mind," *British Journal of Developmental Psychology* 24, no. 2 (2006): 401-418.

<sup>14</sup> Elaine Perignat and Jen Katz-Buonincontro, "STEAM in Practice and Research: An Integrative Literature Review," *Thinking Skills and Creativity* 31 (2019): 31-43.

<sup>15</sup> Perignat, "STEAM."

<sup>16</sup> Georgina Born and Andrew Barry, *Interdisciplinarity: Reconfigurations of the Social and Natural Sciences* (New York: Routledge, 2013), 253-254.

<sup>17</sup> Paul Glinkowski and Anne Bamford, "Insight and Exchange: An evaluation of the Wellcome Trust's Sciart programme," Wellcome Trust, Wellcome Trust, accessed February 8, 2020, [https://wellcome.ac.uk/sites/default/files/wtx057228\\_0.pdf](https://wellcome.ac.uk/sites/default/files/wtx057228_0.pdf).

<sup>18</sup> Born, "Interdisciplinarity," 253-254.

historical representation in STEM fields. Yet, efforts thus far to incorporate art into the transdisciplinary STEAM initiative do not go far enough to combat what lies in store for our future.

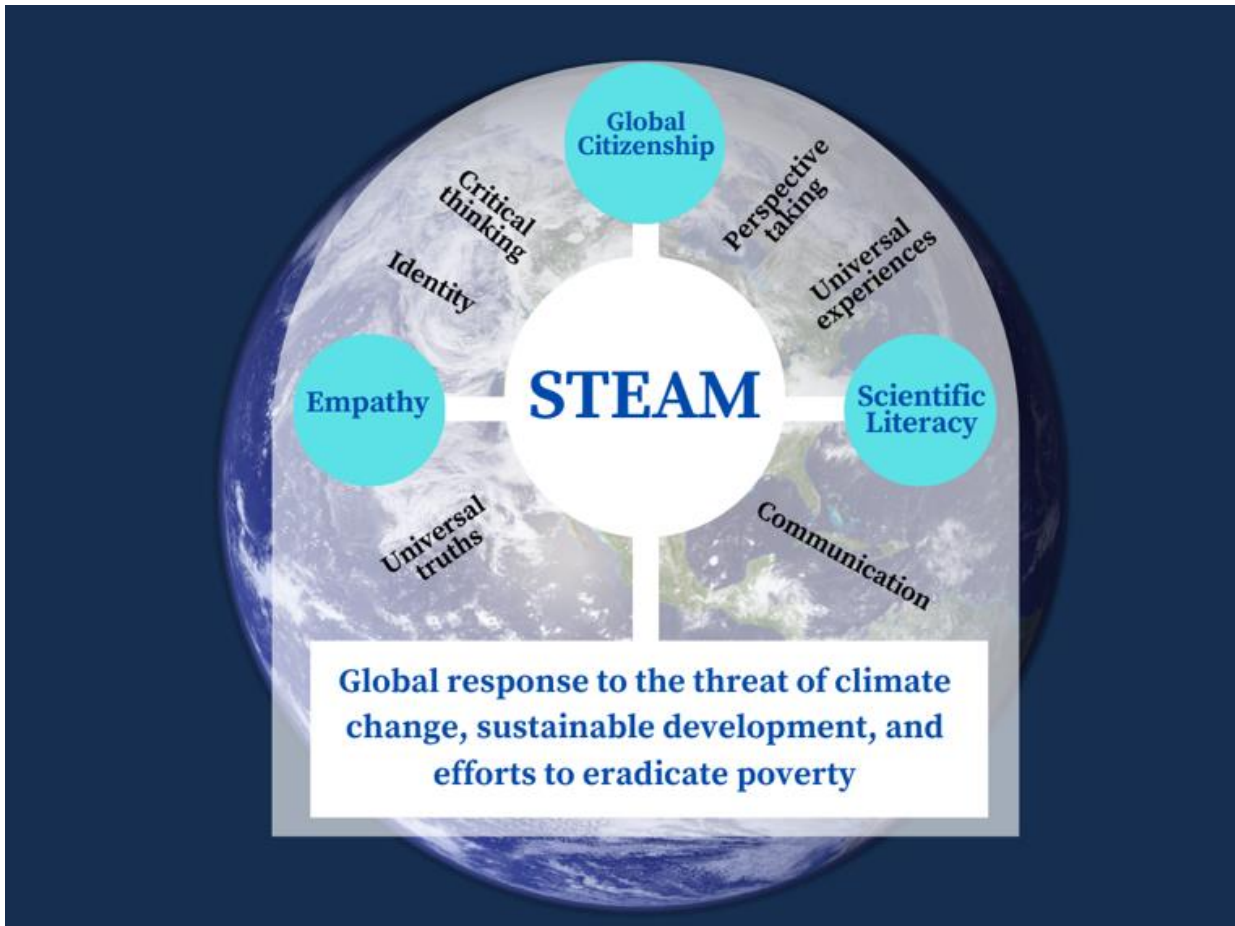


Figure 1: STEAM's interconnectedness with empathy, scientific literacy, and global citizenship.

This is not to say that efforts have been misaligned or ill-intentioned thus far in science education's trials to include art. Rather, the immense variety and vagueness in the definitions of and assumptions about art's role in STEAM education, compounded by educational policy initiatives placing value solely on formal assessment scores, has led to scattershot attempts to implement STEAM-centric learning. Furthermore, a lack of clearly-communicated STEAM success continues to fuel art's publicly-accepted inferior value when compared to science. Yet even with such hurdles, STEAM education holds the potential for an imperative global paradigm

shift. A more robust understanding of effective STEAM application in classrooms, including carefully crafted goals and assessment tactics, can prepare humankind to confront our most pressing issues surrounding climate change, poverty, and sustainable practices, by fostering empathetic scientific literacy and global citizenship.

## **When I Grow Up**

Dreams of becoming an astronaut fill the minds of many people taken with an early interest in science. Youngsters daydream about being the glory of a nation's engineering successes, their gleaming smile broadcast down to Earth after they cement their place in history by solving an impending crisis, saving both the crew and the mission. Apollo 13 screenplay aside, I was not one of those youngsters. Daily life or death scenarios where no one can hear you scream did not appeal to my desires as did careers offered on Earth. Perhaps it is all for the best; my eyesight has drifted far from the required 20/20 vision, and every year the county fair roller coasters become harder to stomach. Despite differing career choices and tolerance levels for nausea, I have come to realize I am more like many astronauts than I previously could have imagined. Over the past three decades, my experiences with science have shaped my mindset and settled it surprisingly close to that of many space travellers; I have become an advocate for a world that embraces global empathy and scientific literacy.

My academic upbringing in mostly California public school systems bred in me a view of science as objective fact. The formalities of the scientific method ran hard and fast through every assignment. After four years of university, I developed not only a growing allergy to laboratory mice, but also pride in my published cancer research regarding new possibilities in chemotherapy

treatments.<sup>19</sup> Such an undergraduate feat surely meant I was doing science “right.” So intense was my conviction that “sciences like mine” were superior to any other involving emotions, uncertainty, or “data” that couldn’t be programmed into Statistical Analysis System (SAS) software without subjective interpretation, that I found myself looking down on any research lacking in such quantitative methodology. “Hard science,”<sup>20</sup> in other words, was going to change the world in a streamlined, tangible, logical fashion while “soft”<sup>21</sup> sciences such as psychology, anthropology, and sociology were for those looking to spend their time talking amongst each other.<sup>22</sup>

In the time since then, I have embraced a gradual shift in my definition of science. Soon after leaving university, along with forgetting the minimal coding required to run SAS analyses, I entered the profession of teaching. This career had been a dream since my middle school years when I was a student of initiatives to highlight the new admixture that was then known as SMET (which was eventually reordered to STEM). To many potential US employers, I was branded a “highly qualified” science teacher, especially after a combined two years teaching abroad in Japan, Ecuador, and Nepal. My shallow belief-turned-sales pitch declaring “everyone can learn science” was all many wanted to hear. Yet a decade of time spent in a world so dissimilar to a sterile lab—notably for eight years at the elementary level—gave rise to new principles I now consider fundamental to science education.

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<sup>19</sup> Megan M. Freeland et al, “Sex Differences in Improved Efficacy of Doxorubicin Chemotherapy in Cbr1+/- mice,” *Anti-cancer drugs* 23, no. 6 (2012): 584-589.

<sup>20</sup> Norman W. Storer, “The Hard Sciences and the Soft: Some Sociological Observations,” *Bulletin of the Medical Library Association* 55, no. 1 (1967): 75.

<sup>21</sup> Keith Devlin, *Goodbye, Descartes: The End of Logic and the Search for a New Cosmology of the Mind* (New York: John Wiley & Sons, 1997), 281-283.

<sup>22</sup> “A Different Agenda,” *Nature* 487, 271 (2012), <https://doi.org/10.1038/487271a>.

In a nutshell, these new principles include a special emphasis on art in science. In my teaching career I have been fortunate to have been called “the science teacher” for 5,400 students. In contrast, an average American elementary teacher with 10 years of experience has likely taught around 300 students. Being responsible for every student’s science experience on four elementary campuses, and now in an eighth grade classroom, has given me special perspective for creating high-impact lessons designed for limited class time, and often with limited resources in mind. Alongside witnessing students’ blossoming science understanding came my own encounters with like-minded scholars whose work began to mirror both my experiences in the classroom and my hope for the future of education; from these coinciding developments came the following conclusions:

1. Science does not begin and end with value-free knowledge regurgitated from generations past and present.
2. Developing student understanding to a level where it can be communicated, critiqued, and applied is highly dependent on student connection with the information.
3. Our world is at an essential point in history where science has never had such a large platform nor such an urgent situation calling for a scientifically literate population to consider the sustainability of our planet.

With these propositions in mind, several areas of science education are in need of reconditioning. First, we must understand science as value-laden and inextricably linked to ethics. Next, student identities must be considered as a valuable piece of their ability to understand content. Finally, science education must emphasize humanity’s need for understanding and participating in the creation of a sustainable future, be it through scientific inventions or democratic participation in policy decisions. Art offers a pathway to address all of these evolutions to education by

encouraging intimate connections between the universal truths of science and the shared experiences of humanity.

## The Overview Effect

Just as I did not proceed down a career path bent on riding supercooled, flammable gasses into the unknown, I did not expect to discover such a comparable personal ethos to astronauts. The aforementioned conclusions surrounding art's essential role in science education took me over a decade to craft; and on the surface they seem incredibly specific to the teaching profession. Interestingly, ten years in a classroom may have a similar effect to ten minutes floating above Earth. Curiosity led me to ask why, over and over, it was astronaut voices out of all the scientific professions that appeared to advocate the loudest for increasing art in science to promote global empathy and sustainable innovation. The answer I found differed substantially from the conclusions drawn by most researchers who tout substantial benefits seen in art-inclusive transdisciplinary education. What sets astronauts apart from the majority of us is the overview effect.

Apollo 14's lunar module pilot Edgar Mitchell became the sixth man to walk on the moon in 1971. After his return, he told *People* magazine: "You develop an instant global consciousness, a people orientation, an intense dissatisfaction with the state of the world, and a compulsion to do something about it. From out there on the moon, international politics look so petty. You want to grab a politician by the scruff of the neck and drag him a quarter of a million miles out and say, 'Look at that, you son of a bitch.'"<sup>23</sup> Profanity aside, Mitchell's impassioned

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<sup>23</sup> "Edgar Mitchell's Strange Voyage," *People*, April 8, 1974, <https://people.com/archive/edgar-mitchells-strange-voyage-vol-1-no-6/>.

response embodies the phenomenon known as the overview effect. That is, experiencing firsthand the view of Earth’s position in space brings an unintentional understanding of our “fragile”<sup>24</sup> planet’s place both in the universe and in regard to its uniqueness therein. The Overview Institute explains the phenomenon further, stating, “From space, national boundaries vanish, the conflicts that divide people become less important, and the need to create a planetary society with the united will to protect this ‘pale blue dot’ becomes both obvious and imperative.”<sup>25</sup> Mitchell was later joined by other space explorers in efforts to convey a passionate call to action for global cohesiveness. Dr. Mae Jemison noted in 2002 that, “We have to know that we have a responsibility as global citizens in this world. We have to look at the education of humans...”<sup>26</sup> Here is where art comes in.

In taking these miraculous overview effect statements a step further, astronauts have repeatedly called upon art as a means to illustrate the necessity of empathetic and cohesive sentiments to those who have always remained on Earth. Convoy Commander Nicole Stott began the Space for Art Foundation upon retiring



Figure 2: Alan Bean, *Is Anyone Out There?* (2006) Acrylic, moondust, and moonprints on canvas, Alan Bean: *First Artist on Another World*, <https://www.alanbean.com/gallery2.cfm?id=2006-Is-Anyone-Out-There>.

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<sup>24</sup> “Declaration of Vision and Principles,” The Overview Institute, accessed March 12, 2020, <https://overviewinstitute.org/about-us/declaration-of-vision-and-principles/>.

<sup>25</sup> The Overview Institute, “Declaration.”

<sup>26</sup> Mae Jemison, “Teach Arts and Sciences Together,” filmed February 2002, TED video, 21:10, [https://www.ted.com/talks/mae\\_jemison\\_teach\\_arts\\_and\\_sciences\\_together](https://www.ted.com/talks/mae_jemison_teach_arts_and_sciences_together).

from NASA, and continues to act as founding director “to inspire creative thinking about solutions to our planetary challenges, to raise awareness of the surprising interplay between science and art, [and to] raise awareness of our role as crew members, not just passengers, on Spaceship Earth.”<sup>27</sup> Others, like the late Captain Alan Bean, became (perhaps obsessively) professional artists. Dean Robbins, a children’s author, writes:

Why didn't [Captain Bean] simply rest on his laurels as one of 12 humans to set foot on the lunar surface? I learned the answer while collaborating with him on the children's picture book ‘The Astronaut Who Painted the Moon: The True Story of Alan Bean.’ If science had sent people into space, Bean knew that art could best express how it felt to float around up there. It mattered that much to speak to a new generation—one that hadn’t followed Apollo 12 on a blurry black-and-white TV set... Bean went a step further to connect viewers with his experience of outer space. He sprinkled his paintings with dust from his astronaut gear, scarred them with lunar tools and even stamped them with heavy space boots. With these expressionist techniques, he rendered the moon—both the object and the idea—as no artist ever had. Bean pursued this taxing work to the end of his life.<sup>28</sup>

Other astronauts such as Jemison concur:

The sciences, to me, are manifestations of our attempt to express or share our understanding, our experience, to influence the universe external to ourselves. It doesn't rely on us as individuals. It's the universe, as experienced by everyone. The arts manifest our desire, our attempt to share or influence others through experiences that are peculiar to us as individuals. Let me say it again another way: science provides an understanding of a universal experience, and arts provide a universal understanding of a personal experience.<sup>29</sup>

If we are to ensure a sustainable future, humanity will need both the ability to understand universal experiences and communicate intimate, personal ones.

Today, it seems that much of our youth activist movement is bent around the principles of those who have experienced the overview effect. Yet there are problems that will require more than a Greta Thunburg–Mae Jemison task force. Even for those with a supportive stance on art’s

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<sup>27</sup> “Space For Art Foundation,” SpaceForArt, accessed April 8, 2020, <https://www.spaceforartfoundation.org/>.

<sup>28</sup> Dean Robbins, “Alan Bean: Astronaut with an Artist's Eye (Op-Ed),” *Space*, June 29, 2018, <https://www.space.com/41035-alan-bean-astronaut-with-artist-eye.html>.

<sup>29</sup> Jemison, “Teach Arts and Sciences Together.”



incorporation into science, persuasions often encounter questioning surrounding an expected “neutrality”<sup>30</sup> of educators. For some critics, “art–science, projects... risk an excessive moralism”<sup>31</sup> and are devised with specific political agendas in mind. However, “[art–science projects] amount to an experiment through which public, knowledge, and their relation [are] expected to emerge in a different form...”<sup>32</sup> So rather than creating a “liberal agenda,” sparking “emotional alarmism,” or inflicting what the American Psychological Association has newly diagnosed as “eco-anxiety”<sup>33</sup> with this project, I propose utilizing art as a pathway to connect empathy to science for the purpose of mitigating climate change, improving sustainable practices, and alleviating poverty.

Having spent 166 days in space, Colonel Chris Hadfield is one of the most experienced astronauts in the world.<sup>34</sup> In his book, he offers humble advice about his journey through education and his extraordinary career. He writes, “what really matters is not the value of what someone else assigns to a task but how I personally feel while performing it...”<sup>35</sup> In order to free ourselves from reliance on stagnant knowledge and policy handed to us, education needs to provide an empowering foundation with which students can derive actionable pathways for causes relevant to their identities and passions. Scientific literacy, otherwise known as “knowledge and understanding of scientific concepts and processes required for personal

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<sup>30</sup> Georgina Born and Andrew Barry, “Art-Science: From Public Understanding to Public Experiment,” *Journal of Cultural Economy* 3, no. 1 (2010): 103.

<sup>31</sup> Born, “Art-Science,” 103.

<sup>32</sup> Born, “Art-Science,” 115.

<sup>33</sup> Anna Kelly, “Eco-Anxiety at University: Student Experiences and Academic Perspectives on Cultivating Healthy Emotional Responses to the Climate Crisis,” *Independent Study Project (ISP) Collection* (2017): 1-4, accessed April 10, 2020, [https://digitalcollections.sit.edu/isp\\_collection/2642](https://digitalcollections.sit.edu/isp_collection/2642).

<sup>34</sup> Chris Hadfield, *An Astronaut's Guide to Life on Earth* (New York: Little, Brown and Company, 2013).

<sup>35</sup> Hadfield, *An Astronaut's Guide*, 279-280.

decision making, participation in civic and cultural affairs, and economic productivity,”<sup>36</sup> is the basis for this empowering foundation. Hadfield continues to state, “[I now] feel I have a personal obligation to be a good steward of our planet and educate others about what’s happening to it.”<sup>37</sup> If we are going to prioritize the stewardship of our planet, global citizens—who are aware of and understand “the wider world,... take an active role in their community, and work with others to make our planet more equal, fair, and sustainable,”<sup>38</sup> —will play an imperative role in our future.

The creation of a scientifically literate population has been on the US’s (and many other nations’) radar for decades. Ask any of the astronauts impressing upon us the significance of the overview effect to speak about the space race that launched them into the interstellar arena in the first place. The US Department of Education, as well as the majority of other nations’ educational programs, largely treats the sciences as objective subjects.<sup>39</sup> Art, identity-driven interpretations, and self-expression do not fit within these programs’ connotations of science. This philosophy has led to many space explorers being ridiculed upon their return to Earth; when asked to describe their impression of Earth from space, “their attempts fell back onto bland, empty adjectives such as ‘beautiful’ and ‘fantastic.’”<sup>40</sup> Upon return to Earth, reflection-laden Major General Michael Collins of Apollo 11 confessed: “We weren’t trained to emote, we were

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<sup>36</sup> National Research Council, "Principles and Definitions," National Science Education Standards, The National Academies Press, accessed March 19, 2020. <https://www.nap.edu/read/4962/chapter/4>.

<sup>37</sup> Hadfield, *An Astronaut's Guide*, 278.

<sup>38</sup> “What is Global Citizenship,” Oxfam Education, Oxfam, accessed April 19, 2020, <https://www.oxfam.org.uk/education/who-we-are/what-is-global-citizenship>.

<sup>39</sup> US Department of Education, “Secretary’s Final Supplemental Priorities and Definitions for Discretionary Grant Programs,” Federal Register 83, no. 42 (March 2, 2018): 9096-9097, <https://www.govinfo.gov/content/pkg/FR-2018-03-02/pdf/2018-04291.pdf>.

<sup>40</sup> Lauren Fuge, “Why we need to send artists into space,” *Cosmos Magazine*, September 24, 2018, <https://cosmosmagazine.com/space/why-we-need-to-send-artists-into-space>.

trained to repress our emotions... If they wanted an emotional press conference ... they should have put together an Apollo crew of a philosopher, a priest, and a poet.”<sup>41</sup> Though the stammering of dazed and speechless astronauts gave the media cause to joke about their self-expression abilities, the lack of inter- and intra-personal investigations in science has been a devastating missed opportunity to promote the need for a collaborative world. We have been so fragmented in the development of our own and of our entire species’ relationship with science that those who have been perhaps most privileged in their life experiences are left incapacitated once forced to fuse their human emotions with what science can offer humanity. Our response to future global issues cannot continue to mimic the dumbstruck astronaut returning to Earth, which forces only a temporary reckoning between science’s offerings and humankind’s spirit. Our approach must be constant, consistent, and thoughtful. Training students to emote both in relation to science and the world around them via art integration in science is a unique opportunity to ensure our most pressing issues will be met with both scientific literacy and the empathy of global citizens.

## **Educational Vacillations in STEM and STEAM**

Art aside for a moment, collaborative and transdisciplinary approaches to teaching science have seen some success in recent educational policies. January 2020 brought young entrepreneurs out in full force across the US, each one ready to take aim at grown-ups’ New Year’s resolutions. Besides pushing cookies, the 2.5 million members of the Girl Scouts of the United States of America build “girls of courage, confidence, and character, who make the world

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<sup>41</sup> Michael Collins, *Carrying the Fire: An Astronaut’s Journey* (New York: Rowman & Littlefield, 2001), 54.

a better place.”<sup>42</sup> Perhaps indicating the ubiquity of STEM within the public’s knowledge is its inclusion on Girl Scout Cookie boxes.<sup>43</sup> Placing faith in STEM as a selling point for Girl Scout cookies without an explanation for the acronym illuminates the positive stance the US has adopted on the transdisciplinary approach to science education. Since its launch by the National Science Foundation (NSF) nearly 20 years ago, STEM now needs no introduction. Yet in the 13 years since STEAM’s inception, art’s addition to the acronym has failed to adorn any non-perishable baked goods.

For those constantly plotting educational reform, earning the celebrity status of programs such as 2001’s STEM and 2002’s No Child Left Behind Act (NCLB) is a fantasy even less attainable than sticking to a New Year’s resolution diet. Perhaps it is no surprise that much of the aforementioned programs’ fame was driven by a national “concern that the American education system was no longer internationally competitive”<sup>44</sup> despite the US’s desire “to maintain global economic dominance.”<sup>45</sup> For both NCLB and STEM, much of the educational program design was:

heralded as a solution or preventative measure to avoid economic downturns in the future, such as the Global Financial Crisis; however the basis for these assumptions does not appear to be based on any hard research, rather conjecture and speculation by political think-tanks. In the US and the UK during the early 2000s, uncoordinated STEM projects burgeoned and large amounts of money were spent. The somewhat naïve reasoning behind this was that in order to increase the pool of engineers and scientists, and to maintain global economic dominance, the spotlight must be focused upon improving education in the disciplines of science, technology, engineering, and

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<sup>42</sup> “Who We Are - Girl Scouts,” Girl Scouts of the USA, accessed February 8, 2020, <https://www.girlscouts.org/en/about-girl-scouts/who-we-are.html>.

<sup>43</sup> See Figure A, Appendix.

<sup>44</sup> Alyson Klein, “No Child Left Behind Overview: Definitions, Requirements, Criticisms, and More,” *Education Week*, April 10, 2015, <https://www.edweek.org/ew/section/multimedia/no-child-left-behind-overview-definition-summary.html>.

<sup>45</sup> Susan Blackley and Jennifer Howell, “A STEM Narrative: 15 Years in the Making,” *Australian Journal of Teacher Education* 40, no. 7 (2015): 110.

mathematics: S.T.E.M. As such, it was developed from a rationale that was non-educational, and then foisted upon educators to enact.<sup>46</sup>

Such reforms meant to bolster US student proficiency and upend depressed reserves of American scientists and engineers caused reverberations in the education community still felt today. Until 2015, results from NCLB's high-stakes student testing could result in the closing or state-takeover of a school should students not meet proficiency standards.<sup>47</sup> With these tests still carrying immense weight on both teachers' reputations and school districts as a whole despite the reprieve of remaining an operating school, "certain subjects are being emphasized to the exclusion and detriment of others."<sup>48</sup> In particular, art instruction has been described by hundreds of schools as "threatened"<sup>49</sup> with "signs of deterioration" and an ultimately "weaker status"<sup>50</sup> than prior to 2002.

Yet NCLB and STEM were not in fact the first iterations of such a push for improving US student performance. The US Department of Education began an "excellence in education"<sup>51</sup> movement in 1983 with a set of goals incredibly similar to that of NCLB and STEM. Program intent was centered around "improving the quality and status of education in the United States in a threatening and increasingly competitive global community."<sup>52</sup> During the "excellence in education" decade, educators "witnessed the demise of behaviorism and the ascent of cognitive

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<sup>46</sup> Blackley, "A STEM Narrative," 103.

<sup>47</sup> Klein, "No Child Left Behind."

<sup>48</sup> Julian Vasquez Heilig, Heather Cole, and Angélica Aguilar, "From Dewey to No Child Left Behind: The Evolution and Devolution of Public Arts Education," *Arts Education Policy Review* 111, no. 4 (2010): 136-145.

<sup>49</sup> Cydney Spohn, "Teacher Perspectives on No Child Left Behind and Arts Education: A Case Study," *Arts Education Policy Review* 109, no. 4 (2008): 3-12.

<sup>50</sup> Klein, "No Child Left Behind."

<sup>51</sup> Delacruz, "The Evolution," 67.

<sup>52</sup> Delacruz, "The Evolution," 67.

science in American public education.”<sup>53</sup> From this example, the degradation of US arts education that followed NCLB and STEM should have been predicted.

We can follow such reform vacillations back to 1912 when the Girl Scouts were founded, and we will find much of the same cyclical repetitions simply with different names. What inevitably followed NCLB, the “excellence in education” movement, and many other previous programs was a secondary reform, usually five years after a test-performance push, which swung the pendulum of educational priorities in the opposite direction. In all cases, reminders of “schools as public institutions [having] students with different learning styles and diverse cultural and ethnic backgrounds”<sup>54</sup> led to the slow dispersal of nationalistic government reforms bent solely on improving test scores.

Yet recently, with diminishing interest in NCLB’s nationwide testing and gradual efforts to resuscitate art programs across school sites, STEAM’s pendulum swing was noticeable, just not strong enough to knock another letter onto cookie boxes. In 2007, The Americans for the Arts’ National Roundtable discussion generated a well-intended program broadening to STEAM from STEM.<sup>55</sup> Since then, most interpretations of STEAM’s purpose in education have fallen into two categories. Firstly, art’s incorporation into the sciences allows for an emphasis on “the importance of advancing learning in STEM disciplines [for] minority and female students in STEM subjects, increasing interest in STEM fields, and developing skills necessary for STEM careers.”<sup>56</sup> Additionally, STEAM brings to light art’s ability to integrate “perspective-taking, creative and problem-solving skills, knowledge transfer across disciplines, and... [an exploration

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<sup>53</sup> Delacruz, “The Evolution,” 68.

<sup>54</sup> Delacruz, “The Evolution,” 68.

<sup>55</sup> Perignat, “STEAM,” 31.

<sup>56</sup> Perignat, “STEAM,” 34.

of] new ways of knowing”<sup>57</sup> with the sciences. Such inter- and intra-personal educational goals coming from NCLB repercussions make the 2002 reform seem almost worthwhile.

## Stealing STEAM’s Spotlight

While goals and reasonings for expanding STEM to STEAM include the deepening of surface-level factual knowledge often measured on standardized tests, art’s integration into the sciences has come up against additional barriers that tend to distract from those goals.

Firstly, such a transdisciplinary approach to studies is nothing new; yet it is a history that is often forgotten. In the past, we have seen an ebb and flow of acceptance for such intertwining of art and science, with a smattering of artist–scientists often being embraced when their notoriety in one specific arena reaches celebrity. Leonardo da Vinci, one of the most well-known artists in history, was revered for his ability to combine scientific observation with expressive artwork. Other artist–scientists include Archimedes, Santiago Ramon y Cajal, Hedy LaMarr, Beatrix Potter, Benjamin Franklin, Su Song, and Samuel Morse. Lauded Stanford University professor Dr. Keith Devlin, even while not referencing STEAM methodologies as they were after the time of his publication, eloquently portrays the benefits of combining scientific thinking with all genres of study:

In real life, who best understands a flower?... The painter who captures its subtleties on canvas?... The mathematician who writes down equations that describe the flower’s symmetry?... In terms of understanding an aspect of our world, the more ways we have to understand a flower, the greater will be that understanding. The poet or the painter who remains ignorant of chemistry, biology, and mathematics is as deprived in his or her vision and understanding of the flower as the scientist who is blind to the flower’s beauty.<sup>58</sup>

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<sup>57</sup> Perignat, “STEAM,” 34.

<sup>58</sup> Devlin, *Goodbye, Descartes*, 281.

In theory, a cohesive bridge between art-inspired, identity-driven cognitive development and the complexities waiting to be discovered and applied in science would be ideal. Yet today many people strive to convey science as value-free and objective. Such notes of “subtleties” and “beauty” do not register as appropriate. Most of my career has been in school districts surrounding Silicon Valley; such districts are not the only ones that view “hard sciences” as more valuable to a student’s future than “soft subjects” such as art and design, communication studies, drama/theatre studies, film studies, home economics, media studies, music, psychology, sociology, [and] sports studies/physical education.<sup>59</sup> Full STEAM implementation has unfortunately suffered from art’s susceptibility to be seen as lacking applicability for direct “readiness for college”<sup>60</sup> in many cases. Arts are not seen as “serious”<sup>61</sup> investments in student education, especially as age increases. Too often “public perceptions of artists are often limited to the stuff of legend—the solitary starving artist living in a squalid garret, the mad Van Gogh severing his ear.”<sup>62</sup> Moreover, communities commonly interpret the subject of science as “... finished or complete, and as needing only to be communicated [or] understood.”<sup>63</sup> If, as scholars claim, such habitual practices in understanding scientific thinking “have probably [approached] the limits of the traditional framework,”<sup>64</sup> future generations will not be able to make the leap

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<sup>59</sup> Anna Fazackerley and Julian Chant, “The Hard Truth About ‘Soft’ Subjects,” *Policy Exchange*, November 30, 2008, <https://www.policyexchange.org.uk/wp-content/uploads/2016/09/the-hard-truth-about-soft-subjects-dec-08.pdf>.

<sup>60</sup> Julia Marshall, “A Systems View: The Role of Art in Education,” *Art Education* 69, no. 3 (2016): 12-19.

<sup>61</sup> Fazackerley, “The Hard Truth.”

<sup>62</sup> Larry Chatman, “A Bright Future Awaits Minorities in Art Education,” *Art Education* 46, no. 4 (1993): 21.

<sup>63</sup> Born, “Art-Science,” 105.

<sup>64</sup> Devlin, *Goodbye, Descartes*, 283.



from generic tools of understanding to the innovation and empathy we need for humanity's sustainability.

With the assumption that science is currently a finished package awaiting consumption, we are at best giving students basic tools to build their future without the means to apply or communicate future developments in a way that is meaningful to the student's identity and the world at large. Content expected to be learned in a dictatorial fashion, even that associated with transdisciplinary STEM content, "cannot be felt by the pupil as a real problem and a personal problem."<sup>65</sup> Personal, empathetic ties to the creation of scientific innovation and associated policy implementations within communities need to be at the forefront of STEAM goals if we are going to produce significant global advancements.

In particular, minority students, who are continually underrepresented in all STEM fields, especially computer science, are markedly prone to discordance with pervasive Eurocentric content and teaching methods void of experiences that validate their identities and abilities.<sup>66,67</sup> Educators can do better, yet our continued foci tend to center around anything but addressing our globe's most urgent issues, let alone doing so with scientific literacy that is enmeshed with empathetic global citizenship.

Recently, the Next Generation Science Standards (NGSS) have received much attention throughout the US. Such standards dictate the science content students learn and are subsequently tested on. Their rather seamless approach to include all of STEM's subject strains

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<sup>65</sup> Diane Ravitch, *Left Back: A Century of Battles Over School Reform* (New York: Simon and Schuster, 2001), 177.

<sup>66</sup> Jane Margolis, *Stuck in the Shallow End: Education, Race, and Computing* (Cambridge: MIT Press, 2010), 63-86.

<sup>67</sup> "Science, Technology, Engineering, and Math, Including Computer Science," US Department of Education, accessed February 15, 2019. <https://www.ed.gov/stem>.

has been met with much applause from US educators.<sup>68</sup> Since NGSS's rollout in 2013, professional development opportunities for science teachers are often myopically centered around NGSS, and therefore STEM, content.<sup>69</sup> In one resource-strapped district where I spent six years teaching, the single professional development offering I received was for an NGSS conference. However, within these NGSS standards that drive science educators' foci, there still remain no art integration efforts even though most science teachers today are aware of the well-intentioned goals of STEAM. It would be no surprise to them to read transdisciplinary art advocate Dr. Julia Marshall's claim that:

[A]rt... represents a deep probing inquiry that looks critically at ideas and issues. Furthermore, it investigates the broader implications of images by making connections and crossing disciplinary boundaries—juxtaposing forms and ideas from areas outside of art to reframe them in a critical light. Above all... art often constructs connections that are surprising and novel—bringing the viewer to new insights and new knowledge. In this way, it is particularly educative. [Arts] are equally driven by ideas and, because they self-consciously focus on the ways ideas are represented, they make the concept-driven character of these images even more explicit.<sup>70</sup>

These research-based observations speaking to the opportunities offered for “insights” and “critical” thinking may as well be checked straight off a list for next generation scientific learning goals. The issue is not with teachers buying into currently touted benefits of STEAM despite NGSS standards omitting art. Schools, down to preschool level, have been funneling money into STEAM programs, with even the most resource-strapped districts braggadociously

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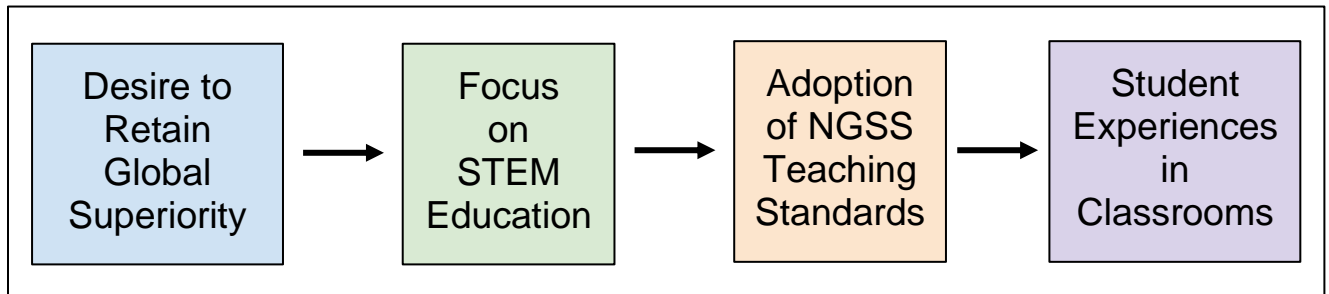
<sup>68</sup> “Implementation of the CA NGSS,” California Department of Education, December 31, 2019, <https://www.cde.ca.gov/pd/ca/sc/ngssintrod.asp>.

<sup>69</sup> “Implementation of the CA NGSS.”

<sup>70</sup> Julia Marshall, “Articulate Images: Bringing the Pictures of Science and Natural History into the Art Curriculum,” *Studies in Art Education* 45, no. 2 (2004): 135-152.

listing such offerings at part of their commitment to twenty-first century science education.<sup>71,72</sup>

Buy-in for STEAM, in my experience, has been extensive at all levels.



*Figure 3: Factors contributing to students' science experiences in US classrooms*

Yet unlike NGSS, there is no clear-cut, standards-based format for educators to follow regarding art's incorporation into science. A basic understanding of how and to what effect art is able to expand science can, between two science teachers, be as different as night and day. Even the definition of "art" can range from "any non-STEM discipline [to] a synonym for project-based learning, problem-based learning, technology-based learning, or making."<sup>73</sup> In interviews with an entire science department at a Bay Area middle school, qualifying reasons for art incorporation included giving students "a variety of activities," assisting "English language learners," and "being good for kids who are artistic."<sup>74</sup> Current practices result in a lot of "poster-

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<sup>71</sup> ENGIE Services U.S., "Hayward Unified School District Launches Sustainable Energy Program Across 33 Sites," November 15, 2019, <https://www.prnewswire.com/news-releases/hayward-unified-school-district-launches-sustainable-energy-program-across-33-sites-to-save-65-million-in-energy-costs-300959399.html>.

<sup>72</sup> "STEM & STEAM," Newark Unified School District, accessed October 20, 2019, <https://www.newarkunified.org/about/stem-steam/>.

<sup>73</sup> Perignat, "STEAM," 32.

<sup>74</sup> Hart Middle School Science Department, personal interview, November 1, 2019.

<b>Educator Group Grade Level</b>	<b>What benefits do you think art can have if incorporated into science curriculum?</b>	<b>What are some examples of ways art can be used in science?</b>
<b>6th grade</b>	Students who are artistic know there is a place for their skills in science; Increased communication of ideas	Artistic observations
<b>7th grade</b>	Variety in activity type	Drawings and modellings
<b>8th grade</b>	Visual art can be referred to during lessons; Helpful for English language learners/special needs students	Poster-making

Figure 4: Bay Area middle school science department interview results regarding STEAM implementation

making” and “drawings and modellings.”<sup>75</sup> These shallow, scattershot responses are, in my opinion, quite typical of science educators implementing STEAM practices, and would fare well under typical administrative scrutiny.

It is also vital to note that common poster-making efforts fail to cultivate the majority of STEAM’s benefits for certain students more than others. In particular, minority students often find themselves underrepresented in STEAM curricular content and career fields; STEAM fields are not immune to the male- and Eurocentric curricular content which pervades much of the American education system.<sup>76,77</sup> If art is not incorporated into STEAM practices in a manner that is intentional, reflective, and inquiry-driven, “vast segments of our society are excluded,”<sup>78</sup> and

<sup>75</sup> Hart, personal interview.

<sup>76</sup> Angela Saini, *Inferior: How Science got Women Wrong and the New Research That’s Rewriting the Story* (Boston: Beacon Press, 2017).

<sup>77</sup> Chatman, “A Bright Future,” 21-24.

<sup>78</sup> Chatman, “A Bright Future,” 24.

those who are excluded are not the only ones hurt. No matter the ways in which students identify, and especially for those who are historically marginalized within the sciences, current STEAM tactics and efforts are continually failing to craft opportunities for “deep probing inquiries” and “novel”<sup>79</sup> discoveries necessary to identify and address threats to our globe’s sustainability.<sup>80</sup>

<b>Factors Inhibiting STEAM Development</b>
<ol style="list-style-type: none"><li>1. Lack of coordination in STEAM implementation and assessment</li><li>2. Overbearing, high-stakes testing</li><li>3. Public value and connotations about sciences</li></ol>

Figure 5: Factors inhibiting STEAM development in US schools

## **Global Vacillations in STEAM’s Purpose**

The combination of a nationwide nonchalance towards aiding others, a vast array of STEAM interpretations, common connotations surrounding “hard sciences,” and teacher-centric pedagogies fixated on high-stakes testing have resulted in a clear message: science education’s current proceedings will not sufficiently equip humanity in the creation of a sustainable future. Content knowledge that is force-fed at face value and shakily absorbed through teacher-centric lessons creates a nation dependent on authority figures and devoid of innovative critical thinking skills.

Even within the handful of months encompassing the short timeline of this synthesis project, increasingly dire threats to humanity and the globe continue to surface. The current COVID-19 pandemic serves as just one more example of the need for global empathy in

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<sup>79</sup> Marshall, “Articulate images,” 151.

<sup>80</sup> Angela Saini, *Superior: The Return of Race Science*, (Boston: Beacon Press, 2019), 12.

conjunction with scientific literacy. However, the US’s intentional severance from international cooperation efforts—from “massive tariffs on more than \$500 billion” in goods, to “unprecedented action to stop the flow of... immigration,”<sup>81</sup> to withdrawal from the Paris Climate Agreement, to the suspension of “all funding to the WHO [World Health Organization]”<sup>82</sup>—mirrors the empathetic connections voided in the process of keeping science value-free. Such failure to strive for perspective-taking and common ground eliminates the potential to integrate valuable knowledge and collaboration responsible for deepening understanding and sustainable engagement with the world.

As mentioned previously, President Trump’s 2019 United Nations address proclaimed disinterest in assisting any nation other than the US. To the General Assembly, President Trump declared, “...we in the United States have embarked on an exciting program of national renewal. In everything we do, we are focused on empowering the dreams and aspirations of our citizens.”<sup>83</sup> Proponents of STEM and STEAM increasingly use “American-born,” “American citizens,” “America’s place,”<sup>84</sup> “American economy,” “global competitiveness,”<sup>85</sup> and “global elite”<sup>86</sup> as thematic in their advocacy for science education. With similar values vocalized by globally-influential administrations, previous avenues and values of collaborative innovation for global, sustainable progress are fading.

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<sup>81</sup> “Remarks by President Trump.”

<sup>82</sup> “President Donald J. Trump Is Demanding Accountability From the World Health Organization,” The White House, published April 15, 2020, <https://www.whitehouse.gov/briefings-statements/president-donald-j-trump-demanding-accountability-world-health-organization/>.

<sup>83</sup> “Remarks by President Trump.”

<sup>84</sup> Michelle H. Land, “Full STEAM Ahead: The Benefits of Integrating the Arts into STEM,” *Procedia Computer Science* 20 (2013): 547-552.

<sup>85</sup> US Department of Education, “Secretary’s Final.”

<sup>86</sup> Mark Wolfmeyer and John Lupinacci, “(Re) Considering STEM Education: Interrupting an Omnipresent Discourse,” *Critical Education* 8, no. 15 (2017): 1.

In addition to the public’s increased exposure to the prejudices of nationalism, “there is a strong prima facie case for the existence of a link between public understanding of science and national prosperity.”<sup>87</sup> With terms like “global competitiveness” and “American economy” spurring support for art-induced creativity leading to innovation in science, many proponents envision the end result of STEAM education to be American-made, innovative marvels that will directly benefit the US.<sup>88</sup> Hesitancy for expanding STEAM’s purpose to benefit the globe is further compounded by the (so-called) distress of several flagship organizations such as the one responsible for documenting the overview effect.<sup>89,90</sup> NASA (National Aeronautics and Space Administration) has been deemed in danger of becoming less globally influential and reliant on participants educated outside the US.<sup>91,92</sup> Some argue this diversification points to further evidence of an undesired loosening of US power in the global arena.<sup>93</sup> This is no space race pitting nuclear Cold War countries against one another. The urgency of global sustainability matters has thus far manifested itself in the US as a threat to American pride, as well as increased how imperative it is to retain our place as a world superpower. Therein lies a tremendous parallel topic: the need to reframe what the title “global superpower” entails. Currently, everything from military might to technological advances to pop culture makes the US an enviable nation. Yet as STEAM continues to be scantily implemented, the expectation of students’ art-cultivated

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<sup>87</sup> Born, “Art-Science,” 108.

<sup>88</sup> Land, “Full STEAM Ahead,” 547-548.

<sup>89</sup> Land, “Full STEAM Ahead,” 548.

<sup>90</sup> Kevin W. Gerrity, “No Child Left Behind: Determining the Impact of Policy on Music Education in Ohio,” *Bulletin of the Council for Research in Music Education* 179 (2009): 79-93.

<sup>91</sup> Land, “Full STEAM Ahead,” 548.

<sup>92</sup> Gerrity, “No Child,” 81.

<sup>93</sup> Land, “Full STEAM Ahead,” 548.

“innovative spirit and drive to advance [solely] the United States forward”<sup>94</sup> is far from an appropriate goal.

By no means is STEAM’s potential to advance the US a pursuit that should be abandoned. Yet it is important to realize that nationalistic assumptions are engraining themselves deeper into the public consciousness as we find ourselves in what some call our time of greatest peril. The many dedicated scholars who continually tout art’s ability to launch the US “full STEAM ahead” do indeed expound on valuable tactics for student learning and science application; but they are all at a scale too small and too narrow-minded for what the globe has incurred in the past, is experiencing at present, and what organizations such as the IPCC have predicted for our future. With issues as encompassing as the continued sustainability of the globe—from addressing worldwide pandemics, to mitigating climate change and its effects, to eradicating poverty—we will need all resources available, not just those of a single nation bent on competing against others. Poverty-fueled “growing inequality... is detrimental to economic growth and undermines social cohesion, increasing political and social tensions and, in some circumstances, driving [global] instability and conflicts.”<sup>95</sup> This inequality continues to flourish today, whether it be disproportionate suffering from health crises as seen with vulnerable and minority populations during the COVID-19 pandemic,<sup>96</sup> or with “persons displaced in the

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<sup>94</sup> Land, “Full STEAM Ahead,” 547.

<sup>95</sup> “No Poverty: Why It Matters,” United Nations Sustainable Goals, United Nations, accessed March 20, 2020, <https://www.un.org/sustainabledevelopment/wp-content/uploads/2016/08/1.pdf>.

<sup>96</sup> Associated Press, “Outcry Over Racial Data Grows as Virus Slams Black Americans,” *New York Times*, April 8, 2020, <https://www.nytimes.com/aponline/2020/04/08/us/ap-us-virus-outbreak-race.html>.



context of disasters and climate change”<sup>97</sup> at the rate of “one person every two seconds.”<sup>98</sup> It is reasonable, therefore, that with such optimistic expectations of procuring deep inquiries and innovative connections in conjunction with perspective-taking in the realm of science, STEAM’s purpose should be shifted from a nationalistic one to address the IPCC’s goals of “strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.”<sup>99</sup> Or, to use the words of Albert Einstein, “We shall require a substantially new manner of thinking if [hu]mankind is to survive.”<sup>100</sup>

In broadening the timeline of this paper to include historical lessons prior to the IPCC’s founding in 1988, the need for worldwide collaboration and empathy remains in the spotlight. The “many bloody chapters in the history of mankind [each begin] when groups of people and nations begin to regard each other as enemies. In time, each side considers the opposition to be evil incarnate... history has unfortunately far too many examples of this philosophy’s self-fertilizing effect.”<sup>101</sup> Such reflections burgeon from the 1985 Nobel Peace Prize acceptance speech given by the International Physicians for the Prevention of Nuclear War. The group continued to stress that “discussions and actions [need to] be raised out of ideological blind alleys.”<sup>102</sup> Publications post-STEAM inception have shown art “... transcend[s] scientific, and more precisely, disciplinary perspectives, creating a ‘third space’ in which existing knowledge,

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<sup>97</sup> “Climate Change and Disaster Displacement,” UNHCR, UN Refugee Agency, accessed March 30, 2020, <https://www.unhcr.org/en-us/climate-change-and-disasters.html>.

<sup>98</sup> “Figures at a Glance,” UNHCR, UN Refugee Agency, accessed March 30, 2020, <https://www.unhcr.org/en-us/figures-at-a-glance.html>.

<sup>99</sup> Masson-Delmotte, “Summary.”

<sup>100</sup> “Award Ceremony Speech,” NobelPrize.org, Nobel Media, accessed March 1, 2020, <https://www.nobelprize.org/prizes/peace/1985/ceremony-speech/>.

<sup>101</sup> “Award Ceremony Speech.”

<sup>102</sup> “Award Ceremony Speech.”

discourses and practices are challenged... From a system perspective, an artistic intervention can be interpreted as a strategy to enable nonconformity, which science has a particular need of because it relies on innovation.”<sup>103</sup> In other words, art’s incorporation into science allows for individualized understanding, empathy, and critical thinking that transcend traditional educational practices by encouraging novel connections to stem from unconventional methods, lifting humankind out of ideological silos. It seems then, with all barriers considered—those muffling STEAM’s potential with vacillations in the realm of educational reform, and those dripping in narrow, nationalistic undertones—STEAM’s current purpose of emphasizing science learning along with perspective-taking, problem-solving, and experiencing new ways of thinking is just the beginning of what this paradigm has to offer.<sup>104</sup>

## **STEAM Enacted**

Teaching new ways of thinking to address the pressures associated with humankind’s survival is far from a refined process in my classroom. For the longest time, I struggled to put my finger on why the applauded switch from STEM to STEAM seemed to fall short of its envisioned potential inside and outside of my lessons. Yes, the overbearing testing, community pressures surrounding “hard science,” and uneven classroom implementation unquestioningly contribute to STEAM’s shortfalls. But outside of those hurdles identified in my ten years of teaching, scholars Elaine Perignat and Dr. Jen Katz-Buonincontro additionally point to cavernous discordances additionally plaguing the majority of STEAM education publications.

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<sup>103</sup> Lizzie Muller, Lynn Froggett, and Jill Bennett, “Emergent Knowledge in the Third Space of Art-Science,” *Leonardo* 53, no. 3 (2018): 321.

<sup>104</sup> Perignat, “STEAM,” 40.

As of 2018, 44 English-language STEAM-specific, peer-reviewed publications all agree that the “impetus for integrating the arts into STEM was to enhance students’ creativity, problem-solving skills, and engagement and interest in STEM fields.”<sup>105</sup> Yet, the following issues point to imperative foci for the future of STEAM implementation:

The articles generally failed to describe cognitive outcomes like design thinking, visual thinking, critical thinking, analyzing, or developing new ideas or perspectives. These implicit learning outcomes are most often described as inherent in the STEAM activity, and lack assessment or evaluation... [educators] often overlook the key aspects of arts education which include critique, self-expression, and conveying meaning.<sup>106</sup>

For the most part, dozens of publications offering some Industrial Revolution-era concluding pun along the lines of “full STEAM ahead” orbit each other in an echo chamber, void of the aforementioned evidence of cognitive outcomes or critique. Such academics would applaud the shift from STEM to STEAM shown by every one of the six science departments with which I have worked. However, my experiences with STEAM—also commonly lacking cognitive assessment, dedication to self-expression, meaning-making, and critique—have mostly failed to elicit much more than poster-making. With no pressures other than the discordance I felt between my own practices and STEAM’s untapped potentials, I decided to try my hand at developing teaching units that included more than the occasional “treat” of instructing students to artistically reiterate objective facts.

In joining a new middle school this 2019–2020 school year, I was able to utilize a curious audience and increased financial resources in my endeavor. Late in 2019, I was alerted to the seventh annual district-wide STEAM Night, which came as no surprise as the two other Bay Area school districts in which I have worked held identically-named community events. After a

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<sup>105</sup> Perignat. “STEAM,” 40.

<sup>106</sup> Perignat. “STEAM,” 39.

decade of witnessing lackluster transdisciplinary art incorporation and unsettling nationalistic sentiments, I was enthusiastic about the opportunity to increase the specificity of my goals and practice regarding STEAM education. Several laudable insights emerged from my STEAM Night experience; but mostly it became clear what areas of art implementation required improvement. Overall, my attempt to integrate art fell short of providing absolute proof that “the inclusion of visual or performing arts... [and] critiques of work and exhibiting final products... [catalyzes] imagination and expressivity, emphasizing new concepts and new possibilities.”<sup>107</sup>

The following mini-unit seen in figures 6A and 6B was executed in January 2020 with 185 eighth-grade students after delivering several lessons derived from traditional STEM-centric, NGSS standards on the topic of mechanical and electromagnetic waves.

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<sup>107</sup> Perignat. “STEAM,” 38.

Day	Classroom Activities	Results Observed
1	<p><u>UNIT INTRODUCTION AND SKETCHING</u></p> <ul style="list-style-type: none"> <li>• Introduce the artist Hokusai and the piece of art <i>The Great Wave off Kanagawa</i></li> <li>• Introduce my personal connections with waves by showing videos of the Japanese tsunami I lived through in 2011, which sadly killed one of my coworkers, and footage from my Maui Channel swimming race</li> <li>• Introduce art and science connections. Selected excerpts: "...And now that you have this knowledge about waves, how can you apply that to real global problems? As our sea levels continue to rise, issues about waves and science are going to continue to grow. How can you tell others what is important to you, or what you value, or what you want to see in the future for science? Let's try art. So, we have this famous painting, Hokusai's <i>The Great Wave off Kanagawa</i>. And over the next few days YOU will be creating it. But there are some things to think about. What interests you the most when it comes to the science of waves? What would you like this piece to say to others? What will this piece mean to you? How do you imagine what it may be like to be in a situation that has been devastated by seismic or tsunami waves? What colors will you choose? Will they be warm or cool, and why did you pick them? Will you use smooth or jagged lines? Will you use thick or thin pastel strokes? What are your thoughts for the future? So keep these questions in mind and let's get started!"</li> <li>• Play pre-recorded video offering suggestions about wave sketching, line placement, and "I can" positive attitude</li> <li>• Begin sketching individually</li> </ul>	<ul style="list-style-type: none"> <li>• Student attitudes were mostly apprehensive about such an undertaking, but quickly dissipated once they saw the simplicity of the introductory sketch video</li> <li>• Students' personal stories related to those I shared were offered to the class and between tablemates</li> </ul>
2	<p><u>OIL PASTEL OUTLINING</u></p> <ul style="list-style-type: none"> <li>• Reiterate: "What would you like this piece to say to others? What will this piece mean to you? What are your hopes for the future of science?" by reading and posting these questions on the whiteboard</li> <li>• Play pre-recorded video offering tips and tricks about oil pastel and reiterating the opportunity to add to, subtract from, or alter your art piece in comparison to the original <i>The Great Wave off Kanagawa</i></li> <li>• Outline sketches with oil pastels</li> </ul>	<ul style="list-style-type: none"> <li>• Student attitudes were mostly positive upon understanding that the entire week would continue to be dedicated to focusing on art and science</li> <li>• Increased communication about the topic and art methodologies was observed</li> </ul>

Figure 6A: Eighth grade waves unit activities and results observed. Days 1 and 2.

3	<p><u>WATERCOLORS</u></p> <ul style="list-style-type: none"> <li>• Reiterate: “What would you like this piece to say to others? What will this piece mean to you? What are your hopes for the future of science?” by reading and posting these questions on the whiteboard</li> <li>• Play pre-recorded video offering tips and tricks about watercolor painting and reiterating the opportunity to add to, subtract from, or alter your art piece in comparison to the original <i>The Great Wave off Kanagawa</i></li> <li>• Use watercolors to paint artwork (or encourage those who had previously contacted me about bringing other paint/color art supplies to proceed)</li> </ul>	<ul style="list-style-type: none"> <li>• This day produced a noticeable increase in communication and praise between students within table-groups</li> <li>• Unique interpretations of <i>The Great Wave Off Kanagawa</i> and artistic messages surrounding science were increasingly apparent</li> </ul>
4	<p><u>SPLATTER AND REFLECTION</u></p> <ul style="list-style-type: none"> <li>• Reiterate: “What would you like this piece to say to others? What will this piece mean to you? What are your hopes for the future of science?” by reading and posting these questions on the whiteboard</li> <li>• Play pre-recorded video offering tips and tricks about creating a “sea foam” effect with acrylic paint and reiterating the opportunity to add to, subtract from, or alter your art piece in comparison to the original <i>The Great Wave off Kanagawa</i></li> <li>• Introduce reflection piece: Students are shown how to customize a new slide on Google Slides with special attention to the instructions:</li> <li>• One sentence introducing the artist that inspired your wave painting.</li> <li>• One sentence telling the amplitude of your wave (in centimeters) which is <math>\frac{1}{2}</math> the total wave height from crest to trough. You might have to make your best estimate.</li> <li>• One sentence telling about what the amplitude means (think about energy and what a taller wave would do...)</li> <li>• Are ocean waves mechanical or electromagnetic?</li> <li>• Which color wavelengths are being reflected into our eyes when we look at your picture?</li> <li>• What interests you the most when it comes to the science of waves?</li> <li>• What would you like to tell your audience about your work of art?</li> </ul>	<ul style="list-style-type: none"> <li>• Even the creation of the written reflection piece garnered individual interpretations and presentations</li> <li>• While not personally interpreted as an extraordinarily “deep probing inquiry,” the written reflections illustrated new-found connections with the material and exposed empathetic sentiments towards others</li> </ul>
Lunch Times	<ul style="list-style-type: none"> <li>• Offer extra time to students who were absent or did not complete any part in the class time allowed</li> </ul>	<ul style="list-style-type: none"> <li>• Students were appreciative of the additional allotment of time so that they did not have to rush their work</li> </ul>

Figure 6B: Eighth grade waves unit activities and results observed. Days 3,4, and lunch times.





Figure 7: Student work being completed in a waves unit lesson



Figure 8: Student waves unit work displayed in the classroom



M

V

The artist that inspired my wave painting was Hokusai, a Japanese artist who used many mediums including woodblock printing, with which he created his most well-known work of art: *The Great Wave Off Kanagawa*. The amplitude of the main wave in my painting is approximately 11 centimeters, measured from the middle of the wave to the top, or the crest. The higher the amplitude, the larger the wave, the more intensity it has, and the more energy it carries. Ocean waves are mechanical, needing something to travel through (a medium), and only carrying energy, never matter.

The colors being reflected into your eyes are different shades of blue and gray and dull greens, appearing either depressing or soothing, from different perspectives. It is meant to show how tranquil the wave appears to be, while capable of so much destruction and loss. In the background, a city is depicted in shades of black and dull blues and greens, and the water behind the main wave accentuates it. The general idea of the painting is to show how irrelevant and inconsequential life is when it comes to the power of waves, however peaceful they may appear to be. Even though everything seems indestructible, it is not.

When it comes to the science of waves, the thing that interests me the most is how much power and energy waves have, and the ability to use it to the benefit of humans. Though waves come with such destruction, I hope that one day we can channel that destruction into something more that will last for many years to come.

M B

The artist that inspired my wave painting was Hokusai. The amplitude of my wave is 7 cm and the amplitude of my wave tells us that there was a lot of energy in the wave. The more energy a wave has, the higher its amplitude. Less energy in a wave means its amplitude will be lower. Ocean waves are mechanical waves, which means they need molecules of matter to travel through.

The color wavelengths being reflected in my picture are red, yellow, green, blue, light purple, grey and white. I chose to color the waves blue and green because blue shows calmness and green is the color of life. The sun in my picture is yellow because the sun is full of energy and happiness, contrasting with the waves and sky's mood of anger, shown with the color red. The mountain is colored very light purple because only those who look closely can see the beauty of mountains.

When it comes to the science of waves, I am most interested in learning about the rising sea levels of waves and how we can work to lower waves' amplitude. I was also wondering how heat energy is transferred to kinetic energy because the ocean waves are rising due to the increase of heat.

My art is symbolizing many things. I tried to make the great wave taller to show us that the waves today are a lot higher than normal because of global warming but tried to show not everything about waves are bad. I included the sun to show us there is still hope for lowering sea levels and used the colors blue and green to show that waves can also be calm and full of life.

Figure 9: Student examples of reflection portions of waves unit



Around the time the paint was drying, STEAM Night was beginning. With after-school help from students and my supportive parents, 185 paintings and explanations were displayed for those who braved the cold January evening. Being a district-wide event, invitations were sent to nearly 15,000 students and their families.<sup>108</sup> Always looking to tout STEAM investments, several school board members and principals from other school sites were in attendance. While I had “perfected” an elevator pitch regarding the need for special emphasis on the art in science, few individuals visited what was, in my opinion, an inviting table booth. Only a handful of conversations were had, mostly with family members of the 185 students whose work was displayed. I was able to engage with a school board member, who trailed off in her commendations after declaring, “We need more integrated opportunities. We need more of this. As you age, you lose the ability to...”<sup>109</sup> In addition to the opportunity for self-congratulations in refraining from completing this quote with an ageist jab, the school board member’s incomplete thought provides a parallel to STEAM’s unmet potential. Overall, STEAM Night was an informative experience for both those in attendance and myself; I imagine the encounters will shape my future STEAM plans to a greater degree than it will those who approached the table booth.

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<sup>108</sup> “Pleasanton Unified,” Education Data Partnership, accessed February 1, 2020, <http://www.ed-data.org/district/Alameda/Pleasanton-Unified>.

<sup>109</sup> Pleasanton Unified STEAM Night, personal interview, January 22, 2020.

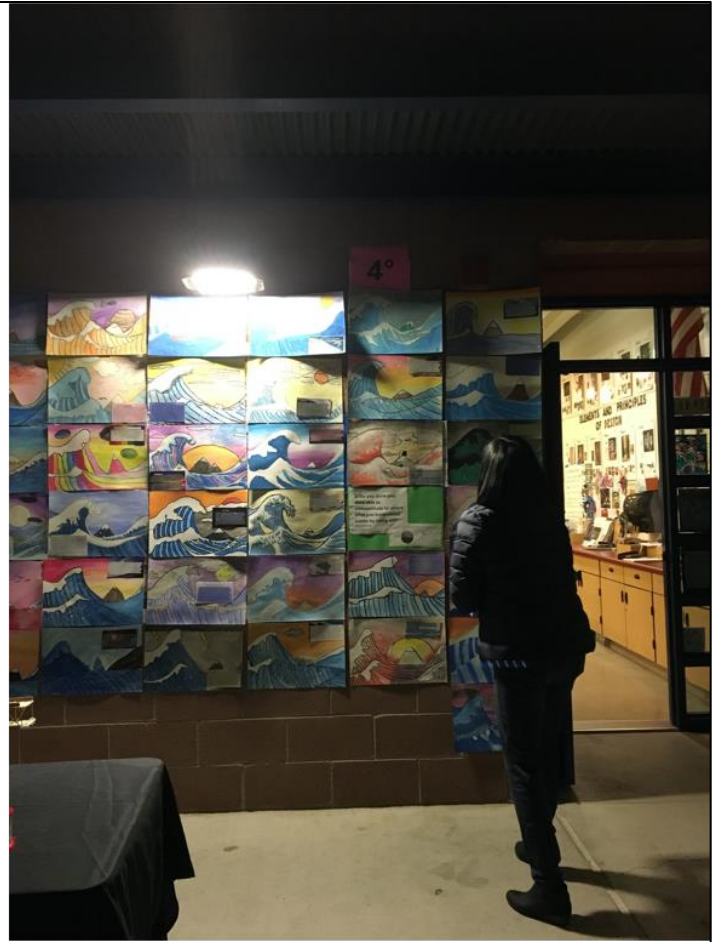


Figure 10: Waves unit display for STEAM Night, January 22, 2020

Like many scholars in the “full STEAM ahead” echo chamber, much of my prior experience in “art-making and the creative process [was] overshadowed by an emphasis on the end result, or product.”<sup>110</sup> In fairness, an “end product” on display was the impetus for this STEAM attempt. With special aversion to this overshadowing shortcoming, I intended for student surveys to showcase attitudes toward and effects of the overall experience. Results from surveys proved to be an interesting first look at qualitative efforts in assessing enjoyment and learning outcomes from art incorporation in the classroom. The first survey registered 95.6% of students enjoying the art components of the waves unit, 95.1% of students responding “yes” or “maybe” to desiring more art opportunities incorporated into science units, and 86.8% of students responding “yes” or “maybe” to being able to communicate knowledge about waves using art.<sup>111</sup>

Additionally, liberties were taken with interpreting some of the data. My aforementioned undergraduate prejudices surrounding the validity of qualitative data were hard to quell in several instances of analyses. The following student sentiments and my best attempt at placing a numeric value to the “resonation” of the lesson with student identity and interest settled my apprehension about the value of both formal and informal qualitative assessments.

Since minority and underrepresented student engagement in STEM fields is a driving factor in art integration, data was collected on student identities and final decisions regarding what became of their painting. The biggest liberty taken was assuming that if students took their painting home, the art integration allowed for some form of resonance with the student to the unit. In any case, there proved to be a statistically significant difference in gender, where males

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<sup>110</sup> Perignat, “STEAM,” 40.

<sup>111</sup> See Figure B, Appendix.

declined to take their paintings home at a higher rate than non-male students.<sup>112</sup> While not statistically significant, larger numbers of white students declined to take their paintings home when compared to non-white students.<sup>113</sup> Whatever conclusions can be drawn from this and whether this proves that art is a key to engaging minority students amidst traditionally male- and Eurocentric fields, or that showing interest in art is more culturally acceptable for non-male students, or simply that white male students are more forgetful in picking up projects, additional student sentiments in conjunction with such data can construct a clearer picture of the impact of STEAM lessons.

The last assessment technique included reading students' reflective sentiments after the waves unit was complete. Data, statistical analyses, and numeric inferences from qualitative assessments undoubtedly allow for a quantifiable and comparable result; however, I encourage scholars in the silo of value-free science to read the following student reflections. While not quantifiable in the same sense as gradient surveys, it is apparent from reflections in figure 11 that some within this group of eighth-grade students understand the many values STEAM can bring to science and their learning.

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<sup>112</sup> See Figure C, Appendix.

<sup>113</sup> See Figure D, Appendix.

I think [art] is a good choice because instead of the monotone events of writing down notes and then reading lectures and listening to the teacher speak, it gives us the ability to express ourselves and our vast knowledge on the subject matter in a way we understand ourselves.

-A.K. (non-white, male)

Art is something everyone can relate to even if they aren't good at it. The fact that art has no real language means that everyone can understand it no matter what language they speak.

-S.C. (non-white, non-male)

People can express things in the world visually through art. Art is a medium for people to translate what they are thinking into something physical.

-S.M. (white, decline to state)

Art is generally a medium that has the unusual ability to communicate alien or abstract ideas, so science can use art to bring knowledge to many more people than it could alone.

-J.S. (white, male)

Usually, I am kind of stressed out about learning about science, but when we include art in science, it makes me kick back and relax and be happier and actually enjoy learning about something because I am also enjoying myself.

-A.K. (non-white, non-male)

Art is a good choice for people to connect with science as it is not all abstract facts and statistics and it will allow you to communicate what the subject means to you.

-C.O. (non-white, non-male)

*Figure 11: Student reflections about the art's inclusion in science*

With this first waves unit and STEAM Night attempt, several areas are in need of attention going forward with art's incorporation into my science classroom. While communication within table groups and between myself and STEAM Night booth attendees generated positive interactions, increased communication including critique could have been fostered to a greater degree. Gaining perspective about others' ideas and identities in addition to sharing one's own interpretations is vital to global cooperation. Also, it is important to vary both

the art forms and their methods of incorporation within STEAM education. Greater choice in content exploration and expression will allow an infusion of identity-laden subjectivity with universal objectivity. Lastly, there is a need for increased emphasis on STEAM's ability to affect the globe, whether by utilizing art to understand new and differing perspectives or providing opportunity to internalize and relate to emotionless charts and graphs. While student awareness was observed (I cannot say "improved" as there was no pre-unit assessment) regarding the diverse benefits of art's integration with science, these benefits need to be expanded to inspire the discovery of impacts STEAM can have on the world.

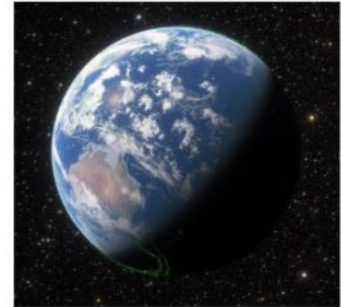
With these weaknesses noted, another STEAM unit has been created for the final unit of the 2019–2020 school year. As we have moved past waves, astronomy, evolution, and into human impact studies, a new art form and new content material will provide another opportunity for cyclical improvements. Similar surveying and assessment techniques will again be utilized in this human impact STEAM unit so as to allow comparison between the two units, keeping in mind one large difference. The response to the COVID-19 pandemic has included shifting schools to online instruction. As a result, students may have difficulty communicating portions of their learning and insights, and I may have difficulty guiding students to resources and inspiring learning. A few workarounds aim to overcome both challenges in assessing this STEAM unit and the realities of distance learning. Figures 12A and 12B show the (COVID-19-adjusted) premise for a human impact unit utilizing poetry as a means of expanding individualized understanding, empathy, and expression.



## **Human Impact Project Guidelines**

**(25 points)**

Instead of a written test for the Human Impact Unit, we are creating a piece of poetry to express how humans have caused change in our world, the effects of the change, and the possible future of human impacts.



This is an individual project. There are TWO parts to the project - your poem AND an explanation.

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After you finish your poem, you can choose if you would like to submit it to the [Alameda County Creative Writing and Literacy Competition](#) for 6th-8th graders.

(It's free to submit! You get a free ticket to the fair! You can see your poem on display (if the fair is not cancelled)! You just have to tell Ms. D "yes"!)

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Your poem can be as short or long as you would like. Some famous short poems are in the style of Haiku or Cinquain, while some longer famous poem styles include Glosa or Chanso. Begin [here](#) if you are curious about more poem styles.

Your poem explanation must showcase your learning from this unit, which includes at least one page (3 paragraphs or more) of an explanation. In your explanation, you should include at least one sentence about each of the following questions:

- **Next Generation Science Standards Components (Paragraph #1)**
  - What is(are) the change(s) humans have made that have resulted in an impact?
  - What are the effects of the changes humans have made?
  - What are your thoughts for the future of humans impacting the earth? Are there any technologies, policies, or progress being made that could change the course of humanity's impact?
  - How do the following vocabulary words link to your project? (HIGHLIGHT each vocabulary word somewhere in this paragraph).
    - Natural resources
    - Sustainable
    - Engineering OR Technology

Figure 12A: Human Impact Project Guidelines, page 1

- **Studio Habits of Mind & Art Standards Components (Paragraph #2)**

- What is the main message of your poem?
- Why did you choose certain components (ex: style, punctuation, line breaks, stanzas, rhyming, spacing)?
- What would you like your audience to know about your poem?



- **Communication Components (Paragraph #3)**

- Include an explanation of how you shared your poem with another person. This includes at least 3 sentences summarizing your discussion/interaction about your project with another person (and make sure you say who you discussed your poem with!). It's a good idea to explain some background information when you share your poem, including why you wrote your poem and if they have any questions or comments.
- **Before you share your project, some items to think about in your explanation could include:**
  - *Why did you choose this person to share your project with?*
  - *How was sharing art with this person different than showing them the results of a written test?*
  - *Do you think your poem made them think any differently about human impacts on Earth?*
  - *Could they understand your perspective about your topic?*
  - *Did they share anything interesting about your topic that you had not thought about before?*
- If you researched and used any sources in your project, make sure to cite them at the end of your paper. [Here](#) is a good resource to check out for correct citations.

- FYI: If you do not wish to write a poem, you can incorporate any art form you wish. If you have another idea, talk to/email Ms. D. for more information designing your project. Some examples include:

- Visual Arts: painting, photography, ceramics, drawing, sculpting, filmmaking
- Performing Arts: dance, music, theater

Figure 12B: Human Impact Project Guidelines, day 2



After reflecting on STEAM Night’s shortfalls, a greater emphasis was placed on critical thinking and communication for gaining perspective and STEAM’s ability to affect the globe, and a variety of artistic mediums could be selected for use as part of this human impact project. Yet, the implications of remote learning required alterations to the original structure of the project’s communication component. Along with a reprieve for my stomach in regards to fair rides, a heavy disappointment accompanies rumors surrounding the imminent cancellation of the Alameda County Fair (for the first time in 108 years).<sup>114</sup> Furthermore, encouragement to approach principals, counselors, teachers, and other members of the community when sharing this project has been diluted to “another person.” The stress of a shift to remote learning has manifested itself in many ways for all community members, some of which include resource-based inequities. Therefore, we will have an optional live online meeting where students can share and discuss their poems/art, and I will offer to share poems/art submitted by students who cannot or do not wish to join the live meeting.

My STEAM Night art integration attempt was not perfect, nor will this upcoming human impact poetry project likely generate extraordinary empathy and problem-solving skills. Entering this second decade of teaching with a refined STEAM mindset is reminiscent of my first year as an educator. Countless lessons within that time period are designated as “awful” within my memory, notably the moment in which I realized the student population was, on average, two years below grade-level literacy proficiency. Just as I learned to develop methods for making science content accessible regardless of students’ literacy levels, I will continue to develop STEAM’s art incorporation to allow an explicit space for diverse individuals to “deconstruct and

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<sup>114</sup> “About Us,” Alameda County Fairgrounds, accessed on May 8, 2020, <https://alamedacountyfair.com/about-us/>.

reconstruct the interdisciplinary, ubiquitous, [and] powerful”<sup>115</sup> STEAM content in relation to personal identities, therefore inducing “long-term transformational learning experiences” that have been shown to increase knowledge retention by up to nine-fold when compared with traditional “lecture and/or reading formats.”<sup>116</sup> I know STEAM’s potential; it is now my job to facilitate the development of empathy and inspire student exploration of the sciences for humankind’s benefit.

However, this cannot be my job alone. Ensuring student opportunities to complete units and projects such as these, as well as participate in events such as STEAM Nights was indeed a consuming experience. It may come as no surprise that no other teacher in the school’s science department offered a similar community showcase or piloted project. From building relationships with integral STEAM Night coordinators, to quickly constructing new online curriculum and assessment, to making the most of a little-desired display location exposed to the January weather, the experience emphasized the often emotionally and physically draining flexibility necessary to implement new teaching methods.

One final site-specific item to mention in the STEAM Night endeavor was the hurdle of procuring art supplies. In my current placement, our generous student families were happy to foot the \$300 bill; the outstanding complication proved to be the short time frame and penta-departmental procedural milestones necessary to authenticate validity of the supply order. Regardless of individualized district purchasing procedures, supply procurement is an obstacle that many schools struggle to budget into their science department, despite claiming to offer a

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<sup>115</sup> Wolfmeyer, “(Re) Considering STEM,” 1.

<sup>116</sup> NaJuana Lee, “Culturally Responsive Teaching for 21st-Century Art Education: Examining Race in a Studio Art Experience,” *Art Education* 65, no. 5 (2012): 51.

STEAM-centric curriculum. Prior to this middle school placement, my budget for the entire year was just \$200 for 700 students across six grade levels.

Because of this, I applied for and was awarded an average of \$2,500 in annual educational grants. Yet for years when I taught these 700 elementary students and six grades, this meant only \$3.85 per student for their entire year of science education. This STEAM Night project, had it been expanded to include 700 students, would have absorbed about half of the annual award money had I been at previous schools. It hardly needs to be mentioned that regularly implementing STEAM units that require any amount of consumable materials without explicit funding is unfeasible for many districts across the US, especially those serving disproportionately large groups of students living at or below poverty level who, due to cycles of inequality, are often composed nearly entirely of minority groups.<sup>117</sup> What should science educators in such situations spend such meager funds on? There are five letters in STEAM; without even five dollars per year per student, how should educators proceed?

In what was an earlier goal of this synthesis project, I anticipated creating an educator “toolkit” of information and ideas for developing global-minded problem solving via a STEAM-centric curriculum. This goal is still in progress. While I may have a few examples continuing to undergo refinement by this year’s end—each one considering site-specific obstacles such as budgetary constraints and community buy-in—one key point stands out in the creation of such a toolkit. When STEAM produces “success” in the realms of social, emotional, or similar holistic content, such results are often implicitly assumed and are rarely replicated using the same

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<sup>117</sup> Nicole M. Stephens, Hazel Rose Markus, and L. Taylor Phillips, “Social Class Culture Cycles: How Three Gateway Contexts Shape Selves and Fuel Inequality,” *Annual Review of Psychology* 65 (2014): 611-634.

methodologies.<sup>118</sup> Besides my informal observations, hastily-conducted surveys, and noting of conversations with community members, I need to ensure goals are clearly stated and assessed regarding “cognitive outcomes [and student capacity for] critique, self-expression, and conveying meaning.” As I continue forward in my personal professional journey, I expect the Action Research process, which includes continued goal-setting, assessment, and subsequent

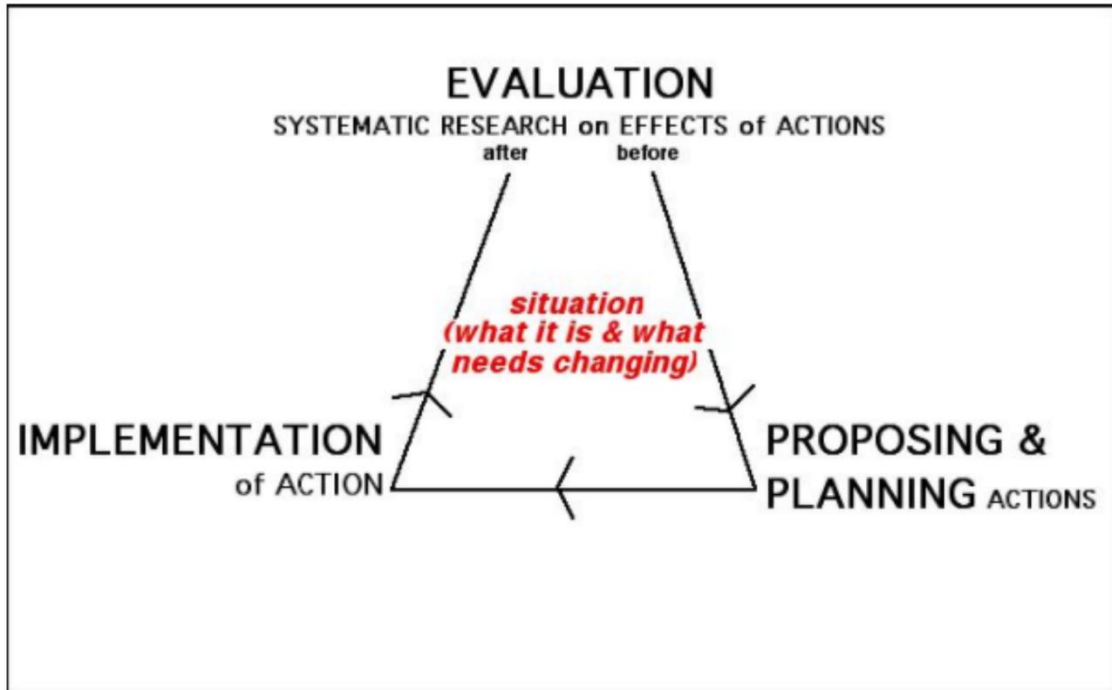


Figure 13: The basic cycle of action research. Kayla D. Faust, "Real World Application of CCT Tools: How Reflection, Dialogue Processes and Action Research were used to promote organizational change and student success in Re-Engagement Work," *Scholarworks Critical and Creative Thinking Capstones Collection* (2017): 15.

procedural refinement, to improve my ability to effectively incorporate art into science in order to create empathetic, scientifically literate global citizens.<sup>119</sup> Whatever the results of such Action Research iterations, stakeholders and constituents looking to develop STEAM’s potential will have long-awaited transparent evidence of cognitive outcomes resulting from STEAM

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<sup>118</sup> Perignat, “STEAM,” 39-41.

<sup>119</sup> Kayla D. Faust, "Real World Application of CCT Tools: How Reflection, Dialogue Processes and Action Research were used to promote organizational change and student success in Re-Engagement Work," *Scholarworks Critical and Creative Thinking Capstones Collection* (2017): 15.

education.<sup>120</sup> By continuing my personal process, I additionally hope to facilitate new avenues of participation, including the eventual advocacy of science educator professional development surrounding STEAM's role in the future of our planet. Just as educators currently use assessments to refine teaching methods, improved data collection and reporting during STEAM education will allow cultivation and revision of key pedagogical components needed to increase empathetic scientific literacy and global citizenship.

## **Earthlings' Responsibilities**

What I am proposing here is nothing short of a paradigm shift. Experts in systems analysis "have a great belief in 'leverage points.' These are places within a complex system... where a small shift in one thing can produce big changes in everything."<sup>121</sup> With the amalgamation of factors impeding STEAM implementation for the benefit of the world, this proposed agenda may not seem like a "small shift." But, maybe it can be considered "one small step for man, one giant leap for mankind."<sup>122</sup> A paradigm shift producing changes in science education is necessary for the sake of humanity. In reflecting on the height of the Cold War, 1985's Nobel Peace Prize physician recipients offered the following sentiments that would be echoed by, among others, 13 Nobel laureates this past January 2020: "We know 100 times more than we need to know. What we lack is the ability to experience and to be moved by what we

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<sup>120</sup> Perignat, "STEAM," 39-41.

<sup>121</sup> Donella Meadows, "Leverage Points: Places to Intervene in a System," Donella Meadows Archives, Academy for Systems Change, accessed March 9, 2020, <http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/>.

<sup>122</sup> *The Encyclopaedia Britannica: Neil Armstrong*, Encyclopaedia Britannica, Inc., October 22, 2019, <https://www.britannica.com/biography/Neil-Armstrong>.

know, what we understand and what we see and believe.”<sup>123</sup> For longer than I have been alive, revered scientific minds have been calling for a paradigm shift entailing increased empathetic global citizenship resulting in action. From Italy to Japan, astronauts worldwide have found themselves turning to art to convey this necessity. Books of poetry,<sup>124</sup> foundations for Noetic Science<sup>125</sup> and Space for Art,<sup>126</sup> and gallery exhibits<sup>127</sup> have been able to produce intrigue for a select audience about our primitive state of “knowing... with the brain and not the heart.”<sup>128</sup> Yet sadly, “astronauts, generally having been government servants, have not come back [from space] with huge resources.”<sup>129</sup> Compounding the minimal reach of the overview effect is “that so far the view from 100,000 miles has been the exclusive property of a handful of test pilots, rather than the world leaders who need this new perspective, or the poets who might communicate it to them.”<sup>130</sup> From this, it would seem to many an untrained eye that a leverage point for a paradigm shift would be to give world leaders a taste of the overview effect either by suiting them up, or delegating artists to do so for them. This is exactly what Elon Musk’s SpaceX has in mind for 2023.

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<sup>123</sup> “Award Ceremony Speech.”

<sup>124</sup> Al Worden, *Hello Earth: Greetings from Endeavor*. (Mechanicsville: Nash Publications, 1974).

<sup>125</sup> “Weaving Together Knowledge and Knowing,” Institute of Noetic Sciences, accessed April 9, 2020, <https://noetic.org/about/>.

<sup>126</sup> “Space For Art Foundation.”

<sup>127</sup> Brett Zongker, “Astronaut Alan Bean opens Smithsonian art exhibit,” *The San Diego Union-Tribune*, July 16, 2009, <https://www.sandiegouniontribune.com/sdut-us-lunar-art-alan-bean-071609-2009jul16-story.html>.

<sup>128</sup> Norah Moran, “The Overview Effect,” Houston We Have A Podcast, National Aeronautics and Space Administration, published September 4, 2019, <https://www.nasa.gov/johnson/HWHAP/the-overview-effect/>.

<sup>129</sup> Moran, “Overview Effect.”

<sup>130</sup> Austin Allen, “Landing On a Dream,” The Moon In Poetry, Poetry Foundation, published July 15, 2019, <https://www.poetryfoundation.org/articles/150505/landing-on-a-dream>.

Stemming from either an attention-generating ploy or true advocacy for global cohesiveness, Japanese billionaire Yusaku Maezawa will be footing SpaceX's astronomical bill for around six artists to capture their overview effect experience and disseminate it to the public.<sup>131,132</sup> This is keeping in mind the financier's previous worldwide "girlfriend" competition instigated to decide who should accompany him on a future trip to the moon.<sup>133</sup> Besides promoting "an example for younger generations of women that their willingness to engage in a romantic relationship could get them farther than hard work in a STEM field,"<sup>134</sup> Maezawa's select invitations reinforce what many assume is the only possible way for the unifying sentiments experienced in the overview effect to ever cause a global mind shift: at the excruciatingly slow pace of "one rich space tourist at a time."<sup>135</sup>

Rather than waiting on sporadic, wealthy individuals blasting off with their contest-winning trophy wives, educators can cultivate the same paradigm shift of individualized understanding, empathy, and critical thinking with the sustainable development of our globe at the forefront of such efforts. As Dr. Georgina Born and Dr. Andrew Barry note, "[Art-science's] meaning-creative capacity of initiatory action [instills]... boundlessness and uncertainty of

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<sup>131</sup> Jackie Wattles, "Why a Japanese Billionaire Wants to Send Artists to the Moon," *CNN Business*, *CNN*, July 9, 2019, <https://www.cnn.com/2019/07/09/business/spacex-moon-tourist-yusaku-maezawa/index.html>.

<sup>132</sup> Sarah Lewin, "#DearMoon: SpaceX's 1st Passenger Flight Around the Moon Will Be an Epic Art Project," *Space*, September 18, 2018, <https://www.space.com/41857-dearmoon-spacex-epic-lunar-art-project.html>.

<sup>133</sup> Chelsea Gohd, "Billionaire Hosts Girlfriend Contest for 'First Woman to the Moon' and (Shocker) People Hate It," *Space*, January 14, 2020, <https://www.space.com/spacex-starship-dearmoon-mission-update-2019.html>.

<sup>134</sup> Gohd, "Billionaire."

<sup>135</sup> Ben Guarino, "The Overview Effect Will Save Earth One Rich Space Tourist at a Time," *Inverse*, December 18, 2015, <https://www.inverse.com/article/6301-overview-everview-effect-space-tourism-environmentalism-spacex-richard-garriot>.

outcome, where ‘boundless’ implies the creation of a ‘myriad new relationships [and] unforeseen constellations’.”<sup>136</sup> Metaphorical space references saved for this concluding section, we need a way to constellate inter- and intra-personal discoveries with scientific literacy. We need a way to initiate far-reaching, unforeseen outcomes driven by equitable sustainability. We need a well-informed public that has sufficient knowledge about issues and the power to resist exploitation. We need to utilize STEAM education to empower empathetic, scientifically literate global citizens.

Even Japan Aerospace Exploration Agency’s (JAXA) collaborative Space Poem Chain project, which was designed “to create a collaborative place through ‘linked verse’ by thinking together about the universe, Earth, and life itself, unfettered by barriers of nation, culture, generation, profession, and position or rank,”<sup>137</sup> recognizes the futility of holding one group responsible for our future. “It cannot be only poets,” whose breed was suggested by astronauts lacking the training to emote, “who believe that we must not entrust our inquiry into the nature of the universe exclusively to science.”<sup>138</sup> All “Earthlings”<sup>139</sup> need to take responsibility for our future.

As of now, our attempts at pairing scientific literacy and global citizenship with sustainable innovation flounder between astronaut retirement projects, a fantasy Greta Thunberg–Mae Jemison “Super Friends” squad, and nescient, adrenaline-junkie billionaires.

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<sup>136</sup> Born, “Art-Science,” 115.

<sup>137</sup> “What is the Space Poem Chain,” JAXA Space Environment Utilization Center, JAXA Japan Aerospace Exploration Agency, published March 19, 2010, [https://iss.jaxa.jp/utiliz/renshi/about\\_e.html](https://iss.jaxa.jp/utiliz/renshi/about_e.html).

<sup>138</sup> “Messages for Space Poem Chain,” JAXA Space Environment Utilization Center, JAXA Japan Aerospace Exploration Agency, published March 19, 2010, [https://iss.jaxa.jp/utiliz/renshi/message\\_e.html](https://iss.jaxa.jp/utiliz/renshi/message_e.html).

<sup>139</sup> “Space For Art Foundation,” SpaceForArt, accessed April 8, 2020, <https://www.spaceforartfoundation.org/>.



Thus far, we have no succinct efforts to shift our paradigm away from prioritizing power-hungry nationalism to growing a society of scientifically literate individuals capable of perspective-taking. As facts shrivel under authoritarian figures, the need for a well-informed public that has both the power to resist manipulation and sufficient knowledge about issues with global implications becomes ever more imperative. Nearly two decades before pervasive (oxy)moronic “fake news,” Jemison noted, “there’s a media that doesn’t support the dissemination of any more than the most mundane and inane of information. [This is not the] information you need to... figure out how to participate in this democracy and determine what’s going on.”<sup>140</sup> We rely on this democracy and the collective voices of the globe to shape “a future for us all, for our children and for our grandchildren. Yes, [we are] concerned with the unborn generations’ right to inherit that earth which we today tend on their behalf.”<sup>141</sup>

For now, our future still holds hope, “a hope for the steady advance of a new way of thinking, so that bridges can be built over the chasms that represent our fear of the future... Mankind in all countries is united in that hope.” Whether STEAM’s refined implementation begins with small steps or abounds with giant leaps, humankind will be pointed in the correct direction for a paradigm launch into building empowered, empathetic, scientifically literate global citizens.

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<sup>140</sup> Jemison, “Teach Arts and Sciences Together.”

<sup>141</sup> “Award Ceremony Speech.”

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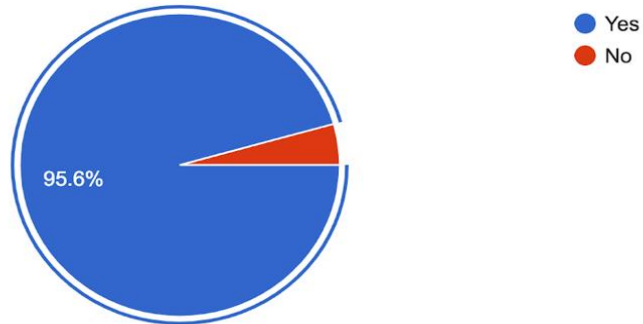
# Appendix



Figure A: STEM advertisement on Girl Scout cookie boxes, 2020 season. Lemon-Ups, accessed April 9, 2020, clip art, <https://www.littlebrowniebakers.com/clipart/lemon-ups/>.

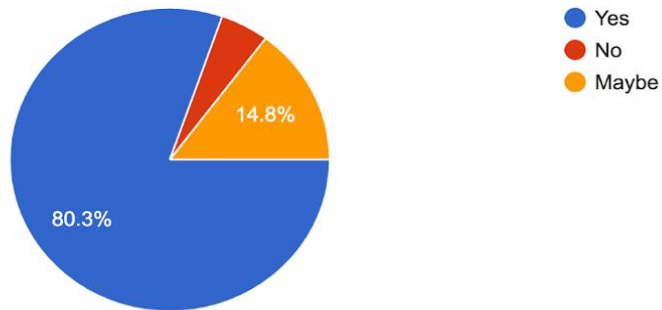
1. Did you enjoy the art components of the waves unit?

183 responses



2. Would you like to have more art opportunities incorporated into science units?

183 responses



3. Do you think you were able to communicate to others what you know about waves by using art?

182 responses

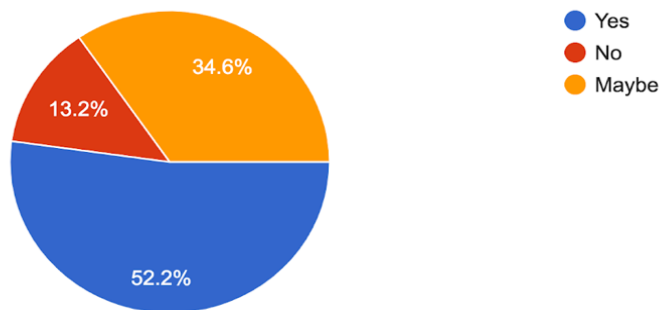


Figure B: Results from STEAM waves unit survey I.

<b>Male</b>			
<i>Taking Painting Home</i>	COUNTA of Reason	COUNTA of Reason	
I took my painting home (or Ms. D is displaying it)		30	50.00%
Left at School		30	50.00%
<b>Grand Total</b>		<b>60</b>	<b>100.00%</b>

<b>Non-Male</b>			
<i>Taking Painting Home</i>	COUNTA of Reason	COUNTA of Reason	
I took my painting home (or Ms. D is displaying it)		65	69.89%
Left at School		28	30.11%
<b>Grand Total</b>		<b>93</b>	<b>100.00%</b>

Figure C: Results from STEAM waves unit survey II broken down by gender identity. Note: Reduced total student count due to some students not following survey directions.

## 2 Proportion z test investigating whether non-male students value their artwork at a higher rate than male students do:

- 1) Let Proportion 1 = the true proportion of non-male students that value their artwork enough to take home and display.
- 2) Let Proportion 2 = the true proportion of male students that value their artwork enough to take home and display.
- 3) Null Hypothesis:  $H_0: \text{Proportion 1} - \text{Proportion 2} = 0$
- 4) Alternative Hypothesis:  $H_a: \text{Proportion 1} - \text{Proportion 2} > 0$
- 5) Acceptable Type I error: Let  $\alpha = .05$
- 6) Assumptions: (there are 3 for this kind of statistical procedure)

i) Simple Random Sample of male and non-male students from their respective populations for this hypothesis test. A master roster was randomly generated by software.

ii). Sample Size check. There are 4 sample size checks, 2 for each sample.

Is  $N_1 * (P_1) > 10$  and  $N_1 * (1 - P_1)$  also  $> 10$ ?  
 $93 (65/93) = 65$  which is  $> 10$  check. And  $93 (1 - 65/93) = 28$  which is also  $> 10$  check.

Is  $N_2 * (P_2) > 10$  and  $N_2 * (1 - P_2)$  also  $> 10$ ?  
 $60 (30/60) = 30$  which is  $> 10$  check. And  $60 (1 - 30/60) = 30$  which is also  $> 10$  check.

The samples are large enough to proceed with a 2 proportion z test.

iii). The samples are indeed  $< 10\%$  of their respective populations.

The assumptions all appear reasonably met to proceed with a 2 proportion z test.

7+8) Formula + Calculation of p-value:

$$z = \frac{(P1 - P2)}{\sqrt{Pc * (1-Pc)/N1 + Pc * (1-Pc)/N2}} \rightarrow$$
$$z = \frac{(.6989 - .5000)}{\sqrt{.6209 * (1 - .6209)/93 + .6209 * (1 - .6209)/60}} = 2.48$$

The area to the right of a z-score of 2.48 is approximately 0.66% on a normal curve centered at a z-score of 0.

9) Conclusion: Reject Ho at alpha = .05, with a p-value of .0066

**There is evidence that non-male students value their artwork and wish to display it a higher rate than male students do, with sufficient evidence to reject the null hypothesis at alpha = .05.**

Note: Total sample number differs from total number of students who participated (185) due to students not following directions to fill out the survey.

White		
Taking Painting Home	COUNTA of Reason	COUNTA of Reason
I took my painting home (or Ms. D is displaying it)		23 53.49%
Left at School		20 46.51%
<b>Grand Total</b>		<b>43 100.00%</b>

Non-White		
Taking Painting Home	COUNTA of Reason	COUNTA of Reason
I took my painting home (or Ms. D is displaying it)		72 65.45%
Left at School		38 34.55%
<b>Grand Total</b>		<b>110 100.00%</b>

Figure D: Results from STEAM waves unit survey II broken down by racial identity. Note: Reduced total student count due to some students not following survey directions.

**2 Proportion z test investigating whether non-white students value their artwork at a higher rate than white students do:**

- 1) Let Proportion 1 = the true proportion of non-white students that value their artwork enough to take home and display.
- 2) Let Proportion 2 = the true proportion of white students that value their artwork enough to take home and display.
- 3) Null Hypothesis:  $H_0: \text{Proportion 1} - \text{Proportion 2} = 0$
- 4) Alternative Hypothesis:  $H_a: \text{Proportion 1} - \text{Proportion 2} > 0$
- 5) Acceptable Type I error: Let  $\alpha = .05$
- 6) Assumptions:

- i) Simple Random Sample of white and non-white students from their respective populations for this hypothesis test. A master roster was randomly generated by software.
- ii) Sample Size check. There are 4 sample size checks, 2 for each sample.

Is  $N_1 * (P_1) > 10$  and  $N_1 * (1 - P_1)$  also  $> 10$ ?  
 $110 (72/110) = 72$  which is  $> 10$  check. And  $110 (1 - 72/110) = 38$  which is also  $> 10$  check.

Is  $N_2 * (P_2) > 10$  and  $N_2 * (1 - P_2)$  also  $> 10$ ?  
 $43 (23/43) = 23$  which is  $> 10$  check. And  $43 (1 - 23/43) = 20$  which is also  $> 10$  check.

The samples are large enough to proceed with a 2 proportion z test.

- iii) The samples are indeed  $< 10\%$  of their respective populations.

The assumptions all appear reasonably met to proceed with a 2 proportion z test.

7+8) Formula + Calculation of p-value:

$$z = (P1 - P2) / \left( \frac{Pc * (1-Pc)}{N1} + \frac{Pc * (1-Pc)}{N2} \right)^{.5} \longrightarrow$$

$$z = (.6545 - .53488) / \left( \frac{.6209 * (1 - .6209)}{110} + \frac{.6209 * (1 - .6209)}{43} \right)^{.5} = 1.37$$

The area to the right of a z-score of 1.37 is approximately 8.51% on a normal curve centered at a z-score of 0.

9) Conclusion: Fail to reject  $H_0$  at  $\alpha = .05$ , with a p-value of .0851

**There is SOME evidence that non-white students value their artwork and wish to display it a higher rate than white students do, but not with sufficient evidence to reject the null hypothesis at  $\alpha = .05$ .**

Note: Total sample number differs from total number of students who participated (185) due to students not following directions to fill out the survey.



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