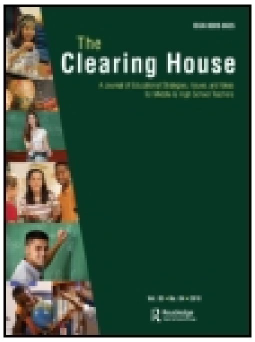

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Innovative Arts Programs Require Innovative Partnerships: A Case Study of STEAM Partnering between an Art Gallery and a Natural History Museum

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ABSTRACT
The arts animate learning because they are inherently experiential and because of their potential to develop creative and critical thinking skills in students. These same skills are valued in science, technology, engineering, and math (STEM) education, but the arts have not been consistently included in STEM lessons. We transformed our STEM programming into STEAM programming (STEM plus arts) by creating an innovative partnership between two informal learning environments, the Braithwaite Fine Arts Gallery and the Garth and Jerri Frehner Museum of Natural History at Southern Utah University. The partnership resulted in a STEAM learning program that integrated art and science for K-12 students. We incorporated an art exhibition, a hands-on lesson in art, and an immersive lesson in science that culminated in a student project that merged concepts from both art and science. Through programs each fall from 2012 through 2014, we helped over 6,000 students from southern Utah use concepts from art to deepen their understanding of caterpillar defenses, fish ecomorphology, and pollinator biology.

KEYWORDS
Arts integration; informal STEM learning; science education; STEAM; museum education

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The arts animate learning because they are inherently experiential, and because of their potential to connect students to human history, develop creativity, and build capacity for critical thinking (Bowen, Greene, and Kisida 2014). An important source for exposure to both the arts and sciences is through informal learning environments such as art galleries and museums (Bowen, Greene, and Kisida 2014; Ramey-Gassert, H. J. Walberg, and H. J. Walberg III 2006). Southern Utah University is home to two informal learning environments, Braithwaite Fine Arts Gallery (hereafter referred to as the gallery) and Garth and Jerri Frehner Museum of Natural History (hereafter referred to as the museum). Both institutions share the mission of serving as experiential learning centers in their respective areas, and they both accomplish part of that mission through contributions by undergraduate and graduate students. Collaboration between the staff at the Braithwaite Fine Arts Gallery and the Garth and Jerri Frehner Museum of Natural History to engage K-12 students in art and science learning began in the fall of 2012 and has continued annually. The goal of the Fall Education Program is to animate learning for K-12 students through the integration of science, technology, engineering, arts, and math (STEAM) facilitated by undergraduate docents and graduate students. This article begins with a quantitative literature review of published works related to STEAM education, and then describes how connections between the arts and sciences have been implemented each of three years of programming with a focus on the development of STEAM activities at the Garth and Jerri Frehner Museum of Natural History. The article concludes with recommendations for the development of a successful STEAM program.

Literature discussion

Because the museum's primary focus is science, technology, engineering and math (STEM) education and because the STEAM educational trend is quite recent, we wanted to gain a picture of the current state of arts integration with STEM fields based on published research and descriptions of STEAM learning activities. We wanted to know if the field of STEAM education research is growing, what grade levels had been investigated, and what proportion of published

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Table 1. Articles used as data points in the current analysis.

Author(s) and year
Baggett, P. V., and E. L. Shaw. 2008.
Bohannon, R. L., and C. McDowell. 2010.
Bush, S. B., K. S. Karp, T. Lentz, and J. Nadler. 2014.
Çil, E. 2015.
Claymier, B. 2014.
DeFauw, D. L., and K. Saad. 2014.
Gurnon, D., A. Voss, and J. Stanley. 2013.
Horton, R. M., T. Hedetniemi, E. Wiegert, and J. R. Wagner. 2006.
Klopp, T. J., A. C. Rule, J. S. Schneider, and R. M. Boody. 2014.
Koester, A. 2014.
Kolstad, R. K., and L. D. Briggs. 1995.
Kong, Y., S. Huh, and H. Hwang. 2014.
La Haye, R., and I. Naested. 2014.
Lee, B. K., E. A. Patall, S. W. Cawthon, and R. R. Steingut. 2015.
Matz, K.A., and C. Leier. 1992.
McMillan, S., and J. Wilhelm. 2007.
Medina-Jerez, W., L. Dambekalns, and K. V. Middleton. 2012.
Moorefield-Lang, H., and M. A. Evans. 2011.
Olsen, B. D., K. S. Zhbanova, H. Parpucu, Z. Alkouri, and A. C. Rule. 2013.
Osborne, M. D., and D. J. Brady. 2001.
Peppler, K. 2013.
Richard, B., and C. J. Treichel. 2013.
Richardson, J. S. 1994.
Smith, S. 2013.
Stokes, N. C. 2003.
Tunks, J., and P. Moseley Grady. 2003.
Walker, E., C. Tabone, and G. Weltsek. 2011.
Zhbanova, K., A. Rule, S. Montgomery, and L. Nielsen. 2010.

STEAM learning research focused on formal classroom settings as opposed to informal learning environments. We used the following terms to search for scholarly articles in Academic Search Premiere: arts integration AND science; arts integration AND STEM; STEAM, education, AND art; and arts integration AND mathematics. Of the 127 articles we found that were published between 1990 and 2014, 38 were related to STEAM education. Ten of the relevant articles were excluded from analysis of their relationship to grade level and learning environment because they were editorial in nature. The 28 articles used as data points in our analysis are shown in Table 1.

The field of STEAM education has undergone exponential growth in the past five years (Figure 1A). From 1990 to 2004, an average of less than one publication per year appeared in the literature. That average increased to just over one per year between 2005 and 2009, but during the five-year period between 2010 and 2014 that average jumped to five publications per year with the majority published in 2013 (seven publications) and 2014 (eight publications). High school and preschool audiences have received the least attention in published work on STEAM activities in our analysis (three and one publications respectively), while elementary, middle school, and college classrooms have received the most (12, 10, and seven publications

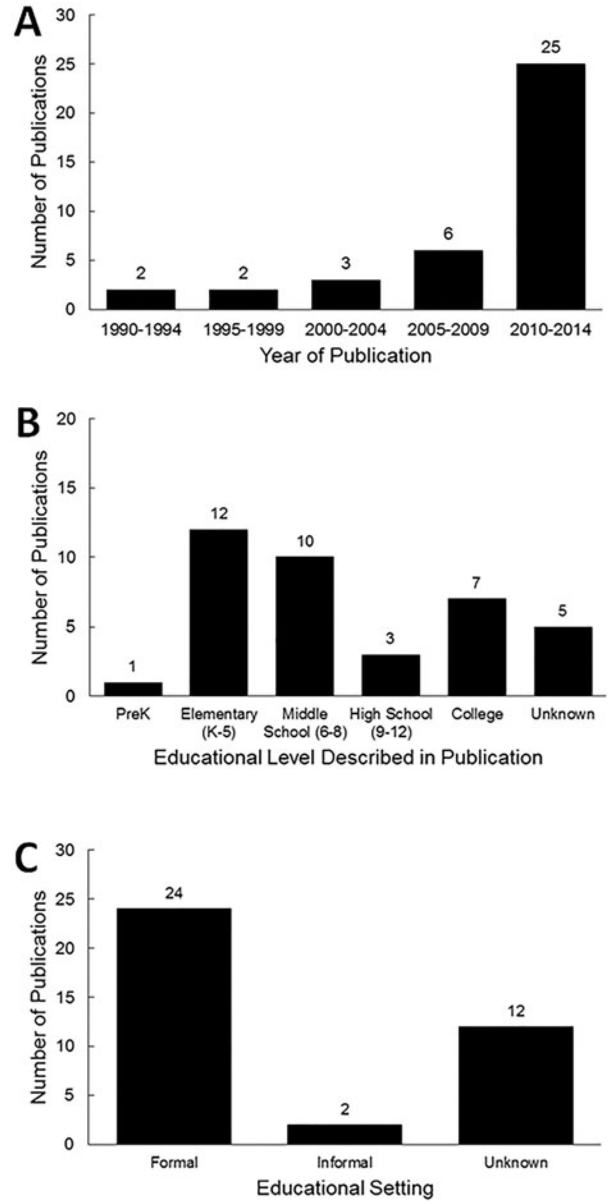

Figure 1. The science, technology, engineering, arts, and math (STEAM) trend in education is on the rise. (A) Over a 25 year period (1990–2014), 38 total STEAM-related papers were published, including ten editorials about STEAM. The number of publications related to STEAM found in Academic Search Premiere more than tripled between the period of 2005–2009 (6) and the period of 2010–2014 (25), indicating a growing trend. (B) Grade level of students described in 28 research-oriented STEAM education publications. Editorials were omitted from this analysis. STEAM activities with students in elementary school (12), middle school (10) and college (7) have received the most attention in the literature. Preschool (1) and high school (3) students have received the least attention. (C) Educational settings described in 28 research-oriented STEAM publications. Editorials were omitted from this analysis. Formal classroom settings (25) received the more attention in the literature than informal learning environments (4) such as museums, galleries, science centers, and libraries. Educational setting was unable to be determined from two publications. The numbers above each bar indicate the number of publications. A single publication may be included in more than one category.

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respectively; Figure 1B). Most published work in our data set has focused on STEAM education in formal classroom settings (24 publications) over informal learning environments (two publications; Figure 1C). The data we compiled correlated with our observations of low participation rates by preschool and high school audiences in our Fall Education Program. For example, in our 2013 Fall Education Program eight percent of the visitors were preschool students and zero percent were high school students.

Project background

To reiterate, the Fall Education Program is a STEAM collaboration between the museum and the gallery at Southern Utah University. Each year faculty in the College of Performing and Visual Arts at Southern Utah University choose an artistic theme for the featured fall exhibition at the gallery. Undergraduate students develop art lessons that revolve around concepts related to pieces in the exhibition. In turn, the museum develops programming based on general concepts related to the art exhibition. In this way, the art drives the science content of the museum program. The Fall Education Program is situated in rural southern Utah and has been serving over 2000 K-12 participants per year from a three-county area (Iron, Washington, and Beaver) since its inception in 2012. Because arts programs in rural school districts such as ours are more impacted by budget than schools in affluent areas (Ruppert 2006) access to arts and science educational opportunities through informal learning environments is extremely important. Through our program, over 6000 students have accessed arts and science resources their schools do not have, and at least 90 teachers have learned how to integrate arts into STEM lessons. Three specific examples from 2012 to 2014 are described below.

Year 1 programming: Quilts and caterpillars

Program content

The gallery's 2012 fall exhibition was *Everything in between: Art quilts, fabric collage, and embroidery*, which showcased 48 contemporary fabric and fiber artists from six countries and 21 states. Students who visited the gallery during the Fall Education Program were able to experience art forms that were new and unusual, including non-functional, wall-hung "quilts" of all sizes and materials, even bronze and ceramic. This prompted discussions of aesthetics versus functionality and the age-old question of "what is art?" Symbols and storytelling were addressed by having students analyze the works, then hypothesize their intended meanings. Not leaving creativity out, many students came up with their own entertaining stories for the pieces, realizing that everyone's perception of art is different. Students became immersed in the art form by creating a temporary "class quilt" installation on a wall in the gallery. Each student was given a fabric shape attached with Velcro to make their contribution to the quilt, resulting in a unique quilt for each class that came through the program. Programming was validated by focusing on Utah's Visual Arts Core, Foundations I, Standard III: creating meaning and content in art (Utah Education Network 2012). After observing the quilts, students discussed themes and interpretations of the art quilts, including the art elements and design principles used to convey them.

The museum based its science programming on two concepts from the gallery exhibition that resulted in a lesson related to the science of color and fiber in nature. Some artists in the exhibition created quilts from silk, and used contrasting and analogous colors to create eye-catching artworks. These easily translated into the science of caterpillar defenses because caterpillars create silk as a defense against being eaten, use contrasting and complementary colors to advertise noxious defenses, and use analogous colors to create camouflage patterns (Grant 2007). Because caterpillar coloration is a function of their interaction with other organisms, the museum focused on Utah's Secondary Science Standards for grades 9–12 Biology Standard I: Students will understand that living organisms interact with one another and their environment (Utah Education Network, 2013).

Year 2 programming: Painting with fish

Program content

The fall exhibition of 2013 was *Jim Jones: The San Blas Years*, a series of paintings from the artist's time spent in the coastal Mexican village of San Blas. The gallery integrated technology into this year's programming with a set of iPads loaded with a color palette mixing app. Students used the app to mix and match

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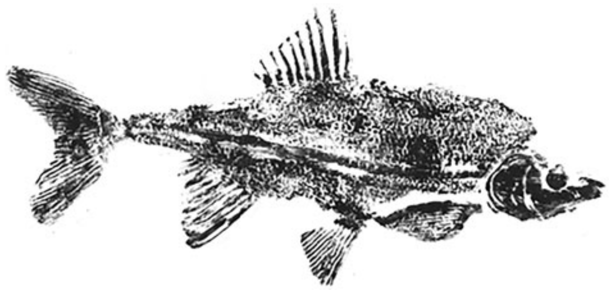

Figure 2. An example of a *gyotaku* print created with one of the replica fish (humpback chub, *Gila cypha*) from the Garth and Jerri Frehner Museum of Natural History.

colors seen in the paintings, which taught them observation skills because many students found that they were able to discover more colors when they looked deeper into the paintings, as opposed to simply glancing at them (K. Heaps, pers. comm.). Students also learned about the artist and why he traveled to San Blas and some of the stories behind his works (Aton 2015). One of Jim Jones's painting in particular (*Untitled*, 1969) represented a funeral service that the artist observed. This led to discussions of how different cultures honor those who have died, and the Mexican celebration of *Dias De Los Muertos*, or the Day of the Dead. Because part of this celebration is to make and decorate sugar skulls (Brandes 1997), students designed their own sugar skull masks from paper plates.

The program focused on the Visual Arts Core, Foundations I, Standard I: making and standard II: perceiving (Utah Education Network 2013). Students evaluated the art and exhibition as a whole, and analyzed the color palettes that Jim Jones used in his paintings. During the gallery portion of the program students made their own art by designing paper sugar skull masks. By creating their own Day of the Dead-themed art, students were able to connect with the artist and imagine how he felt during his time in Mexico. During the museum portion of the program, students created *gyotaku* prints. A *gyotaku* print is a print made with a fish that has been painted or inked then pressed onto paper (Figure 2). *Gyotaku* artists use real fish to create their prints. However, because real fish are not readily available or durable enough for use by thousands of students, teachers often use rubber replicas of fish. The museum created its own set of rubber replica fish for this program because the focus of the fall program was on fish species native to Utah, and commercial suppliers of rubber fish replicas do not normally carry native species. Many of the species native to Utah are sensitive or endangered species, which also limits their use as sacrificial specimens for educational *gyotaku*. We chose *gyotaku* printmaking for the museum's portion of the program because of the natural connection between the coastal environments that were depicted in several paintings from the *Jim Jones: The San Blas Years* exhibition and the natural history of fish. *Gyotaku* also directly relates to sugar skull art because they both have roots in the preservation of memory. Sugar skulls preserve the memory of loved ones, while *gyotaku* preserves the memory of a fish. Furthermore, *gyotaku* was a completely new art technique and process for the students. Exposure to new art techniques fulfills Standard I's first objective to "explore a variety of art media, techniques, and processes" (Utah Education Network 2013). These standards were provided to teachers on the gallery's education page, along with lesson extensions and resources.

The museum based its programming on the gallery exhibition's concept of painting, its theme of seascape paintings from the coast of Mexico by Jim Jones, its sugar skull mask art activity based on the Mexican tradition of the Day of the Dead, fish morphology through *gyotaku* printmaking, and the relationship between skull structure and animal characteristics through a lesson.

Fish can be divided into three ecomorphologies, or shapes related to their environment and species with which they interact. The three basic fish ecomorphologies are: hiders, spinners, and rovers. Students learned about how fish shape is related to diet, swimming speed, and habitat. Students were then introduced to *gyotaku* printmaking, a historical Japanese art form where fish are painted or inked, then pressed onto paper and rubbed to create a print of the fish. Prior to the education program, rubber replicas of species native to Southern Utah were sculpted for the students to use in their prints. Students painted and printed with these rubber fish, then incorporated appropriate backgrounds to match the type of habitat in which their fish would likely be found. Integration of the art of *gyotaku* with the science of fish ecomorphology allowed us to meet Utah's Secondary Science Standards for grades 9–12 Biology Standard I: Students will understand that living organisms interact with one another and their environment (Utah Education Network 2013).

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Year 3 programming: Ceramics and pollinators

Program content

In 2014, students who participated in the third year of the Fall Education Program examined the concept of form versus function through an examination of ceramics and sculpture. The gallery exhibition was *50 from 6*, an invitational ceramics show of contemporary ceramic artworks from 6 states bordering Utah. The fragile nature of the *50 from 6* exhibition posed a challenge for the school tour program, as the students were not allowed to walk through the display for fear of breaking the valuable pieces. To remedy this, the museum housed its own ceramics exhibition that featured pottery and ceramics from local artists, SUU students, and Native American pottery. The art lesson focused on how ceramics were historically made solely for functional purposes, but have evolved into more abstract pieces made to be admired and collected. Students learned how ceramics are made and the different ways they can be finished, including specialty glazes, wood, and *Raku* firing. Younger students then designed their own pots on paper with motifs inspired by the Native American pottery found in the museum. The relationships between form and function were also emphasized during a lesson utilizing the bronze campus sculpture, "Starmaker" by Angelo Caravaglia and Nolan Johnson. The sculpture depicts a girl floating in a hoop, similar to acrobats, with stars extending from her hand. At the time of the education program, the stars had been stolen. We capitalized on this theft by asking students to compare the risks of displaying art in outdoor public spaces to indoor galleries and museums.

We implemented new national arts education standards (National Art Education Association 2014) into our lesson planning for the 2014 program. We provided teachers who visited the museum with copies of the standards, and made them accessible online. Our program applied to each Anchor standard: Creating, presenting, responding, and connecting for every grade level. Through the museum science programming described below, students addressed arts education standards related to the conceptualization of ideas into ceramic artworks by brainstorming how best to approach the medium and how to convey the wings, petals, and antennae of flora and fauna through the clay. They analyzed the differences between 2-D and 3-D artworks and how presenting art in different environments can take its toll on the art itself. Students looked at historical pottery and learned about its context for the people who initially created them, thus revealing more about how the Native American peoples lived. Last, students were able to compare and contrast cultures by examination of the functions and aesthetics of historical and contemporary pieces.

The museum based its programming on the exhibition's concept of form and function by developing a lesson based on how pollinators and their flowers are "formed" to best allow pollination to occur. This phenomenon is called pollination syndrome, and it explains the coevolution of physical characteristics seen in plants and pollinators (Rosas-Guerrero et al. 2014). Students learned specifically about the pollination syndromes associated with bees and bats by comparing the morphologies of flowers to which each pollinator is attracted. They then reinforced their knowledge by matching pictures of bees and bats with the appropriate flower types. To strengthen the lesson that the form of many flowers is related to the form of each flower's pollinator, students created an air-dry clay sculpture of a bee, a bat or a specific type of flower then discussed how their sculpture related to its counterpart. For example, if a student chose to sculpt a bee-flower, they described how the open, flat shape of the flower provided a place for a bee to land, and how the petals would be more likely to be yellow than red because bees favor yellow flowers. This lesson on the relationship between structure and function in plants and their pollinators met Utah's Secondary Science Standards for grades 9–12 Biology Standard I: Students will understand that living organisms interact with one another and their environment (Utah Education Network 2013).

Undergraduate and graduate student involvement

College students involved in the Fall Education Program experienced firsthand the importance of STEAM education and how integrating art and science can excite students, and their teachers, about learning. Undergraduate art education students were docents at the gallery during the programs, where they gained experience in teaching art concepts, lesson implementation, classroom management techniques, and confidence in their own voice and abilities. All of these skills

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were beneficial for students pursuing careers as art educators. Undergraduates who participated in the program were made keenly aware of how informal learning environments such as museums, galleries, and arts centers could be integrated into formal classroom activities by their direct interaction with the museum's programs as docents. For example, docents wrote lesson plans based on the Utah Educational Network Science Standards, and developed museum activities that were brought back into the classroom by teachers. For example, K-12 students brought their fish prints back to the classroom where they could perform research to learn more about each species.

Some student docents became more deeply involved in the education program by writing full-length arts integrated lesson plans that were distributed to teachers who participated in the program, so teachers could continue the discussions and lessons taught in the gallery after their visits. These lessons were inspired by the media, works, and artists from the exhibitions and provided teachers with an external resource to create an in-depth learning experience. For example, during the *Everything in Between: Art Quilts, Fabric Collage, & Embroidery* exhibition, the exhibition featured a beautiful batik art quilt by Anne Munoz, titled "The Perfect Storm." The quilt was inspired by a photograph taken by the Hubble Space Telescope. Our accompanying lesson for teachers explored a simplified batik process using school glue, muslin fabric, and acrylic paint. The subject matter for the lesson was also based on space photography, and encouraged students to look at photographs while creating their own batik art. This lesson intended to provide students with a hands-on glimpse into the painstaking and unique process the artist used when creating the piece.

Undergraduate students from the museum were docents as well and wrote lesson plans related to the science programming that were also given to participating teachers. In these lessons, students would participate in artistic activities based on the scientific topics addressed in the programs, again deepening their learning from the program. One such lesson allowed students to continue exploring insect camouflage and aposematism (bright, warning colors), which they initially learned about at the museum. In the lesson plan, students create a diorama with an environment and an insect which displayed either camouflage or aposematic coloration. As students built their dioramas, they explained their choices in writing, namely the identity of their insects, the environment of the insect, the predators and prey of the insect, and the reasoning why it exhibited specific adaptations and behaviors. This lesson incorporated three-dimensional art making with biology, and allowed students the opportunity to creatively apply and build upon the knowledge learned during the field trip.

As of 2014, both the museum and gallery sides of the Fall Education Program became fully coordinated by graduate students in the Master of Fine Arts in Arts Administration program at Southern Utah University. These students took on the rather large task of organizing lesson writers, marketing, scheduling the program, ordering and preparing supplies, hiring and training docents, requesting teacher evaluations, and ensuring that the program ran successfully. All of these duties coincided with what was learned in the master's degree and provided an experiential learning opportunity at the graduate level. Graduate students occasionally served as docents, which gave them the experience needed to understand fully how to design and manage all aspects of an educational program.

Discussion

STEAM trend in education

As reflected by our analysis of the published literature, the STEAM trend in education is growing by leaps and bounds because of the perception that engagement in the arts encourages independence, creativity, and critical thinking (Lampert 2006; Land 2013; Watson and Watson 2013). Our analysis points to a need for research on the development of programs that are relevant to preschool and high school audiences because STEAM lessons for these groups were underrepresented in the literature and in our school tour scheduling over three years. Our observations indicate that preschool may be missing from the published STEAM literature because teachers have difficulty integrating science into the classroom for this young age. Conversely, instructional time in the fine arts becomes reduced in the high school classroom. For example, Utah mandates only 1.5 credits in Fine Arts out of 24 required credits for grades 9–12 (Utah State Office of Education 2015). However, the main point of STEM and STEAM instructional strategies is to integrate the fields of study, not to parse them out as has been traditional practice. Lessons that seamlessly integrate all five STEAM areas and meet educational standards would be highly prized and necessary for STEAM to be successful.

Informal learning environments such as science museums, art galleries, after-school programs, zoos, libraries, aquaria, summer camps, and nature centers are important because they provide resources (Gutwill and Allen 2012), free-choice learning opportunities (Schwan, Grajal, and Lewalter 2014), and examples of STEAM lessons for teachers (this paper). Surprisingly, our analysis documented few published examples of STEAM learning taking place in informal learning environments. This does not mean that informal learning environments are not engaging in STEAM activities. For example, the Getty Museum provides three STEAM-focused lesson ideas with adapted lessons for grades K-5, 6–8, and 9–12 (J. Paul Getty Museum 2013). These lessons delve into insect anatomy and scientific illustrations, the science of pinhole cameras, and corrosion on ancient Greek bronze statues. All of the lessons come with visual materials from the Getty's collection and link to visual art and science standards for the state of California, and the Common Core's English language arts standards. Given the importance of informal learning environments, more research on their effectiveness and how they contribute to STEAM education is warranted.

Room for improvement

The Fall Education Program is still in its relative infancy, and continues to grow both in participation and interconnectedness between the arts and sciences. Efforts to increase participation from middle and high school groups include graduate student outreach to middle and high schools, for example, by giving presentations about the 2014 *50 from 6* exhibition at targeted schools. In 2014 a select group of middle schoolers were introduced to Art-Science through in-class "maker" activities taught by Southern Utah University undergraduate and graduate students at the museum. While these activities help to increase middle school and high school student participation, they do not address how our work is communicated through the scientific literature. Our review of the literature made it clear that we, as an informal learning program, needed to collect more data on demographics, participant satisfaction, and how learning is achieved through our programming. In 2015 we received funding from the National Science Foundation to bring on a social scientist to help us complete this task.

Conclusions

Over the past three years we have integrated art, science, and technology through our combined programming at the museum and gallery. However, to truly be a STEAM program, we must integrate all five areas of study and that is a tall order. We embedded more complete integration with our 2015 program that integrated the arts of assemblage, book arts, and collage with the science of water conservation and engineering design applied to green infrastructure. For institutions considering a STEAM program, we recommend the following: (1) collaborate with professionals from all five STEAM areas because it is very difficult for one person to know it all; (2) collaborate with students at the high school, undergraduate, or graduate level because they can use the experience and will provide your program with a fresh perspective; and (3) survey your program's participants to learn how you are doing, how they are learning, and what data can then be communicated to the general public and research community.

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