Fostering STEAM

Final Summative Evaluation Report

May 24, 2022

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This material is based upon work supported by the National Science Foundation under Grant Numbers 1713155 & 1713276 Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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This report provides the Fostering STEAM summative evaluation findings and addresses the question: What aspects of the professional development were particularly effective and contributed most to the achieved outcomes? Fostering STEAM, funded by NSF grant "Collaborative Research: Advancing professional development and broadening participation in informal science learning via the integration of the science and art of color," provided professional development to informal educators – librarians, science center staff, and after school program staff – through a three-part professional development program that included: 1) in-person workshops that leveraged the Colors of Nature kits focused on the biology, chemistry, and optics of color to teach about STEAM practices; 2) online, asynchronous learning activities featuring interactive instructional videos around the Fostering STEAM practices; and synchronous sessions to debrief content and foster communities of practice; and 3) coaching to support design work around the development or redesign of STEAM activities. In addition, Fostering STEAM provided in-person workshops to K-12 educators in partnership with the National Art Educators Association (NAEA).

Key Findings

Fostering STEAM provided exceptional professional development that was highly rated by participants and contributed to expected participant learning outcomes. During the five-year grant period, Fostering STEAM provided ten in-person workshops, reaching 197 participants; nine instances of a Canvas-based course, reaching 98 participants, and provided coaching to 40 participants.

Professional Development Best Practices

The in-person Fostering STEAM workshop reflected professional development best practices:

- The professional development was focused on supporting the effective implementation of integration of STEM and art content using STEAM approaches.
- Participants had numerous opportunities for active learning, such as practicing instructional routines to build student engagement and student collaboration (e.g., "think-pair-share") and to engage in the same learning activities they would be using with their own youth learners.
- The professional development created a trusting space for collaboration between the participants and between participants and facilitators.
- Facilitators modeled effectives practices throughout the workshop, such as using questions to uncover prior knowledge, help learners engage, identify with, and interpret the learning experience, and deepen learner thinking around STEAM concepts and practices.
- The facilitators held explicit discussions of implications and adaptations of the pedagogy for their learning environment or classroom throughout the workshop.

Likewise, the online Fostering STEAM course reflected indicators of effective online continuing education and professional development:

- The overall design of the course was made clear to learners at the beginning of the course.
- Learning objectives described what learners will be able to do upon completion of the course.
- Assessment strategies were integral to the learning process and were designed to evaluate learner progress in achieving the course's learning objectives.
- Instructional materials enabled learners to achieve stated learning objectives.
- Course technologies supported learners' achievement of course objectives.
- The course design reflects a commitment to accessibility and usability for all learners.

Finally, coaching supported participants to design new STEAM programs. With the Sitka Sound Science Center, a coach supported the development the Colors of Copper summer camp. With the Pima County Public Library, a coach worked with one individual to design activities for the library system around the phenomenon of fluorescence. With the Seattle Public Library, two coaches worked both with the group of participants to provide follow-up instruction and to coach individuals to integrate STEAM strategies into existing library activities, such as story time.

Participant Satisfaction

Three indicators suggest that participants were extremely satisfied with the in-person workshop.

- The average value to participants of the workshop to their professional position was 9.5 out of 10.
- The average satisfaction scale score was 4.8 out of 5.0.
- Interviews indicated the best parts of the workshop were learning from a child's perspective, the hands-on nature of the activities and the modeling facilitators provided.

ANOVA with a post hoc test strongly indicated that participant satisfaction with the in-person Fostering STEAM workshop contributed to the positive learning outcomes related to Fostering STEAM beliefs; preparedness to develop and implement STEAM activities that support STEAM identity among youth, and preparedness to develop and implement STEAM activities that support a STEAM mindset among youth. Satisfaction with the in-person Fostering STEAM workshop was not predictive of participants' reported preparedness to implement STEAM practices, including developing activities, facilitating activities and using the STEAM design framework.

Table 1: ANOVA results indicate that participant satisfaction was essential for positive outcomes related to participant preparedness to support youth development of STEAM beliefs, mindset, and identity.

Scale	R Square	df	Residual df	F	Sig
Beliefs	0.154	1	41	8.632	0.005
Mindset	0.121	1	41	6.776	0.013
Identity	0.157	1	41	8.793	0.005
Practices	0.032	1	41	2.368	0.132

Two indicators suggest that participants were satisfied with the online course.

- The average satisfaction score was 4.1 out of 5.0. Satisfaction with the course content (learning materials and activities) received the highest satisfaction rating. The time spent on the course received the lowest satisfaction rating.
- Almost 20% of those interviewed reported they didn't finish the online course due to time constraints, the structure of the course, or technical difficulties.

Finally, interviews suggest that coaching participants were also extremely satisfied with the support they received.

- Coaching built trusting relationships among the participants and the coaches. These relationships then enabled the participants to work collaboratively with the coach to develop and improve their lesson plans.
- Participants appreciated the follow-up to reinforce or remind them of the content that they learned during the in-person workshop, particularly in comparison to professional development without any follow-up.
- The combination of the in-person workshop, the online course, and the coaching was important because the workshop and the course laid the groundwork for the team to understand the coaching feedback and input.

Learning and Attitudinal Changes

The Fostering STEAM professional development contributed to significant growth in participant agreement with

- principles or beliefs related to the Fostering STEAM instructional approach;
- preparedness to develop and implement STEAM activities that support STEAM identity among youth;
- preparedness to develop and implement STEAM activities that support a STEAM mindset among youth; and
- preparedness to implement STEAM practices, including developing activities, facilitating activities and using the STEAM design framework.

Table 2: One-way repeated measures ANOVA results indicate that learning and attitudinal outcomes related to STEAM beliefs, mindset, identity, and practices significantly increased overtime from pre-post participation

Scale	df	Error	F	Sig	Partial Eta Squared
Beliefs	1.513	63.526	21.686	< .0001	0.340
Mindset	1.715	72.035	98.996	< .0001	0.700
Identity	1.937	81.374	140.503	< .0001	0.770
Practices	1.868	78.451	101.316	< .0001	0.710

Participants began the professional development with the least preparedness to develop and implement STEAM activities that support STEAM identity among youth and the most knowledge about STEAM beliefs. Most of the participant growth happened during the in-person Fostering STEAM workshop, with only slight increases after the online course and the coaching in the mindset, identity, and practices scales. The beliefs scale decreased slightly from the in-person workshop to the final survey.

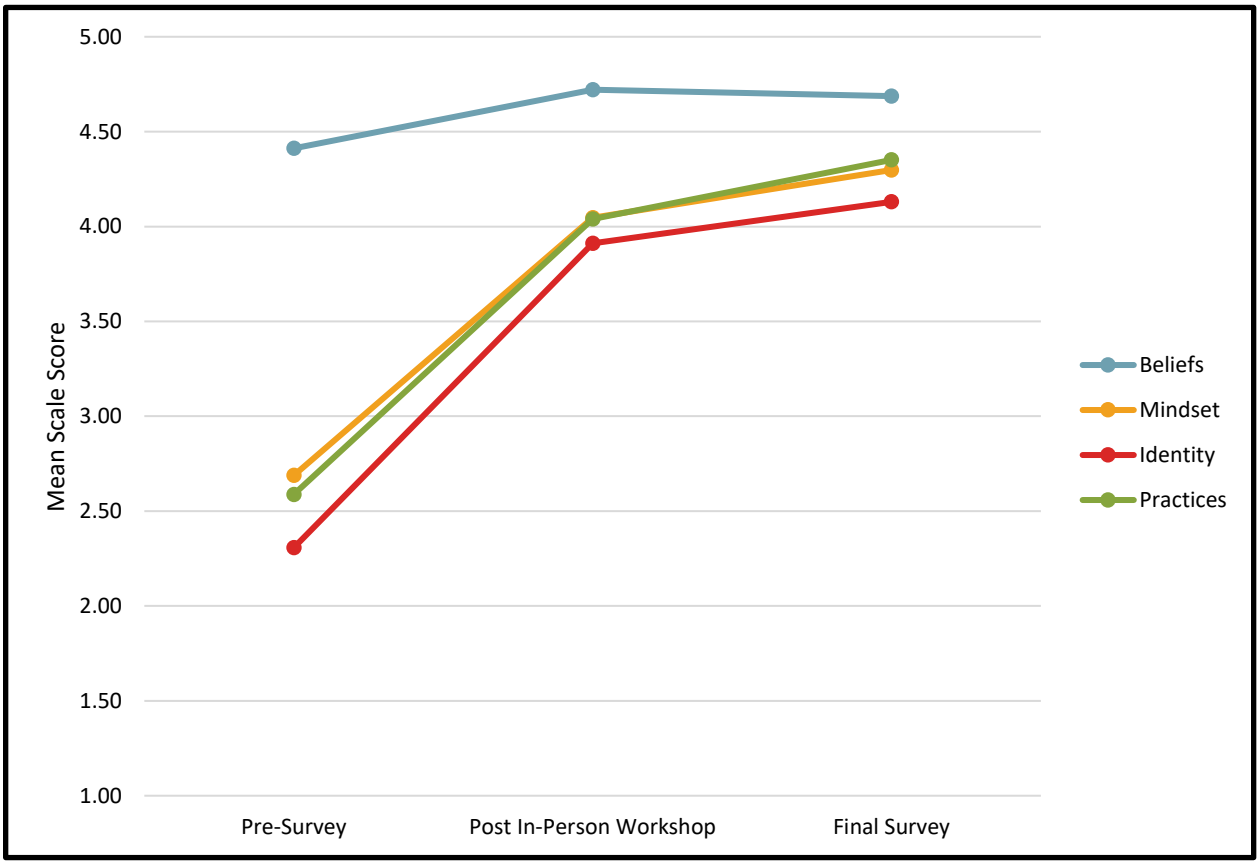


Figure 1: Mean scale scores for STEAM beliefs, mindset, identity, and practices by survey

Implementation

Of the 91 participants who were surveyed six months after starting the program, 39 reported that they implemented a STEAM program or activity or integrated a STEAM strategy into their existing activities or programs. Participants who facilitated STEAM programing reported that they implemented the core STEAM practices identified by the Fostering STEAM investigators, fostering STEAM identity, fostering a STEAM mindset, and developing STEAM activities that use the STEAM practices:

- 67% reported their STEAM programing focused on outcomes that have a personal and/or aesthetic meaning
- 90% reported their STEAM programming included conducting open exploration in the context of both science and art
- 79% reported their STEAM programming included designing with intention
- 72% reported their STEAM programing included iteration through several drafts, prototypes, or models
- 82% reported their STEAM programing included communicating about process and outcomes
- 95% reported their STEAM programing fostered a STEAM mindset
- 64% reported their STEAM programing connected to identity and culture
- 100% reported their STEAM programing engaged youth in close observation

There were not differences in who implemented STEAM strategies by either satisfaction or learning outcomes. Interviews suggest that those who didn't implement activities may not have had the time to develop activities or had other priorities.

Discussion

The purpose of this summative evaluation was to identify **aspects of the Fostering STEM professional development that were particularly effective and contributed most to the achieved outcomes**. Findings suggest that the numerous and varied opportunities for participants to engage in active learning contributed to positive outcomes. During the in-person workshop, participants engaged in the same learning activities as their students – learning from the "child's perspective" was one of the best parts of the in-person workshop and helps participants to understand how their learners may respond to various learning activities. During the online course participants used the STEAM Activity Design Starter to plan or modify a STEAM lesson. With the support of a coach, the participants developed and/or modified activities to implement in their own setting or practiced instructional methods and received feedback from a coach. Asking educators to develop products as part of professional development provides an authentic way for participants to practice new approaches and will improve the likelihood that new approaches will be implemented with the participants' learners.

Findings also suggest that the collaborative spaces for participants to share ideas and cooperate in their learning contributed to the positive outcomes. Enthusiastic, exploration-

focused collaborative interactions occurred throughout the in-person workshop, which provided the participants with numerous opportunities to share their ideas and learn from one another. Coaching sessions were generally described as collaborative, with the coaches and participants also working together to share ideas and learn from one another. The Pima County Public Library participants worked in small collaborative groups to complete the online course. The Pima participants were the most satisfied with the online course. The lack of spaces for other participants to share ideas and collaborate in their learning while online may have contributed to the number of participants who didn't complete the course, even though for many the reason given was lack of time.

There is also promising evidence to suggest the coaching provided scaffolding needed for participants to develop or review new learning materials. Expert scaffolding was also apparent throughout the program in other ways as well. The in-person workshop defined key Fostering STEAM concepts, provided model lessons, and used think, pair, share as a strategy for discussing new information. The online course provided a template – the STEAM Activity Design Starter for participants to use to develop their own lessons. This scaffolding likely contributed to participants' feeling of being supported.

Overall, evidence also suggests that an in-person workshop followed quickly by coaching might be the right combination for ensuring implementation of STEAM strategies. The online course, while beneficial as a stand-alone component, did not significantly contribute to reported learning. It is also possible that the survey used to assess self-reported learning was not sensitive enough to capture changes in participant understanding of the STEAM concepts after the online learning. This is not to say that an online course would not be beneficial, but perhaps an online course could be offered in place of an in-person workshop for those who could not attend in-person, rather than a supplement to the in-person workshop.

Limitations

This evaluation has several limitations, which are common to evaluations of professional development. First, learning data was self-reported, by a relatively self-selected group of individuals, although a some of the participants were required to attend the training. Therefore, we do not know how someone might take up the Fostering STEAM concepts who was not part of this self-selected audience. Second, observations of professional development activities may reflect evaluator-bias. Observations were conducted by two different evaluators with similar findings, but evaluator bias cannot be overlooked. Third, interviews were conducted by a combination of the research team and the evaluation team. The research team also implemented the professional development and provided the coaching. While this created collaborative relationships, it also may have biased participants willingness to honestly share their opinions about the professional development. Finally, while evidence points to the importance of coaching in taking up the

STEAM strategies, the evaluation did not assess the extent to which the participants who did not receive coaching implemented STEAM strategies.

Introduction

This report provides the Fostering STEAM summative evaluation findings and addresses the question: What aspects of the professional development were particularly effective and contributed most to the achieved outcomes? Fostering STEAM, funded by NSF grant "Collaborative Research: Advancing professional development and broadening participation in informal science learning via the integration of the science and art of color," provided professional development to informal educators – librarians, science center staff, and after school program staff – through a three-part professional development program that included: 1) in-person workshops that leveraged the Colors of Nature kits focused on the biology, chemistry, and optics of color to teach about STEAM practices; 2) online, asynchronous learning activities featuring interactive instructional videos around the Fostering STEAM practices; and synchronous sessions to debrief content and foster communities of practice; and 3) coaching to support design work around the development or redesign of STEAM activities. In addition, Fostering STEAM provided in-person workshops to K-12 educators in partnership with the National Art Educators Association (NAEA). During the five-year grant period, Fostering STEAM provided ten in-person workshops, reaching 197 participants; nine instances of a Canvas-based online courses, reaching 98 participants, and provided coaching to 40 participants.

Evaluation Methods

The evaluation, guided by a program logic model used an outcomes-based evaluation approach (Fitzpatrick, Sanders, and Worthen, 2004) to address the following summative evaluation question: **What aspects of the professional development were particularly effective and contributed most to the achieved outcomes?**

Data Collection and Analysis

Observations

Evaluators observed six in-person workshops and the online course. Evaluators took extensive field notes. Field notes were coded for evidence of effective professional development indicators (Guskey 2000, Darling-Hammond et al 2017, Desimone 2009, Blank et al 2007).

- Content focused: Focuses on specific content knowledge and/or content-specific pedagogy.
- Opportunities for participants to engage in active learning: Provides opportunities for interaction that support active learning; participants practice instruction methods; opportunities for planning implementation are provided; activities require participants to develop products/work on activities cooperatively and to share results and feedback with others; practice instructional routines to build student engagement and student collaboration (e.g., "think-pair-share"); engage in the same learning activities they are designing for youth learners.

- Collaboration: Supports collaboration: creates space for educators to share ideas and collaborate in their learning, often in job-embedded contexts.
- Use of models and modeling: Uses models of effective practices; modeling of instruction provides educators with a clear vision of what best practices look like.
- Coaching and expert support: Provides coaching and expert support – recent literature suggests that coaching or other expert scaffolding can support the effective implementation of new curricula, tools, and approaches by educators (as referenced in Darling-Hammond et al, 2017, Gallagher et al, 2017).
- Feedback and Reflection: Offers feedback and reflection focused on ways to implement new learning with their own youth learners.
- Duration: The activity is of sufficient duration, including both span of time and number of hours in the activity.

Quality Matters Non-Annotated Standards form the QM Continuing and Professional Education Rubric, Second Edition. We used the QM Continuing and Professional Education Rubric to score the Fostering STEAM online course. The QM Continuing and Professional Education Rubric is a set of eight general standards and 43 specific review standards used to evaluate and aid the design of online and blended courses that have pass/fail, skills-based or other completion or certification criteria, but do not carry academic credit. The rubric has a scoring system to determine whether a course meets standards. Standards with the highest point values are considered essential and must be satisfied for a course to meet QM standards overall. The eight General Standards of this Rubric are: course overview and introduction, learning objectives (competencies), assessment and measurement, instructional materials, course activities and learner interaction, course technology, learner support, and accessibility and usability.

Written Survey

The written survey assessed the extent to which participants met the following learning and attitudinal outcomes:

- Increased agreement with principles or beliefs related to the Fostering STEAM instructional approach
- Increased preparedness to develop and implement STEAM activities that support STEAM identity among youth.
- Increased preparedness to develop and implement STEAM activities that support a STEAM mindset among youth
- Increased preparedness to implement STEAM practices, including developing activities, facilitating activities and using the STEAM design framework.

We developed four scales to measure these outcomes and used a Cronbach's alpha to determine how much the items on the scale were measuring the same underlying dimension. These scales were included in all surveys distributed. All four scales had a high level of internal consistency (Table 3).

Table 3: Cronbach's Alpha for Fostering STEAM outcome scales

Scale	Number of Survey Items	Number of Cases	Cronbach's Alpha
Beliefs	10	211	0.843
Mindset	5	212	0.947
Identity	5	213	0.942
Practices	8	213	0.955

The Post 1 (after the in-person workshop) written survey included a satisfaction scale to assess participant satisfaction with professional development provided during the in-person Fostering STEAM workshop, and the Post 2 (after the online Canvas course) written survey included a satisfaction scale to assess participant satisfaction with professional development provided by the online Canvas course. Both scales had a high level of internal consistency (Table 4).

Table 4: Cronbach's Alpha for Fostering STEAM satisfaction scales

Scale	Number of Survey Items	Number of Cases	Cronbach's Alpha
Post 1 (after in-person workshop)	11	71	0.845
Post 2 (after online course)	12	39	0.924

The final survey (Post 3), disseminated after design work around the development or redesign of STEAM activities and/or implementing STEAM activities, included several additional questions to assess the extent to which participants implemented STEAM programing. Additionally, the final survey included questions related to administrative support of STEAM ideas and concepts.

Survey Sample: The survey sample is described in the table below. We did not use the Post 2 survey outcome data in the evaluation because the Post 3 survey included both Post 2 and Post 3 questions for the Pima County Public Library participants and for about two thirds of the Seattle Public Library participants. Of the participants, 43 (61% of those who completed the pre-survey) completed the Pre, Post 1, and Post 3 surveys; these data are included in the analysis used in this report.

Table 5: Fostering STEAM respondents by survey and partner

Partner	**Pre**	**Post In-person Workshop**	**Post-Canvas Workshop**	**Post-Implementation**	**Pre, Post 1 Post 3**
		Post 1	**Post 2**	**Post 3**	
Sitka Sound Science Center	11	11	6	7	7

Seattle Public Library	31	31	12	21	18
Fairbanks North Star Borough School District	14	14	0	13	12
Pima County Public Library	15	15	9	6	6
National Art Education Association	93	86	0	0	0
Grand Total	**164**	**157**	**27**	**47**	**43**

Survey Analysis: We analyzed the survey results in several ways. We used descriptive statistics to summarize participant satisfaction for both the in-person workshop and the online Canvas course. We also used descriptive statistics to summarize the reported implementation of STEAM activities as well as the specific STEAM practices participants used.

To assess if there were any differences in satisfaction, outcomes, or implementation among groups (partner organization, whether respondent feels they can teach STEAM effectively, whether respondents implemented STEAM activities), we used an ANOVA or a Welch ANOVA when the assumption of homogeneity of variances was violated. If there were significant differences among groups, we then used post hoc tests to compare all combinations of group differences.

To assess whether participants reached expected outcomes, we used a one-way repeated measures ANOVA to determine if there were differences in the beliefs, mindset, identity, and practices scale scores from before the Fostering STEAM workshop (Pre), after the workshop (Post 1), and after the implementation of STEAM activities (Post 3). We then conducted a Bonferroni post hoc test to determine statistical significance for each pairwise comparison.

Interviews: The interview protocol collected both evaluation and research data. The evaluation data included participant descriptions of STEAM strategy implementation and perceptions of the professional development. We coded 38 interviews using Atlas.ti and analyzed for common themes.

The findings are organized by the professional development element. First, we look at the in-person workshop, then the online course, and finally we look at the coaching element. In section four of the findings section we report on the overall participant learning and in section five of the findings section we report on the implementation of STEAM activities.

1. In-Person Workshop

Over the course of two days, the in-person Fostering STEAM workshop focused on the following STEAM practices:

- close observation
- focusing on outcomes that have a personal and/or aesthetic meaning
- conducting open exploration in the context of both science and art
- designing with intention
- iteration through several drafts, prototypes, or models
- communicating about process and outcomes
- strategies for integrating art and science in instruction
- specific ways in which art and science share common practices
- strategies for supporting STEAM-linked identities in learners
- strategies for supporting a steam mindset in learners, such as emphasizing process over product.

1.1. Effective Professional Development

The in-person Fostering STEAM workshop reflected indicators of effective professional development. It was content-focused, provided numerous opportunities for active learning and collaboration, modeled instructional strategies, and integrated time and space for feedback and reflection.

Content-Focused

The workshop content included chemistry, biology, and optics as well the core STEAM practices. STEAM practices were reinforced during open exploration of materials, during moments when participants ask questions, during debriefs, between participants as they work through their own processes independently or in table groups, and during larger debriefs at the end of each investigation.

The following exchange during a Suminagashi debrief shows facilitators helping to reinforce these STEAM practices, tying participant statements back into those concepts:

> *Participant 1: Having four pieces of paper – we come from a sense of lack all the time. Having the experience of having different materials was good.*

Facilitator 1: *It's so true when you have authentic experiences -- the materials make a difference.*
Facilitator 2: *Lab coats […can have] negative connotations.*
Facilitator 3: *Putting it on as an authentic reason to put it on is very identity-building [….] but using it as a symbol can have a negative effect.*
Facilitator 1: *You can use any resources [...] it's the questioning process that is important.*

Between Investigations 1 and 2, one of the facilitators spent additional time grounding participants in the concept of STEAM identity and what measures participants have the power to take to affect the degree to which their youth identify with a STEAM identity. She jokingly asked if students "*will come into a program […] and magically come out with a STEAM identity*" – to which the answer was no. She then followed up by asking: "*What are the small nudges that we can build into our programs, specific strategies [to] allow students to make choices?*"

She then elicited and often reworded responses from participants, who collaboratively came to the following list:

- position students as emerging experts,
- reflect on how science and art connect to everyday life,
- use STEAM practices that were specifically designed to build identity.
- Agency: allowing students to make substantial decisions around their own learning and have those really be authentic choices that they want to make

Facilitators focused not only on the STEAM practices, but ensured that STEAM content knowledge itself – the science and art concepts – also received enough focus. This was most commonly accomplished through questioning participants while facilitators introduced concepts, and through reinforcing target concepts that participants surfaced while reflecting on their activity work. The following example is from a discussion during a transition within the cabbage paper investigation. This conversation took place just after participants finished exploring by creating test strips, and were about to shift to creating a "painting" on a new piece of cabbage paper.

Facilitator: *We are going to talk about pH. What are some things that you know about pH?*
Participant 1: *It can be used to test a bunch of substances.*
Participant 2: *It's on a scale.*
Facilitator: *It's on a scale of one to 14. Seven is neutral. Acidic things are on the lower end of the scale like hydrochloric acid. You might want to guess where they are. […] If you want to quantify it you*

can use a pH strip to quantify it. Then we are going to go on and use the evidence you just created to create some art.

Active Learning

Active learning was clearly addressed during the in-person workshops. Facilitators taught five model lessons with participants engaging as learners. These lessons were developed and refined through a series of 2-week summer academies for girls around the theme "Colors of Nature," which focused on the biology, chemistry, and optics of color. Participants received copies of the lessons, which included instructional approach, art and science background information, materials and supplies needed, and step-by-step instructions. Descriptions of the investigations below are drawn from these lessons.

- Investigation 1: Participants used Suminagashi, a traditional Japanese marbling technique, to build awareness of central, overlapping practices in science and art, such as observation and experimentation. The technique also reinforces that "mistakes" can have positive outcomes.
- Investigation 2: Participants explored a chemical reaction, and its effect on color, through the creation of a watercolor painting. Using red-cabbage juice as a painting medium, participants explored adding acids and bases to change the color of the pigment in the red cabbage juice and expand their painting palette. A change in color is one of the indications that a chemical reaction has occurred when substances are mixed together. The lesson focused on the following STEAM practices: close observation; focusing on outcomes with a personal and/or aesthetic meaning.
- Investigation 3: Participants explored how light interacts with objects through reflection and absorption, resulting in most of the colors we see in the world around us. Participants then applied their knowledge of reflection and absorption to develop models of dynamic set designs that change when viewed under different colored light sources. The lesson focused on the following STEAM practices: iterating through several drafts, prototypes, or models.
- Investigation 4: Participants explored why animals have the colors they do and considered how different coloration strategies help them survive and reproduce. They then analyzed the formal elements (shape, color, pattern, and value) of animal camouflage and used their observations as a guide to design an effective camouflage pattern for a specific habitat. The lesson focused on the following STEAM practices: designing with intention.
- Investigation 5: Participants explored an adaptive coloration strategy that is common in plant and animals: ultraviolet signals that are seen only by animals with eyes that can detect UV. Then the participants designed a stop motion animation that models the function of UV "secret signals" in the survival and reproduction of certain plants and animals. The lesson focused on the following STEAM practices: communicating about process and outcomes.

Participants were extremely engaged in these activities. The following experimentation was observed between two participants during the Suminagashi investigation:

> *Participant 1: I wonder if you dunk them in this way what would happen? I wonder if it would [change if] attached vertically. I am going to put all of the colors in -- add the final color...*
>
> *Participant 2: [mixing the colors] This is so cool-- now I wonder if you do it this way? I wonder if we should do this? Oh that is cool too… I wonder if I do it this way. Maye not so much on this side. If the water was a little deeper...maybe we should put more water in? [Putting more water in the bucket] It kind of looks like glasswork. It's really spreading out. Look at that little bubble? I wonder if you just submerged it? Let's try dunking it under the water….that is actually really cool. It's very similar to ...I wonder what the basis is. Would it work for eggs?*

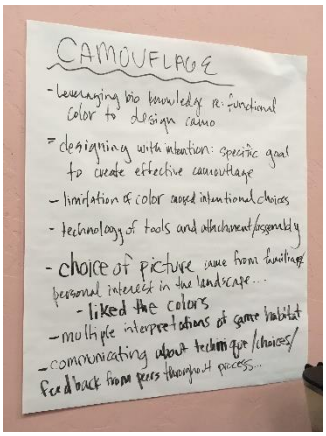
Within each investigation, activities were carefully structured to maximize opportunities for participants to engage in the same active learning activities that would be asked of their students. For example, for investigation 4: designing a camouflage fabric swatch, participants were guided through a multi-part process, beginning with the open-ended questions "What is your favorite animal?" and "What color is it and why is it that color?" Participants shared their thoughts with the whole group as they felt like it, stating things such as "bees, but I have no idea why they are what color they are" and "fox […] you'd think they'd be green, but no. […] I have no idea why they're red."

Facilitators then handed a set of cards with animals on them to each table with the instructions to "talk about why each animal is the color that it is. Think about habitat." Participants could divide cards into categories if they wished; all tables engaged in robust conversation about how each animal might be benefitting from its coloration. Facilitators then elicited from participants 'what categories did you come up with?" together as a whole group, providing additional active participant engagement in communication of concepts, sharing small group results with the whole group. Participants were highly engaged and shared many ideas, including the following quotes captured in field notes:

- *some are brightly colored…others are hard to see because they blend in so well*
- *protection for the ones that camouflage very well, and protection slash hunting, for the ones that have it for both.*
- *we talked about mating vs hunting vs protection.*
- *we broke things down into two major categories – wanting to scare predators off, and blending in.*
- *are lobsters red to lobsters?*
- *we too had difficulty with the skunks*
- *protection in numbers. […] a big blob of flamingos looks like one very large animal.*
- *we also had questions about the lobster*

As part of wrapping up that segment of Investigation 4, a facilitator used participants' engaged conversation to frame a main takeaway of the investigation: "some of you had trouble categorizing them. [… that shows that] colors have more than one function."

Left: Participants choose colored paper for swatch design. Right: Habitat image and completed swatch.



Participants were given the final task for this investigation: choose an image of a habitat from the different options on the back counter, and create a swatch of "fabric" to camouflage the wearer against the background. Participants could choose three different colored pieces of paper to use in their fabric swatch design, but were not limited to these materials (some chose to also draw on their swatch, for example). Participants worked independently but frequently talked with each other to bounce ideas off table partners; some looked at work being done at other tables. In at least one instance, conversation shifted to other ways humans camouflage themselves, such as when travelling abroad and not wanting to be singled out as American. Facilitators engaged participants as they circulated, asking questions about design decisions. Participants were then asked to share with the whole group, proving additional opportunity to articulate their design choices. Finally, to bring together the highly engaging active learning of the various stages of Investigation 4, the debriefing engaged participants in active reflection on how the activity they did enacted the STEAM practices, how it fostered STEAM identity and mindset, and how these might apply in participants' own work with youth they serve. One facilitator wrote down salient observations of participants as another facilitator elicited responses for each discussion topic.

Participants showed robust engagement with each activity and discussion asked of them. For example, during the card sorting activity described for Investigation 4: designing a camouflage fabric swatch, sample participant speech recorded in field notes included the following exchange at one table:

> *Participant 1: is there a moth on that?*
> *Participant 2: it feels like… they need more context. Is this [lobster] close to the surface or […] maybe the predators don't see very well, so it doesn't matter what color he is.*
> *Participant 3: he's a faker; and this might be 'I look like the dangerous one!'*
> *Participant 1: to me that looks almost like an owl's face."*

A few moments later, someone at this table talked about coyotes being camouflaged. Participant 3 then enthusiastically shared a personal anecdote related to coyote camouflage: "I'll be going [on a trail] and then like, 'oh! there's a coyote right there.'"

When faced with frustrating challenges, librarian participants remained engaged, often talking through the problem with their table partners. During the stop-motion film activity of Investigation 5, the following dialogue was recorded in field notes:

> *Participant 1: well, should we get started?*
> *Participant 2: [iPad in hand; puts paper with scene on the floor.] how's this gonna work? [Tries to make iPad cover bend back further.] Ugh, I wish this flap wasn't here. [Aims iPad at paper] it's too far. [puts paper back on table; shoots a few frames.]*
> *Participant 3: Ok, now stop 'cause I'm trying to figure out where the speech bubbles go. [They talk through ideas for how to handle placement of speech bubbles] I think we can… [demonstrates a possible solution]*
> *Participant 1: Oh that's better, yeah.*
> *Participant 2: [Enthusiastically] Yeah.*

Then, this same group was observed completing their video at the end of the work period for this activity; the same participant has had the videographer role for the duration of the activity, and tackled a difficulty without frustration. She simply stated what the new problem was – how to repeat a specific character motion a few times – and talked herself through the task while maintaining enthusiasm. That enthusiasm was matched by the whole group:

> *Participant 2: We should do one where all the legs come off a little bit, they're so excited.*
> *All participants: Wooo! [Laughter; wave hands in imitation of happy spider legs]*

Participant 2: We should do that a few times—oh, maybe I can just copy it
Participant 1: Yes, and then the spiders [go off paper] with the baby spiders trailing behind.

For homework between the first and second days of the workshop, participants were tasked with bringing in a personal STEAM object. The task was open-ended; participants could bring in anything that they interpreted as representing STEAM in their own personal lives. Day 2 began with participants sharing with their table partners about their object, then sharing out with the whole group. Through this activity, participants actively engaged in the core STEAM practice of focusing on personal meaning. They also practiced communicating their object selection process, and were able to do so twice, both with their table partners and then to the whole group, potentially gathering listener feedback each time.

The hands-on activities were one of the most valuable parts of the workshop and likely contributed to participants' increased learning about implementing STEAM practices with youth. One aspect of engaging in the lessons as learners that stood out was the idea of being "uncomfortable" as a learner, not knowing all the answers or how to complete an assignment. One participant compared their experience to the youth experience,

> *Yeah. I think as an adult and a parent and a teacher it was valuable and it's constantly a good reminder to be like this is so uncomfortable. I'm really good about critiquing literature. I remember there was one where we had to draw on a bookmark for the colored ink. Somebody was just like God dammit I don't want to do this. She was so good and I just want to stop and I was like, this is what my kids feel like every day. We experience that every once and awhile as teachers, but very rarely am I as an adult forced to step out of my comfort zone in that way. A lot of times kids aren't given the option. So that's a good reminder and I don't know if that was what the intention was with the lesson, but that was definitely something that hit hard with me.* (Seattle Post 33)

Another explicitly reported that engaging in the lessons gave them confidence to teach the lessons without a strong STEM background.

> *So that, I guess I really like the in-person STEAM training. I think that I learned better that way, and I really... so, I guess I just appreciated, for me, a lot of the hands-on activities that we did as a group. For me, that was my favorite part, was just getting... For me, just getting a little bit more comfortable doing some of these activities, and helping me feel a little bit more confident that maybe someone without a huge scientific background, that I could lead these types of activities, I didn't necessarily have to be an expert,*

that I could help facilitate and help kids just ask questions, and be sort of more of a facilitator, rather than thinking of myself as the teacher with all the answers. So, I think that, for me, the best parts were just the hands-on learning, and helping relax some of my anxieties about needing to feel like an expert, in order to lead these programs and activities. Or needing to do it the right way, or one right way. (Seattle Post 15)

Collaboration

This example of a table group's interactions from Investigation 1: Suminagashi is emblematic of the types of enthusiastic, exploration-focused collaborative interactions that occurred throughout the workshop:

Participant 1: Oooh, that looks cool – or will it? I don't know.
Participant 2: [Experiments with dipping folded paper] Aaaand you get nothing. Aaah kay. [disappointed sound]
Participant 3: I wonder …try a swirl. Gonna just swirl swirl swirl, swirl, and see what happens.
Participant 1: Well we learned when you mix all the colors together, it looks like poo.
Participant 3: I like this – I wonder if you could write something?
Participant 2: You want me to go get fresh water?

While Participant 2 retrieved fresh water, the rest of the table was excited about trying to write something in ink during the drip-in-water process and seeing if it will transfer to the paper legibly. Participants thought together about what might work for writing; one participant said *"you think painting on top of the water like this?"* (demonstrates with brush).

While all investigations featured ample collaboration opportunities that participants engaged in with enthusiasm, the stop-motion animation task garnered some of the most enthusiastic, fruitful collaborative moments of the workshop. Participants were tasked with creating a stop-motion animation video, from story concept through storyboarding to set design to video capture. This intensively collaborative process resulted in some minor frustrations (as described elsewhere) but ultimately led to four clever, engaging, narratively rich videos. Field notes and photos reflect that the process was highly collaborative for all librarian participants. Laughter and enthusiastic dialogue was emergent from all four groups, with all members taking a turn with hands-on tasks at least some of the time. In this photo example, the group's participants can be seen all physically supporting the production of the video.

During the stop-motion debrief, when a facilitator asked if there were any parts of the process participants found exciting, several participants reflected explicitly on being excited by how readily and effectively everyone collaborated to create videos:

- *it was fun seeing it all come together.*
- *I really liked the collaborative effort…everybody had to do their part.*
- *I was surprised everyone COULD come up with something, and work together, and film it.*

Participants also shared resource ideas during the debrief segments of this investigation (one group featured music in their video – one of the group members noted: "that [song] was from Freegle everybody!"). Resources were also shared during other moments throughout the two-day workshop as opportunities arose, such as when one participant described how his personal STEAM object, a kazoo, was something he used to help youth transition between tasks as well as to provide funny sounds and moments of levity for when someone makes a mistake.

Modeling

Modeling effective instruction and using the Fostering STEAM strategies was evident throughout the in-person Fostering STEAM workshop. The facilitators modeled numerous techniques throughout the in-person workshop, particularly using questions to uncover prior knowledge, help learners engage, identify with, and interpret the learning experience, and deepen learner thinking around STEAM concepts and practices. The following exchange occurred during the facilitation of the Painting with Chemistry lesson, providing an explanation about why she is asking the questions.

Facilitator: *The central question is, how can we manipulate chemistry to paint….we want to prompt learners to get some opportunities to get some ideas…I am curious what happens when you mix two substances together. I am wondering what some questions you might use to help your students articulate open ended question ….what will happen? Let's keep those questions in mind. So go ahead and do some experiments with the cups.*

Facilitator: *What do you think is going on here? What do you think was happening to make that blue? What were the substances that made blues and greens? This is an opportunity to transition between the art project and the science -- many learners are familiar with acids and bases, but you can talk about the substances that changed to blues and greens share common characteristics and those that have pink share common characteristics. What do scientists use other than pink cabbage paper? Why else would we want to understand pH?*

Participant: *pH testing of water.*

Facilitator: *Why do you want to test pH?*
Participant: *Ocean acidification. Most high school students have a hard time understanding acids and bases and it hard to understand that leap.*

In another example, the facilitator used questioning to uncover prior knowledge about the functions of color.

Facilitator: *What were some of the advantages that the colors your animals had….what do you think the role of color is in survival and reproduction. How does it help them in their environment?*
Participant 1: *We have a group more advertising of their defense so other critters wouldn't want to eat them….other that are avoiding being eaten or ambush predator. Then we have the bee that has bright yellow stripes, but also matches the environment…*
Facilitator: *What do we want to call that...warning.*
Participant 1: *Then we looked at this of the lobster -- if you looked at this underwater with red light you couldn't see it….*
Facilitator: *Can animals have multiple strategies with their colors?*
Participant 2: *They can have finery they display.*
Facilitator: *What do you want to call that [wrote the words on the board] functions of color -- camouflage, warning, display (disco finery).*
Participant 3: *We also had another one that could mimic another snake to mimic a snake that was poison –*
Facilitator: *What do we want to call that category? Deception? (eye spots and mimic patterns).*

The facilitators also modeled the "gallery show," which relates to a core STEAM practice (communicating about process and outcomes) and gives the participants a chance to talk about their design process and iteration.

Facilitator 1: *Let's gather around the gallery space...we had a lot of underwater scenes….Does anyone want to share?*
Participant 1: *With mine...the red just really jumped out at me. I wanted to pull that out...there are some yellow things in there...looking back if I had some black to do shadows…*
Facilitator 1: *Would you change the colors?*
Participant 1: *I would make the brown much darker -- keeping the red as a background color.*
Facilitator 1: *How about the rest of the group -- what elements work for you. What were effective choices?*

Participant 2: *They all have the same colors used.*

Facilitator 2: *[explaining the importance of the process] What this provides a great opportunity --this activity allows time for iteration….either improving the one that they created and changing it or making a new one.*

Within the "gallery show," the facilitators also emphasized other core STEAM practices: providing learners with choices and the chance to iterate.

Participant 1: *I am going to explain why I cheated. I used the tracing paper as my other value of white. It does do shading.*

Facilitator 2: *There really is not cheating…..I love all of those innovations -- there is always a boundary -- if you give all of the extra colors gives the learners choice….there is really no reason to let the group try it. So often learners come with the expectations that there are rules….really the limitations are about instructions and getting started. But then to look around you and see what else there is to use...*

Facilitator 2: *Back to the facilitation aspect….it is very useful so that when there are innovations that arise, they can adopt or share techniques and having the opportunity to make revisions is very important. I also want to connect this back to this morning to it was really exciting hear your diverse experiences. And the emotional connection to your objects was very important and apparent and you knew a lot about those things and had expertise connecting that to this….were there moments when you were choosing one option over another, to deepen your own connections.*

Feedback and reflection

The in-person Fostering STEAM workshop also provided ample time and expertly facilitated feedback and reflection. The facilitators held explicit discussions of implications and adaptations of the pedagogy for their learning environment or classroom. Below is an example of this reflection. After the Painting with Chemistry investigation, one of the participants raised the idea of using the cabbage painting process to explore ocean acidification. The facilitators further explored this idea with the group:

Facilitator 1: *How would you integrate this into a lesson about acidification of the oceans?*

Participant 1: *You could create a map –*

Facilitator 1: *Maybe you could test the water around here and use the painting project to map it.*

Participant 2: *You could use this as an introduction or just an art project -- coming back to it.*

Facilitator 2: *This is a really adaptable activity -- if you want to think about the larger concepts -- is it gardening, pH of the ocean...these chemical processes are important to know for everyday reasons.. The concepts are not the end all be all….there is so much more beyond the chemical processes. Finding creative ways to learn about the world through experimentation.*

Participant 3: *I was thinking about the gradient...you could think about the value….the gradient of blues or pinks. Think differently about how to present.*

Facilitator 2: *That connects to the STEAM practice -- using experimentation to create something that has meaning to the person...*

After this light reflection and absorption activity, there was more explicit feedback related to facilitating this project with students.

Facilitator: *How did you make choices in your group? How did your design evolve to what you showed?*

Participant 1: *Did you make a conscience decision to start us under the red light? So then we started with the scary things.*

Facilitator 2: *I always start with the red light -- so then you work totally with the values….with the green and blue light you can tell what paper is what. That would be something to test...in an iterative process. I would love to see these on a full-scale theatre stage.*

Participant 2: *I was curious why you didn't give us white paper. Also it was very open ended -- does that open endedness work with students. Make a set. You have something in front of you and good luck...*

Facilitator 2: *You are going to change it based on the context...you might want to have more constraints….I have noticed that doing this with kids, sometimes everyone has a good idea what to do and other times, there are groups that need more guidance. Also something I have learned that a lot of this project is trial and error and iterating through design...as you work through the lights you start to make revisions….that is something that we encourage for all of these projects….if you have multiple days to work on something going back to revise with these projects is really valuable.*

Finally, at the end of the workshop the facilitators modeled a round robin brainstorming session to discuss ideas for collaborating on projects for the youth they each work with – pairs of participants were asked to address the following topics:

1) Can you think of activities that would benefit from collaboration?
2) Shared inquiry -- what kinds of questions are you exploring related to STEAM? What questions do you want youth to be asking?
3) Shared expertise - what kinds of expertise can you share with each other? What KINDS of expertise can you share with the youth from your colleagues' organization?
4) Shared topics or themes- are there particular topics/themes that you feel would lend themselves to shared programming? Which of your current programs would benefit from collaboration?

1.2. Participant Satisfaction

Participants were extremely satisfied with the in-person workshop. The average value to participants of the workshop to their professional position was 9.5 out of 10. And the average satisfaction scale score was 4.8 out of 5.0. The following table summarizes how the participants rated each of the satisfaction questions.

Table 6: In-person Fostering STEAM Workshop participant satisfaction descriptive statistics

Survey Item	***N***	***Mean*** [1]
Activities were carefully planned.	153	4.79
Objectives were clear.	152	4.50
Time was used effectively.	152	4.60
The presenters were effective instructors.	153	4.78
The presenters were well prepared.	153	4.84
Questions and concerns were addressed.	153	4.74
Participants were active learners.	153	4.73
Interactions between presenters and participants were collegial.	153	4.87
Interactions among participants were collegial.	153	4.82
The facilities were conducive to learning.	152	4.56
An appropriate balance between presentation and interaction was achieved.	153	4.76

[1]Mean is calculated from responses where 1=strongly disagree, 2-disagree, 3=neither agree nor disagree, 4=agree, 5=strongly agree

A one-way ANOVA determined that there were statistically significant differences among partner sites (Welch's[1] $F_{(4,40.553)} = 3.720$, $p = 0.011$), and the post-hoc tests concluded that only one pairwise comparison was significant. The Games-Howell Post Hoc test concluded

[1] The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p = 0.004$), and we used the Welch ANOVA.

that the results for the Pima County Public Library, which had the highest satisfaction mean (M = 4.87, SD = 0.15) were significantly higher than the results for the Seattle Public Library, which had the lowest satisfaction mean (M = 4.60, SD = 0.33, p = 0.004).

Table 7: In-person Fostering STEAM workshop satisfaction scale mean scores and descriptives by partner

					95% Confidence Interval for Mean	
Partner	**N**	**Mean**	**SD**	**SE**	**Lower Bound**	**Upper Bound**
Sitka Sound Science Center	11	4.79	.33	.10	4.57	5.00
Seattle Public Library	30	4.60	.33	.06	4.48	4.72
Pima County Public Library	15	4.87	.15	.04	4.79	4.95
FNSBSD After School Program	15	4.70	.30	.08	4.54	4.87
National Art Education Association	82	4.75	.51	.06	4.63	4.86
Total	153	4.71	.31	.04	4.63	4.78

Likely the most appreciated aspect of the in-person workshop was the hands-on way in which the participants participated as learners in much the same way their own learners would. By learning engaging in the lessons, participants gained confidence in doing the lessons as well as a better understanding of the child's perspective.

> *So that, I guess I really like the in-person STEAM training. I think that I learned better that way, and I really... so, I guess I just appreciated, for me, a lot of the hands-on activities that we did as a group. For me, that was my favorite part, was just getting... For me, just getting a little bit more comfortable doing some of these activities, and helping me feel a little bit more confident that maybe someone without a huge scientific background, that I could lead these types of activities, I didn't necessarily have to be an expert, that I could help facilitate and help kids just ask questions, and be sort of more of a facilitator, rather than thinking of myself as the teacher with all the answers. So I think that, for me, the best parts were just the hands on learning, and helping relax some of my anxieties about needing to feel like an expert, in order to lead these programs and activities. Or needing to do it the right way, or one right way. (Interview 5)*

> *Yeah. I think as an adult and a parent and a teacher it was valuable and it's constantly a good reminder to be like this is so uncomfortable. I'm really good about critiquing literature. I remember there was one where we had to draw on a bookmark for the colored ink. Somebody was just like God dammit I don't want to do this. She was so good and I just want to stop and I was like,*

this is what my kids feel like everyday. We experience that every once and awhile as teachers, but very rarely am I as an adult forced to step out of my comfort zone in that way. A lot of times kids aren't given the option. So that's a good reminder and I don't know if that was what the intention was with the lesson, but that was definitely something that hit hard with me. Yeah, yeah. (Interview 4)

So one of the most important and interesting things I learned from the STEAM training was how easy it is to try. I think part of what was really scary about STEAM was just these big concepts, and then when we were at the training we were doing these wonderful the cabbage ink drawing, and the cyanotypes elicited with the water. I think there was this like, "Wow, this is actually very easy to try and figure out." And I think it made the idea seem less scary and more approachable for myself, in terms of how I viewed what I could do. So, I think that was the most important takeaway, because that translated to the types of things I was willing to do this summer and how comfortable I was standing in front of another group of people and trying to convey that across. I think that really helped me. (Interview 44)

A second, equally important aspect of the in-person professional development was the way in which the facilitators modeled their instruction.

Having the actual words thing, Oh, this is what you could say to kids now, oh, this is how you can approach or set it up so that kids discover these things. Not that we're teaching them, it's how to set it up so that kids are discovering it. And then encouraging that discovery. It seems forced in slack sometimes when you're doing it in trainings, but when you do it in person and see the aha moments, I just find, and I've heard from other people that that was really reinforced so that you had the actual terminology. (Interview 8)

Sure. I think it was something I'd kind of talked about or heard about before and kind of used, but it's nice to be able to go through it and basically, it's some examples of ways to talk about it. So I liked basically where we were like, if kids are having, if they're feeling down about what their project looks like and coming out negatively, we can be like, "OK, well you know what? No one's perfect and we just keep working at it. This is great." I really like the discussion of the growth mindset kind of thing, where you actually talk about it and, and explain basically as I would explain, giving me some ideas and tips on how to explain it to kids where, we're working on this thing and we may not get it right away, but it's something we can work towards and we don't have to be perfect. You just keep iterating and keep getting better and then go from there. So that, and I like the hands-on and part where you

actually brought in activities that we could bring out to the kids. (Interview 12)

Yeah. I would have to say the very best thing for me was the examples of the instructors. I watched very closely how the instructors broached the topic, like the next topic. So when they started for example, the Suminagashi or the camouflage or any of the programs, they didn't come in heady and all full of themselves. I'm going to impart something on you now. Even the way that they approached and they opened discussions and started the discussions were what are the materials in front of you and take a look at those and explore those a little bit. You've got some vials and you've got some Q-tips you know whatever. What do you think of that? Does that look really complicated? What do you want to do with those? You have a natural inclination to put the Q-tip in the water. I'm not telling you to, we're going to be doing something real soon. But bringing you and focusing you on the table, focusing on the curiosity, getting the curiosity started. It wasn't like now I'm going to stand up here and talk to you and I'm going to blah, blah, blah, blah. It really got to let's get to what you want to know. You want to know why you got that crap on your table, let's explore it a little bit but when it comes to library and it comes to programs, the STEAM programs, you don't want to be heady about it. You don't want to beat them over the head with it. Again, you want it to be approachable. So, I learned that from the instructors really well and then everything was in increments. It wasn't like I want to just tell you everything out front and then I'm going to let you go. They put it into digestible chunks and that was a really important part of it too. (Interview 43)

1.3. Participant Learning and Attitude Changes

After the in-person Fostering STEAM Workshop, participants reported significant increases in their agreement with Fostering STEAM beliefs, preparedness to develop and implement STEAM activities that support STEAM identity among youth, preparedness to develop and implement STEAM activities that support a STEAM mindset among youth, and preparedness to implement STEAM practices, including developing activities, facilitating activities and using the STEAM design framework.

Table 8: Paired samples t-test results indicate that learning and attitudinal outcomes related to STEAM beliefs, mindset, identity, and practices significantly increased for participants after attending the in-person Fostering STEAM workshop

Scale	N	Pre mean	Post mean	Mean change	Std. Dev	T	df	Sig.
Belief	147	4.38	4.74	0.36	0.33	13.044	146	< .0001
Identity	149	2.45	4.15	1.69	0.79	26.235	148	< .0001
Mindset	149	2.81	4.24	1.43	0.79	22.133	148	< .0001

Practices	149	2.63	4.25	1.61	0.83	23.789	148	< .0001

Using a one-way ANOVA, we concluded that there were no statistically significant differences in participants preparation to implement Fostering STEAM practices with youth by partner site (Welch's[1] $F_{(4,33.819)} = 0.617$, $p = 0.654$); participants beliefs about STEAM (Welch's[1] $F_{(4,35.098)} = 0.925$, $p = 0.460$); preparation to support a STEAM identity among youth (Welch's[1] $F_{(4,33.938)} = 1.200$, $p = 0.329$); or in participants preparation to support a STEAM mindset with youth (Welch's[1] $F_{(4,33.493)} = 2.259$, $p = 0.083$).

2. Online Course

The online Canvas course continued where the in-person Fostering Science course ended, diving deeper into STEAM practices, mindset, identity and equity in STEAM, facilitating STEAM activities, designing STEAM activities, and using questioning strategies, with the central focus on developing STEAM activities or modifying STEM activities to be STEAM activities.

2.1. Effective Professional Development

The Fostering STEAM online course followed standards for online education developed by Quality Matters, an international organization that supports quality assurance in online learning. The course clearly addressed all or most of the criteria for six of the standards.

- Standard 1: The overall design of the course is made clear to the learners at the beginning of the course. This standard was met by providing clear instruction, describing the purpose and structure of the course, describing the technology needed for the course, describing the prerequisite knowledge and technical skills, and providing opportunities for the learners to know one another.
- Standard 2: The learning objectives were clearly described, written from a learner's perspective, and were clearly related to the course activities.
- Standard 3: Assessment strategies were integral to the learning process and were designed to evaluate learner progress. The summative assignment to design a lesson using the STEAM Activity Design Starter was an authentic assessment measuring learner use of the STEAM strategies in a lesson for their own youth.
- Standard 4: Instructional materials enabled learners to achieve stated learning objectives or competencies. The Edpuzzles, discussion questions, research articles, and the STEAM Activity Design Starter contributed to the achievement of the course objectives.
- Standard 6: Course technologies support learners' achievement of course objectives or competencies. The technologies supported the learning objectives, promoted engagement, were readily obtainable and were current.
- Standard 8: Finally, the course design reflects a commitment to accessibility and usability for all learners. The course navigation provided easy access to the content, the technologies required by the course were readily available, alternative means of

accessing content were provided (e.g., videos and transcripts), the course design facilitated readability, and the multimedia facilitated ease of use.

Table 9: QM Continuing Education and Professional Development (CPE) Rubric Summary Scores for the Fostering STEAM Online Course: Professional Development in Art + STEM Integration (Full rubric is included in Appendix B)

Standards	**Points Assigned**	**Possible Points**	**Percent of Points**
1. The overall design of the course is made clear to the learn at the beginning of the course.	13	16	81%
2. Learning objectives or competencies describe what learners will be able to do upon completion of the course	15	15	100%
3. Assessment strategies are integral to the learning process and are designed to evaluate learner progress in achieving the stated learning objectives or mastering the competencies.	13	13	100%
4. Instructional materials enable learners to achieve stated learning objectives or competencies.	14	14	100%
5. Course activities facilitate and support learner interaction and engagement.	6	21	29%
6. Course technologies support learners' achievement of course objectives or competencies.	9	10	90%
7. The course facilitates learner access to support services essential to learner success.	5	21	24%
8. The course design reflects a commitment to accessibility and usability for all learners.	12	12	100%

Two areas of the rubric scored lower – Standard 5 and Standard 7, however the overall score for these standards is misleading. For example, for Standard 5, the course activities clearly facilitated and supported learner interaction and engagement – this is the most important part of this standard. However, no evidence of an instructor's plan for classroom response time and feedback on assignments was clearly stated on the course and the requirements for learner interaction were not clearly stated. Standard 7 relates primarily to institutional supports. While the course linked to Canvas support and provided instructions on how to navigate Canvas, the course instructions did not articulate or link to an institutions' accessibility policies or services and did not articulate how the institution might support learners. While these are essential indicators for a university course, they were less important for the success of the Fostering STEAM online course.

2.2. Participant Satisfaction

Most participants were satisfied with the online course (Table 11). Satisfaction with the course content (learning materials and activities) received the highest satisfaction rating. The time spent on the course received the lowest satisfaction rating.

Table 10: On-line Canvas Fostering STEAM course participant satisfaction responses

Survey Item	**n[1]**	**Mean[1]**
Learning objectives for the online course were clear.	42	4.36
Time was used effectively.	41	3.88
The instructional materials contributed to my learning.	41	4.24
The learning activities contributed to my learning.	41	4.20
The learning activities were engaging.	41	4.32
Participants were active learners.	41	4.12
I knew who to ask if I had a question.	42	4.21
The content was arranged in a clear and logical way.	42	4.31
The time I spent on this course was appropriate for the content.	42	3.90
The course contained opportunities for interactive learning.	42	4.29
Instructions to navigate the online course were clear.	42	4.26
Overall, how would you rate the online course?	41	3.66

[1]Post-online Canvas course satisfaction questions were included in both Post 2 and Post 3 surveys
[2]Mean is calculated from responses where 1=strongly disagree, 2-disagree, 3=neither agree nor disagree, 4=agree, 5=strongly agree

A one-way ANOVA determined that satisfaction differed significantly among partners ($F_{(3,37)} = 3.872$, $p = 0.017$). A Tukey Post Hoc test concluded that the results for Pima County Public Library, which had the highest mean (M = 4.36, SD = 0.50) were significantly higher than the Seattle Public Library, which had the lowest mean (M = 3.78, SD = 0.41) was statistically significant ($p = 0.003$).

Table 11: Online Canvas Fostering STEAM workshop satisfaction scale mean scores and descriptive statistics by partner

					95% Confidence Interval for Mean	
	N	**Mean**	**SD**	**SE**	**Lower Bound**	**Upper Bound**
Sitka Sound Science Center	6.00	4.33	.49	.20	3.82	4.85
Seattle Public Library	12.00	3.78	.41	.12	3.52	4.04
Pima County Public Library	14.00	4.36	.50	.13	4.07	4.65
FNSBSD After School Program	9.00	4.06	.45	.15	3.72	4.41
Total	41.00	4.12	.51	.08	3.96	4.28

Interviews suggest that some participants appreciated the online Fostering STEAM course because it mirrored the in-person workshop, in both content and structure.

The online I think did an excellent job of doing that exact same thing, of putting things in digestible chunks and I loved that it had that you could read a lecture, you could watch the video, you could do both. You could go back and see elements, like wait a minute did I just get those two terms transposed, I'm going to go and check that out. It was also very human computer accessible, human computer interaction aware. So it understood where buttons and things should be. A forward arrow and a backward arrow did what a forward arrow and backward arrow should do. So even the structure of it was clear. So I just found all of that a very equal approach, a similar structure to how they did the class. To how you did the online part. So when I went to the online part I was like wow, this is completely different from what the personal training was. It helped because there were these little video clips and it's talking to you like you were being told at the training. So anyway I just found it really synergistic if that's a word." (Interview 43)

Interviews also suggest that many of the participants did not complete the online course. Most simply reported a lack of time in their work day. Others found the assignments too demanding to complete in a setting with interruptions, distractions, and other tasks to complete at that same time.

And the online piece, if it's possible to just make it really short? Should be a little shorter. And a little bit less of the hands-on. It's a lot easier ... You know how there are some where it was like, "Okay, now go find five things ..." And it's like, "I'm on desk. I'm doing this during my desk time because it's the only time I can do it. I can't go get five things. I was like, "I can't do this on desk while multitasking." (Interview 21)

I do not do well with the online stuff. It's just so crazy busy here and trying to get any time, even if they set aside time for you, it doesn't really translate into time. It translates into I'm doing a little bit and then I get interrupted, and then I do a little bit and I get interrupted. So that wasn't terribly effective for me, but I often would just print the stuff out and read it at the desk or ... So, I definitely got stuff out of it, but I ... The in-person stuff was so much more effective for me than anything that I did online." (Interview 13)

I did as much of it as I could, but it was kind of hard because at the same time I'm onboarding into the job. So, yeah..... I guess, for me because I was so new, a little more structure would have been helpful whether that would have been planning something out with my regional manager or recognizing that I could block out time to do things. We're in a very open work environment, so it was really hard for me to do the online learning and be fully focused on it in that

there's people walking in and out, there's people asking questions about just day to day stuff. (Interview 1)

Finally, the interviews suggested that for some technology issues were a barrier to completing the online course.

And I actually, I feel really bad saying it. I quit....I struggled doing them. And then, somehow the technology sometimes wasn't working for me and I'm sure it was operator error. You know, it's like, wait a second, I just did this one. (Interview 3)

While not all the Pima County Public Library participants completed the course, they were generally more positive about the online course. One reason may be that they worked as cohorts in small groups to complete the course. This structure helped several of the participants work through the online course successfully. One of the participants from the Pima County Public Library described how others in her group helped her successfully complete the design starter.

Yes, but it was great because I got totally stuck [on the design starter]. It was super frustrating. And then she had already finished. I saw that she had finished and so we're chatting about it and she just totally helped me figure it out. And just helped talk through it. So I really like, and similar to that children's meeting, caring what other people are thinking about it is like... I feel like as much as working in teams, on any of this would have been really... Whatever we did work on teams, it was helpful and useful. (Interview 19)

These comments further illustrate that an asynchronous online environment is not a preferred method of learning for all learners.

3. Coaching

Coaching was the least developed part of the professional development and had important impacts nonetheless. The coaching provided support to participants in developing and implementing new STEAM programming or in modifying activities or lessons the participants were already providing.

At each of the partner sites, the coaching looked different. In Sitka, the coaching was defined by the Sitka Sound Science Center. They wanted specific help developing a summer camp focused on STEAM. According to the coach for Sitka, the most important part of her role was to initiate conversations about how to incorporate identity and mindset practices, so that those were folded into the whole planning process from the beginning. Throughout the process she reminded the groups to consider all aspects of the learning experience, and brought attention to planning of facilitation strategies in addition to procedural elements of

the activity design. She also connected to the workshop experiences as a reference for what the identity/mindset component looks like (e.g., their personal connections to STEAM objects and the discussions surrounding that).

For the Seattle Public Library, the coaches worked with the whole library system rather than a small group. Their coaching included observations of members of the Children's Services staff implementing STEAM activities and two follow-up meetings with the Children's Services staff. These meetings provided opportunities for the coaches to build relationships with the participating staff and some requested individual coaching.

In Pima, a coach worked with one participant who was tasked with developing a STEAM lesson. Over a month the coach and participant held two of zoom meetings about the project design, interspersed with back and forth comments and revisions of the participant's lesson plan and back pocket questions. The participant tried to fit "a lot" of big ideas and multiple explorations into one activity, which meant that she had an overwhelming amount of complex phenomena to wrap her head around before she could figure out how to tie it all together. A lot of what the coach did was try to tease out what was both realistic and essential to her ideas of incorporating 1) a critical exploration of the trend of "lifehack" DIY instructional videos 2) exploration of the phenomenon of fluorescence and 3) using the results of these investigations to create fluorescent art. "It was A LOT wrapped into one activity, so, in addition to thinking about how the STEAM principles and mindset/identity could be woven in, we really thought about how to narrow down the scope, and then how to build on those essential ideas throughout the various phases of the activity." (email correspondence with coach).

3.1. Effective Professional Development

Regardless of the way the coaching was implemented, interviews suggest that coaching provided scaffolding the participants needed to support their implementation of new STEAM concepts.

> *Yeah. So, it was really helpful for me to talk to her because I had the concept but I really needed help fleshing it out, because I started with too many questions or trying to cover too many things and she really was able to help me narrow down that focus and help me understand that it's okay to cover just one or two things. I don't need to give them a whole hour lecture and how to phrase my questions so that they were something that they could answer." (Interview 22)*

One of the interviewees described the process of coaching and how this process supported their effective integration of learning targets into the program they were developing.

I thought it was really helpful, because obviously she knows the ideas behind this, the workshop we did she knows them very well. Being able to bounce our ideas off of her and having her remind us of things, and was very helpful. Because even in I can think of, when we were coming up with for each of our camps to come up with specific learning targets that we want the kids to know, there were a few cases where simple things like having students gain confidence in these areas. Like learning targets such as that is something that we would've left out because it's not a specific, it's not directly related to a science topic. But having [name of coach] there to kind of remind us about those aspects of it, incorporating that, sort of her open-mindedness and putting ideas into it I thought was very helpful. I mean that was her, I think like once every other week, maybe, for two months leading up to it. Yeah it was very helpful. (Interview 40)

Another participant framed the support received around translating learned strategies into programming.

It was really a good like how do we apply this to the things we're already doing and real-world application and what... I think it made it feel a lot more doable in terms of applying the principles, even if we weren't like, Okay, we're going to lead a eight-week class with these exact activities and with these resources. But it's like, Hey, I'm already doing this naturals program. How do I apply this? We get a lot of one-and-done trainings around here, where we don't get much transfer of training out of them. But in terms of actual like, "Hey, this is doable within my current structure and job description and time, because even the things that I'm already kind of doing or this type of program I'm doing, I can tweak it in certain ways to enrich it without having to completely reinvent the wheel or get additional resources. (Interview xx)

These interviews underscore the challenges that educators often face when trying to implement new learning and the importance of providing support to them as they work through new curricula, tools, and approaches. Following are some of the ways that supported participants were able to develop and/or revise activities using STEAM strategies. The first illustrates a participant who developed several new activities.

So I had done some for three to five year olds and so I walked back and I had created six activities and I added to those activities different supplemental to give up different options for librarians to use. So once they went through the program once, then they would need a new activity in case they had the same students. So I went back through and I developed one with flashlights and building blocks. So we give them flashlights to talk about cellophane and different colors and create their own little art piece, and then I added an

activity to talk about shadows and how they can measure shadows and whether moving the flashlight back and forth and having them try to build a tower that reaches the tape on the wall. So I used that. I'm trying to remember the others, but I added little supplements to activities that for parents so that they could have those to do either at home or during the program. (Interview 22)

Another participant was part of a group in Sitka who developed a Colors of Copper camp. The group participated in bi-weekly meetings for two months with a coach.

And we actually did copper patina work. We used different chemicals on copper, and saw how they reacted, and then the colors that they created. And just the first couple days of the camp we're kind of just all about experimentation and using different chemicals, different substances. And then, yeah I mean for them to be able to come up with their final product, they came up with their own recipe. They were able to design that bracelet themselves, how they wanted it to look, that it had more personal meaning and more personal connection for them. (Interview 40)

The following participant illustrates a participant who revised current activities to incorporate STEAM concepts into interactions and not programming.

What I would do differently is rather than trying to build a new container, which feels so daunting, and then it's really easy to put off and then be like, "I didn't do anything," rather than trying to build a new container, using a container that I already have and leveraging the knowledge that I already have and then figuring out, "How can I mix this this up within it?" Which I did to a very small extent, but I could have done differently, where I'm like, "We're going to do ... Today's going to be Dinosaur Day and we're going to dig in the blah blah blah." Or "Today's going to be like we're doing ... We're going to paint on the blah blah blah." You know, whatever it is. Then you end up with the downside of people being like, "But I came for Story Time." And it's like, "Too bad. This is what I got." (Interview 21)

These examples provide evidence of the type of activities or modifications supported participants developed. Unfortunately, we do not know whether they would have developed the same type of work without the support.

3.2. Participant Satisfaction

Three important themes emerged in interviews which illustrate participant satisfaction related to the coaching. First, interviews suggested that coaching built trusting relationships among the participants and the coaches. These relationships then enabled the

participants to work collaboratively with the coach to develop and improve their lesson plans.

> *I remember feeling really supported and all my questions, it felt like it wasn't like, Oh yeah, you got it. There was a jazz, I mean, I felt jazz. I felt encouraged, I felt just like, Oh, that makes so much sense. It was a two-way conversation. That's kind of where I went. It wasn't just me coming and asking questions. It felt like a two way, both learning, it was really fun. It was just a sharing, more of a sharing than it was than it was, I have these questions kind of thing. And it felt like, Oh, I want to do your job. (interview)*

> *So by having that opportunity, even though it wasn't a children's librarian, having somebody that I can just discuss my ideas with, talk about my work ... sometimes we can get into this. At least I personally will feel like I'm just doing the same things over and over and over again and not really getting a chance to make it better, which we could try to get feedback from parents and those types of things. But sometimes it doesn't feel like anybody wants to hear what we're doing, or doesn't understand the depth that goes into the work that we do. And so being able to have these coaching sessions where people are really interested in what are our ideas and what are our goals and what are we trying to accomplish, that was really, really helpful and encouraging. And it just gave me a sense of support that I haven't had before.(interview)*

Second, interviews suggested that participants simply appreciated the follow-up to reinforce or remind them of the content that they learned during the in-person workshop, particularly in comparison to professional development without any follow-up.

> *But just that sense of, 'We're really here and we're really willing and easy to reach and we're really invested in your success. What can we do to help?' was really, really nice. As opposed to sometimes, you go to a PD ... I've been to so many PDs. You go to a PD and then it's like, 'Okay, well, that was nice.' That's the thing about teacher PDs, too, is that yes, there's this expectation of your doing PDs, but how many of them is just another eight-hour day of whatever, and then you go home and you're like, 'Well, that was a nice ...' And then you lose it, right? It's not like teacher PDs are necessarily effective. (Interview 21)*

> *There was one where they came to a children's librarian meeting a while back, it was just like a refocus. I think it was nice to have that refocus of what we went over early this year, yeah. Because this was just before Summer of Learning began, so I think it was kind of useful having a recap of what we went over earlier in the year before we started going out and doing a lot of our*

> *Summer of Learning programming. It's just I had gotten the mindset of like, "If I'm doing all this planning for all these Summer of Learning programs ..." which it was themed Explore Your World, which there was a lot of STEAM elements involved in that. But, it was nice to have that as a recap back in, I think, May or June. (interview #)*

Finally, the interviews suggested that the combination of the in-person workshop, the online course, and the coaching was important because the workshop and the course laid the groundwork for the team to understand the coaching feedback and input.

> *I mean that was, I think that sort of following the workshop and the online course, was extremely helpful. Because then we knew sort of exactly what to comment, when she would bring something up to us we knew what she was talking about it wasn't just like some soaring concept that we hadn't heard of. I definitely think that was really helpful by having that like in conjunction with the workshop and the online course was definitely important. (Interview 40)*

These comments suggest that the coaching was well implemented even if not fully developed.

4. Overall Participant Learning and Attitude Changes

From pre-test to final post-test, participants reported significant increases in their agreement with Fostering STEAM beliefs, preparedness to develop and implement STEAM activities that support STEAM identity among youth, preparedness to develop and implement STEAM activities that support a STEAM mindset among youth, and preparedness to implement STEAM practices, including developing activities, facilitating activities and using the STEAM design framework.

Fostering STEAM Beliefs

The Fostering STEAM training contributed to statistically significant changes in participants knowledge of Fostering STEAM beliefs over time, ($F_{(1.513,\ 63.526)} = 21.686$, $p < 0.0001$). There was a significant increase in the mean beliefs scale score from 4.41 (SD = 0.34) from before the in-person Fostering STEAM workshop to a mean of 4.72 (SD = 0.32) after the in-person workshop of 0.31 (95% CI, 0.23 to 0.39; $p < 0.0001$). The mean beliefs scale score did not change significantly after the online course and/or coaching (mean of 4.69 (SD = 0.32). The mean principles score declined by 0.03 (95% CI, -0.13 to 0.07), which was not statistically significant ($p = 0.521$).

Table 12: Fostering STEAM descriptive statistics of belief scales score by test

	Mean	Std. Deviation	N
Pre-Survey	4.4121	.34070	43

Post In-Person Workshop	4.7209	.31740	43
Final Survey	4.6884	.32087	43

Changes in Fostering STEAM beliefs were not statistically different among partnering organization (Welch's $F_{(3,16.493)} = 0.667$, $p = 0.584$).

Preparation to Support a STEAM Mindset with Youth

The Fostering STEAM training contributed to statistically significant changes in mindset scale scores over time ($F_{(1.715, 72.035)} = 98.996$, $p < 0.0001$). There was a significant increase in the mean mindset scale score from 2.68 (SD = 0.91) from before the in-person Fostering STEAM workshop to a mean of 4.05 (SD = 0.64) after the in-person workshop of 1.37 (95% CI, 1.10 to 1.62; $p < 0.0001$). There was also a significant increase in the mean mindset scale score from 4.05 (SD = 0.64) after the in-person Fostering STEAM workshop to a mean of 4.30 (SD = 0.55) after the online course and/or coaching of 0.25 (95% CI, 0.056 to 0.446; $p = 0.013$).

Table 13: Fostering STEAM descriptive statistics of mindset scale scores by test

	Mean	Std. Deviation	N
Pre-Survey	2.6884	.90533	43
Post In-Person Workshop	4.0465	.64267	43
Final Survey	4.2977	.55097	43

Changes in preparation to support STEAM mindset with youth were not statistically significant by partnering organization ($F_{(3,43)} = 1.856$, $p = 0.151$).

Preparation to Support a STEAM Identity Development with Youth

The Fostering STEAM training contributed to statistically significant changes in identify development scale scores over time ($F_{(1.937, 81.37442)} = 140.503$ $p < 0.0001$). There was an increase in the mean identity scale score from 2.31 (SD = 0.80) from before the in-person Fostering STEAM workshop to a mean of 3.91 (SD = 0.67) after the in-person workshop of 1.61 (95% CI, 1.35 to 1.86), which was statistically significant ($p < 0.0001$). The mean identity scale score increased from 3.91 to 4.13 (SD = 0.54) after the online course and/or coaching by 0.22 (95% CI, 0.000 to 0.434), but this was not statistically significant ($p = 0.050$).

Table 14: Fostering STEAM descriptive statistics of identity scale scores by test

	Mean	Std. Deviation	N
Pre-Survey	2.3070	.79684	43
Post In-Person Workshop	3.9116	.66519	43
Final Survey	4.1302	.53787	43

Changes in in preparation to support STEAM identity development with youth were not statistically different among partnering organizations ($F_{(3,43)}$ =1.631, p = 0.196).

Preparation to Implement STEAM Practices with Youth

The Fostering STEAM training elicited statistically significant changes in practices scale scores over time ($F_{(1.868, 78.451)}$ = 101.316 p < 0.0001). There was a significant increase in the mean practices scale score from 2.59 (SD = 0.86) from before the in-person Fostering STEAM workshop to a mean of 4.04 (SD = 0.55) after the in-person workshop of 1.45 (95% CI, 1.17 to 1.73; p < .0001). There was also a significant increase in the mean practices scale score from 4.04 (SD = 0.55) after the in-person Fostering STEAM workshop to a mean of 4.35 (SD = 0.64) after implementation of STEAM activities of 0.31 (95% CI, .08 to .54; p = 0.009).

Table 15: Fostering STEAM descriptive statistics of practices scale scores by test

	Mean	Std. Deviation	N
Pre-Survey	2.5880	.85953	43
Post In-Person Workshop	4.0399	.55269	43
Final Survey	4.3509	.63579	43

Changes in in preparation to implement STEAM practices with youth were not statistically different Fostering STEAM beliefs were not statistically different among partnering organizations (Welch's $F_{(3,13.437)}$ = 0.923, p = 0.456).

5. Implementation of STEAM Activities

Of the participants who completed the Post 3 survey (n = 47), 83% implemented or facilitated STEAM programing for youth at some point after attending the in-person Fostering STEAM workshop. Although most of the STEAM strategies were implemented by more than 60% of the participants, conducting open exploration in the context of both art and science and fostering a STEAM mindset were implemented by the most respondents.

Table 16: Fostering STEAM strategies implemented following in-person Fostering STEAM workshop

	n	**Count**	**Percent**
Facilitated STEAM programming	47	39	83.0%
Focusing on outcomes that have a personal meaning	39	26	66.7%
Conducting open exploration in the context of both art and science	39	35	89.7%
Designing with intention (e.g. choices around medium, use of genuine science and/or art tools)	38	30	78.9%
Iterating through several drafts, prototypes, or models	39	28	71.8%
Communicating about process and outcome	38	31	81.6%
Fostering a STEAM mindset	39	37	94.9%
Connecting to identity and culture	39	25	64.1%

Engaging in close observation[1]	5	5	100.0%
[1]This strategy was added to the survey only for the FNSBSD After School Program participants. Of the FNSBSD After School participants who completed the survey and reported they implemented STEAM activities, all indicated they engaged youth in close observation.			

Satisfaction did not affect implementation. Post in-person Fostering STEAM mean satisfaction of 4.70 (SD = 0.33) was not different for those who implemented STEAM activities versus those who did not implement STEAM activities (Mean = 4.74, SD = 0.19). Nor was post-online Canvas mean satisfaction different for those who implemented STEAM activities (Mean = 4.15, SD = 0.50) versus those who did not implement STEAM activities (Mean = 4.03, SD = 0.76) ($X^2 = 0.989$).

Participant Post 3 mean learning and attitude scale scores were also not different between those who implemented STEAM activities and those who did not implement STEAM activities (Table 11).

Table 17: Mean scale scores for participants who implemented STEAM activities and for those who did not implement STEAM activities. Mean differences are not statistically significant (all p > 0.05).

Scale	Implementation/No Implementation	N	Mean	SD
Practices Post 3	No Implementation	11	4.18	0.73
	Implementation	28	4.49	0.58
Mindset Post 3	No Implementation	11	4.22	0.52
	Implementation	28	4.36	0.56
Identity Post 3	No Implementation	11	3.93	0.57
	Implementation	28	4.21	0.55
Principles Post 3	No Implementation	11	4.80	0.27
	Implementation	28	4.66	0.35

Across partner organizations, slightly more than 80% of participants reported implementing STEAM Activities. There were no significant differences among partner organizations.

Table 18: Percent of participants who implemented STEAM activities by partner organization

Partner	n	No Implementation	Implemented
Sitka Sound Science Center	7	14.3%	85.7%
Seattle Public Library	21	19.0%	81.0%
Pima County Public Library	13	15.4%	84.6%
FNSBSD After School Program	6	16.7%	83.3%
Total	47	17.0%	83.0%

The purpose of this summative evaluation was to identify **aspects of the Fostering STEM professional development that were particularly effective and contributed most to the achieved outcomes**. Findings suggest that the numerous and varied opportunities for participants to engage in active learning contributed to positive outcomes. During the in-person workshop participants engaged in the same learning activities as their students – learning from the "child's perspective" was one of the best parts of the in-person workshop and helps participants to understand how their learners may respond to various learning activities. During the online course participants used the STEAM Activity Design Starter to plan or modify a STEAM lesson. With the support of a coach, the participants developed and/or modified activities to implement in their own setting or practiced instructional methods and received feedback from a coach. Asking educators to develop products as part of professional development provides an authentic way for participants to practice new approaches and will improve the likelihood that new approaches will be implemented with the participants' learners.

Findings also suggest that the collaborative spaces for participants to share ideas and cooperate in their learning contributed to the positive outcomes. Enthusiastic, exploration-focused collaborative interactions occurred throughout the in-person workshop, which provided the participants with numerous opportunities to share their ideas and learn from one another. Coaching sessions were generally described as collaborative, with the coaches and participants also working together to share ideas and learn from one another. The Pima County Public Library participants worked in small collaborative groups to complete the online course. The Pima participants were the most satisfied with the online course. The lack of spaces for other participants to share ideas and collaborate in their learning while online may have contributed to the number of participants who didn't complete the course, even though for many the reason given was lack of time.

There is also promising evidence to suggest the coaching provided scaffolding needed for participants to develop or review new learning materials. Expert scaffolding was also apparent throughout the program in other ways as well. The in-person workshop defined key Fostering STEAM concepts, provided model lessons, and used think, pair, share as a strategy for discussing new information. The online course provided a template – the STEAM Activity Design Starter for participants to use to develop their own lessons. This scaffolding likely contributed to participants' feeling of being supported.

Overall, evidence also suggests that an in-person workshop followed quickly by coaching might be the right combination for ensuring implementation of STEAM strategies. The online course, while beneficial as a stand-alone component, did not significantly contribute to reported learning. It is also possible that the survey used to assess self-reported learning was not sensitive enough to capture changes in participant understanding of the STEAM

concepts after the online learning. This is not to say that an online course would not be beneficial, but perhaps an online course could be offered in place of an in-person workshop for those who could not attend in-person, rather than a supplement to the in-person workshop.

Limitations

This evaluation has several limitations, which are common to evaluations of professional development. First learning data was self-reported, by a relatively self-selected group of individuals, although a some of the participants were required to attend the training. Therefore, we do not know how someone might take up the Fostering STEAM concepts who was not part of this self-selected audience. Second, observations of professional development activities may reflect evaluator-bias. Observations were conducted by two different evaluators with similar findings, but evaluator bias cannot be overlooked. Third, interviews were conducted by a combination of the research team and the evaluation team. The research team also implemented the professional development and provided the coaching. While this created collaborative relationships, it also may have biased participants willingness to honestly share their opinions about the professional development. Finally, while evidence points to the importance of coaching in taking up the STEAM strategies, the evaluation did not assess the extent to which the participants who did not receive coaching implemented STEAM strategies.

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We conducted a reliability analysis on each of the four scales using SPSS. Cronbach's alpha showed the four scales included on the pre-post in-person survey reached acceptable reliability ($\alpha > 0.70$). Most items appeared to be worthy of retention, resulting in a decrease in the alpha if deleted.

Table 19: Scale /10Reliability Statistics

	Statistics for Scale			
Scales and Scale Items	**N**	**Item Mean**	**Item Variance**	**Alpha**
Beliefs	**10**	**4.579**	**0.025**	**0.824**
A STEAM mindset is learned and developed through practice and reflection				
Artists use creativity in their work				
Culture is related to STEAM learning				
I think about issues of equity in my work with youth				
Identity is related to STEAM learning				
It is important to foster STEAM identity among the youth in my programs				
My personal mindset influences the mindset of the youth I work with				
Practicing STEAM mindset supports self-directed learning				
Scientists use creativity in their work				
STEAM is connected to my life				
Identity	**5**	**2.981**	**0.031**	**0.938**
Articulate STEAM learning goals that have a personal meaning for youth				
Articulate STEAM learning goals that have a aesthetic meaning for youth				
Design STEAM activities that are relevant and meaningful to youth				
Support STEAM identity development among the youth				
Use strategies for supporting STEAM-linked identities in learners				
Mindset	**5**	**3.256**	**0.025**	**0.94**
Address fear-based attitudes and assumptions with youth that can create barriers to STEAM participation				

Scales and Scale Items	Statistics for Scale			
	N	Item Mean	Item Variance	Alpha
Help youth approach new activities with a growth mindset				
Help youth quiet their inner negative voice				
Mitigate/manage negative self-talk of youth				
Support a growth mindset with youth				
Practices	**9**	**3.172**	**0.068**	**0.957**
Develop STEAM activities that integrate art and science in instruction for youth				
Facilitate communication among youth about their STEAM processes and outcomes				
Facilitate STEAM activities for youth				
Support youth in conducting open explorations in the context of both science and art				
Support youth to design STEAM projects intentionally				
Support youth to iterate their designs through several drafts, prototypes, or models				
Support youth to leverage science components to create artwork				
Use the STEAM design framework to tailor lessons for the youth I work with				
I can teach STEAM effectively				

Appendix B: QM Continuing Education and Professional Development (CPE) Rubric Summary Scores for the Fostering STEAM Online Course: Professional Development in Art + STEM Integration

Standard	***Points***	***Possible Points***	***Percent***
1. The overall design of the course is made clear to the learn at the beginning of the course.	13	16	81%
1.1 Instructions make clear how to get started and where to find various course components.	3	3	
Evidence: instructions are provided on the home page; instructions include how to return to the home page at any time; a welcome video and video transcript provided instructions			
1.2 Learners are introduced to the purpose and structure of the course	3	3	
Evidence: length of time to complete the modules is described; dates that the course is instructor-supported is described; the schedule is described; the structure of modules is described; clarification is made about tests and quizzes, which are used as reflection and not graded; a suggested schedule is provided			
1.3 Etiquette expectations for online discussions, email, and other forms of communication are stated clearly.	1	2	
Evidence: two email contacts are provided; there is no other specific information for expectations for online discussions or other communication.			
1.4 course, institutional, or organizational policies with which the learner is expected to comply are clearly stated, or a link to current policy is provided.	0	2	
Evidence: evidence was not apparent			
1.5: Minimum technology requirements are clearly stated, and instructions for use are provided.	2	2	
Evidence: yes, the orientation provides an overview of the technology needed and provides instructions (e.g., support for obtaining edpuzzle)			
1.6 Prerequisite knowledge in the discipline and/or any required competencies are clearly stated.	1	1	
Evidence: yes, during the orientation the required competencies are described			

Standard	*Points*	*Possible Points*	*Percent*
1.7 Minimum technical skills expected from the learner are clearly stated.	1	1	
Evidence: yes			
1.8 The self-introduction by the instructor/facilitator is appropriate and available online.	1	1	
Evidence: how to contact your instructor page is in the linear flow of the course; each of the course instructors provides a brief introduction to themselves at different times in the course. The course instructors had also met the participants in person, so the instructor introduction was not as important.			
1.9 Learners are asked to introduce themselves to fellow learners.	1	1	
Evidence: yes, the learners are asked to update their profile so that the instructor and peers are able to contact and identify other learners; asks for a provide picture; asks for preferences for notifications;			
2. Learning objectives or competencies describe what learners will be able to do upon completion of the course	15	15	100%
2.1. The course learning objectives, or course/program competencies, describe outcomes that are measurable.	3	3	
Evidence: The course orientation provided an overview of the learning objectives; each module provides learning objectives for that module. Learning objectives are measurable.			
2.2 The module/unit learning objectives or competencies describe outcomes that are measurable and consistent with the course-level objectives or competencies.	3	3	
Evidence: each module provided learning objectives that were consistent with the course-level objectives (e.g., learn about the core STEAM practices, identify some of the fear-based attitudes and assumptions that can create barriers to STEAM participation, Articulate strategies for cultivating a STEAM mindset, articulate the connections between STEAM and everyday life, explain the relationship between identify and learning. These are consistent with the course-level objectives.			

Standard	*Points*	*Possible Points*	*Percent*
2.3 All learning objectives or competencies are stated clearly and written from the learner's perspective.	3	3	
Evidence: yes, all objectives are from the learner's perspective and focus on the learner's implementation of the practices with youth.			
2.4 The relationship between learning objectives or competencies and course activities is clearly stated.	3	3	
Evidence: yes, module 1 assignment, "take a look at what these practices might look like in action" by watching a video of STEAM practices; followed by reflection – what are some examples in your own teaching when learners have used one or more of these practices? What were the outcomes? How did you facilitate that experience? In STEAM mindset the assignment asked the learners to discuss a situation they encountered where they noticed a fixed mindset, and to share their ideas for how to reframe the situation using strategies for cultivating a STEAM mindset. In the introduction to Module 6, the facilitator said: *In this module, we'll be exploring questioning as one of the most important tools in your facilitation toolkit. Today we'll be exploring some of the different types of questions you can ask, their purposes, types of questions to avoid, and how to respond to questions.*			
2.5 The learning objectives or competencies are suited to the purpose or level of the course.	3	3	
Evidence: yes, the course is an introduction to the strategies for supporting a STEAM mindset with learners, all of the objectives contribute to the overall goal of supporting a STEAM mindset.			
3. Assessment strategies are integral to the learning process and are designed to evaluate learner progress in achieving the stated learning objectives or mastering the competencies.	13	13	100%
3.1 The assessments measure the stated learning objectives or competencies.	3	3	
Evidence: yes, the reflection questions ask the learners to apply what they learned to their own instruction; reflection questions ask learners other methods that they have tried or think would be helpful (e.g., mistake			

Standard	*Points*	*Possible Points*	*Percent*
monsters, magic word). The STEAM Activity Design Starter is an authentic assessment measuring learners use of the STEAM strategies in a lesson for their own youth.			
3.2 Course information specified how successful completion of the course will be recognized.	3	3	
Evidence: no evidence available on the Canvas course, however learners received a syllabus prior to the course outlining expectations for receiving credit for the course from the University of Alaska Fairbanks.			
3.3 Specific and descriptive criteria are provided for the evaluation of learners' work and are tied to the course policy for determination of successful course completion.	3	3	
Evidence: no evidence available on the Canvas course, however learners received a syllabus prior to the course outlining expectations for receiving credit for the course from the University of Alaska Fairbanks.			
3.4 The assessment instruments selected are sequenced, varied, and suited to the learner work being assessed.	2	2	
Evidence: yes, the assessments are suited to the learner work being assessed. For example, STEAM self-documentation provides an opportunity for the learners to consider what STEAM is and how it is part of their everyday life, reflect on what STEAM and STEAM education mean to them, and reflect on how STEAM is related to their own lives, ad the lives of the youth with whom the learners work. Finally, the learners complete the STEAM Activity Design Starter to develop a lesson of their own. This assessment requires learners to apply their learning to an authentic assignment.			
3.5 The course provides learners with multiple opportunities to track their learning progress.	2	2	
Evidence: yes, at the end of each module is a congratulations page, and the Canvas overview provides a list of the assignments and whether they have been completed.			
4. Instructional materials enable learners to achieve stated learning objectives or competencies.	14	14	100%

Standard	*Points*	*Possible Points*	*Percent*
4.1 The instructional materials contribute to the achievement of the stated course and module/unit learning objectives or competencies.	3	3	
Evidence: Yes, reflection questions encourage learners to describe ways that that their students will respond or engage (for example, How do you think your mindset might affect how your learners engage with new material, or overcome obstacles?) Research articles extend the content for each module. For example, resources for identity and equity included How to avoid know pitfalls associated with culturally responsive instruction. Yes, the deign and facilitation guide introduced in Module 4 specially helps to meet learning objectives, such as be able to articulate STEAM learning goals, analyze why a STEAM lesson is designed the way it is, and make informed choices about strategies to include as a designer or facilitator. After analyzing the painting with chemistry investigation, learners used the Design Starter to design their own STEAM activity.			
4.2 Both the purpose of instructional materials and how the materials are to be used for learning activities are clearly explained.	3	3	
Evidence: yes, for example in Module 4 the learners are introduced to the design framework which will help them modify or develop their own lessons and understand the rationale behind choices in the activity design. Later in the Module, the learners are instructed to download or print a copy of the STEAM Activity Design Starter and the Painting with chemistry investigation. Learners used the STEAM Activity Design Starter to analyze how the painting with chemistry investigation used the STEAM strategies.			
4.3 All instructional materials used in the course are appropriately cited.	2	2	
Evidence: yes, for example optional resources for STEAM mindset were provided with links; other references/articles have full citation.			
4.4 The instructional materials are current.	3	3	

Standard	*Points*	*Possible Points*	*Percent*
Evidence: yes, the materials are all based on current research, including the National Research Council. 2012. A framework for science education: Practices, crosscutting concepts and core ideas. National Academies Press.			
4.5 A variety of instructional materials is used in the course.	2	2	
Evidence: yes, instructional materials included videos, articles, vignettes of students participating in STEAM activities, videos of professionals who represent people who do STEAM work. STEAM Activity Design Starter			
4.6 The distinction between required and optional materials is clearly explained.	1	1	
Evidence: Yes, particularly further reading – These resources are optional for those who are interested in learning more, and are not required for completion of the module. In comparison at the end of each module the completion prerequisites are clearly described.			
5. Course activities facilitate and support learner interaction and engagement.	6	21	29%
5.1 The learning activities promote the achievement of the stated learning objectives or competencies.	3	3	
Evidence: yes, reflection questions ask learners to focus specifically on the topic areas, such as asking about a time learners encountered a fixed mindset and how it affective the potential for growth or learning in the situation. Videos of STEAM professional talking about their work engages learners in understanding how STEAM can be embedded in a variety of professions.			
5.2 Learning activities provide opportunities for interaction that support active learning.	3	3	
Evidence: yes, learners complete various activities. For example, learners look at their own attitudes and assumptions towards learning by completing a mindset profile; yes, learners participate in discussion where they can read and comment on others' posts. For example, the STEAM Self-documentation discussion asked learner to discuss 1) how is STEAM connected to both your life and the lives of the youth with whom you work and 2) how can you help youth make connections			

Standard	*Points*	*Possible Points*	*Percent*
between their everyday lives and STEAM? Leaners use edpuzzle to learn more about the connection between identity and learning. Learners also read articles and responded to discussion questions (e.g., Facing Cancer: Social Justice in biology class). STEAM Activity Design Starter provides an authentic assessment for learners to apply their understanding about the STEAM strategies to a lesson they will teach with their own youth. Throughout Module 6 the course continues to coach learners through the example lesson with leading questions, such as what will learners do? What opportunities do learners have to communicate their designs and thinking to peers and other audiences? Each section also included support strategies and examples of ways the facilitators taught the example lesson. Module 6 then prepared them to continue developing their own lesson using the STEAM Activity Design Starter.			
5.3 The instructor/facilitator's plan for classroom response time and feedback on assignments is clearly stated.	0	3	
Evidence: no evidence of this indicator was apparent			
5.4 The requirements for learner interaction are clearly stated.	0	2	
Evidence: no evidence of this indicator was apparent			
6. Course technologies support learners' achievement of course objectives or competencies.	9	10	90%
6.1 The tools used in the course support the learning objectives or competencies.	3	3	
Evidence: yes, the edpuzzle tool allowed learners to watch a video, stop the video and answer questions, and revisit sections of the video.			
6.2 Course tools promote learner engagement and active learning.	3	3	
Evidence: yes, edpuzzle provided an interactive way to watch a video, discussions allowed learners to comment on topics.			
6.3 Technologies required in the course are readily obtainable.	2	2	
Evidence: yes			

Standard	*Points*	*Possible Points*	*Percent*
6.4 The course technologies are current.	1	1	
Evidence: yes			
6.5 Links are provided to privacy policies for all external tools required in the course.	0	1	
Evidence: no evidence was apparent			
7. The course facilitates learner access to support services essential to learner success.	5	21	24%
7.1 The course instructions articulate or link to a clear description of the technical support offered and how to obtain it.	3	3	
Evidence: Canvas provides support and a link appears at the bottom of each course page.			
7.2 Course instructions articulate or link to the institution or organization's accessibility policies and services.	0	3	
Evidence: no evidence of this indicator observed			
7.3 Course instructions articulate or link to an explanation of how the institution or organizations support services and resources can help learners succeed in the course and how learners con obtain them.	2	2	
Evidence: yes, provides an embedded video and a link to Canvas Guides that show learners how to search for help guides that provide different lessons to help each user understand how Canvas works; provides a downloadable PDF manual;			
7.4 Course instructions articulate or link to an explanation of how the institution or organization's learner services and resources can help learners succeed and how learners can obtain them.	0	1	
Evidence: no evidence of this indicator was observed			
8. The course design reflects a commitment to accessibility and usability for all learners.	12	12	100%
8.1 Course navigation facilitates ease of use.	3	3	
Evidence: linear progress, next buttons to move to the next page, questions linking one module to the previous provide			
8.2 Information is provided about accessibility of all technologies required in the course.	3	3	

Standard	***Points***	***Possible Points***	***Percent***
Evidence: orientation provides an overview of the equipment needed, included an internet connected device, account to use edpuzzle (provides instructions to use edpuzzle using video and text and practice);			
8.3 The course provides alternative means of access to course materials in formats that meet the needs of diverse learners.	2	2	
Evidence: all videos have a corresponding written transcript; written descriptions of video content are provided; can access Canvas on a mobile device as well (course provides instructions to do so);			
8.4 The course design facilitates readability.	2	2	
Evidence: yes, the design is bright, colorful, uses well-spaced and minimal words			
8.5 Course multimedia facilitate ease of use.	2	2	
Evidence: videos provide information and content that can be either read or listened to.			