Art + Science:

Broadening Youth Participation in STEM Learning

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Exploratorium
Science Gallery, Trinity College Dublin
University of Washington, Institute for Math and Science Learning

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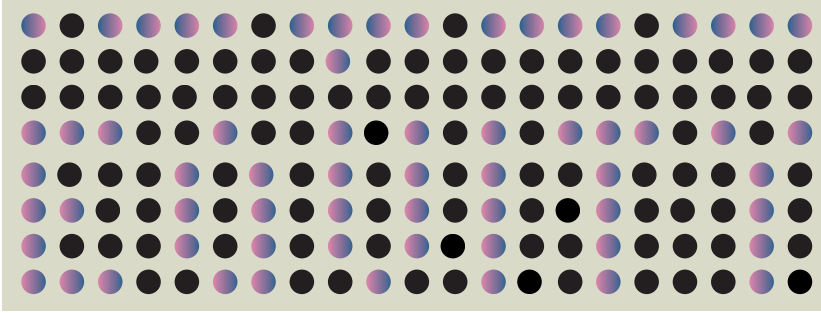

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Opportunity

Art and science represent two powerful human ways of investigating and understanding the natural and social world. Both are creative processes involving acts of observation, interpretation, meaning-making, and the communication of new insights. While standards of evidence may vary between the two fields, there are also many common practices. Many artists, for example, employ a range of computational, digital and engineering practices. Many scientists are guided in part by aesthetic considerations in the formulation of questions, theories, and models.

In this report we share the results of a cross-disciplinary, collaborative inquiry into how programs that integrate art and science do, or might, enrich and broaden the participation of young people in science, technology, engineering, and mathematics (STEM) learning.

The project, funded by the Science Learning+ initiative in Phase 1, involved some 24 educators and researchers from 5 countries, and included the participation of 15 youth from Dublin and San Francisco. In particular, we were interested in how such programs can advance equity (access as well as full and meaningful participation) in STEM learning for youth from communities historically underrepresented in STEM fields.

The project reviewed the current research literature and leading art+science programs in the field; identified key constructs that were integrated into a research framework; piloted two formative assessment tools that sought to measure student engagement and support facilitator reflection; and identified gaps in the knowledge-base that future research-practice partnerships might address.


S
T
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M

Broadening Participation in STEM Learning

STEM literacy is increasingly critical for full participation in civic life[1] as well as for future employment[2]. It is thus fundamentally an issue of social justice that all adolescent youth have opportunities to pursue STEM learning. But, as plenty of studies show, such opportunities are not equitably distributed[3,4].

Research is clear that identity is central to STEM learning[5, 6]. Young people who identify as STEM learners — who feel capable in STEM and who are socially recognized by others as being capable in STEM — are more likely to pursue additional opportunities to engage with STEM, and in the process to deepen their interest and expertise in STEM[7–10]. But in communities and populations that have been historically excluded from STEM fields, young people may not have access to the social networks, role models, and learning communities that research shows are crucial for cultivating productive STEM learning identities[6]; thus they may be less inclined to take up opportunities to engage with STEM even when they are available[11, 12].

To broaden participation in STEM learning, decades of research suggests that programs need to build on youth interests and concerns, positioning STEM not as an end in and of itself but, rather as the means for advancing youth interests or purposes[4, 13-15]. For example, as young people pursue their passion for video-gaming, they need to and want to learn to code in order to design and produce their own videogames [16]. As they pursue their passion for civic justice, they need to and want to collect and analyze environmental data to share with community leaders[17]. Thus designing programs that recognize young people's existing positive social identities — as designers, musicians, or social activists, for example — may be a key way to invite and welcome participation in STEM learning programs, build productive STEM learning identities, and lay the foundation for future STEM learning.

But simply creating cross-disciplinary, or art + science STEM programs is not enough. To be successful in broadening participation in STEM learning, there is a need for such programs to critically address issues of equity and inclusion. A central question our project examined is, how art + science programs can be designed and implemented in ways that can

- → Appeal to a more inclusive cross-section of youth.
- → Leverage a broader cultural repertoire of interests and expertise, and thus deepen engagement and STEM learner identity development.
- → Broker and support ongoing opportunities to engage in STEM learning, both in and out of school.

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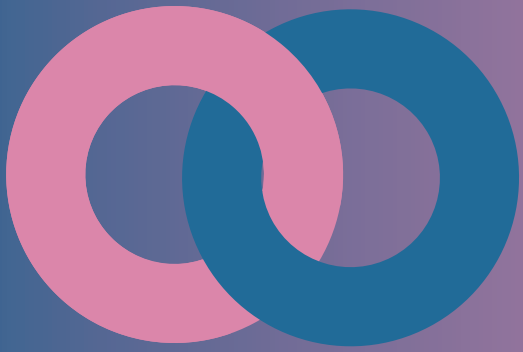

Epistemics / Youth Resources / Reflective Practice

Strategies: Epistemics, Youth Resources, and Reflective Practice

With the support of the Science Learning+ programme, in May 2015, an international group of educational program leaders and researchers met at Science Gallery Dublin to examine the evidence base with respect to how informal learning art + science programs could effectively engage adolescent youth from communities historically underrepresented in STEM fields.

Building on a literature regarding the development of research-practice partnerships, the group attended to power dynamics and distinct areas of expertise in order to equally privilege both research- and practice-based knowledge. Particularly in fields where practice may be ahead of research, as may be the case in the study and theorization of interdisciplinary STEM programs designed for underserved youth, accessing practitioner insights is essential for knowledge development. In addition to reviewing current program strategies and outcomes, we examined the research literature in areas of learning and the arts, youth development, and equity to address:

- → How art + science programs can meaningfully leverage **epistemic intersections** as an authentic form of sense-making and production.
- → How art + science programs provide powerful contexts for equity-focused teaching and learning, through their efforts to **leverage young people's interests and cultural resources.**
- → How art + science program design and implementation can be advanced through **data-driven reflection**.

Test / Revise
Re-test

Small battery-powered creatures
made with natural materials

Epistemic Connections Across Art + Science

Programs, such as *XTech* in Exploratorium in San Francisco, are demonstrating how to build and nurture supportive youth learning communities around shared practices of Making. In these programs, maker activities integrate aesthetics, design, and engineering with the goal of expanding young people's skills, identity, and interests in STEM[18, 19]. Artistic practices in these programs not only motivate participation and stimulate ideas, they also provide important learner-driven design constraints for the engineering tasks. For example, in the design and construction of NatureBots, small battery-powered creatures made with natural materials, students sketch out ideas for Bots they would like to build. They make careful observations about the properties and constraints of the asymmetrical materials they have selected, and how they affect the creatures' stability and motion, and revise their designs accordingly. They test, revise, and re-test until the objects are able to locomote in ways that meet the learner's goals. Frequently the movement of the objects (which may be slow or fast, jittery, erratic, or loopy) suggests a "personality" that leads to further design choices, which may then complexify the design task. For example, adding a cane to a creature that moves like an elderly person could affect the object's balance and symmetry and consequently require further adjustments.

Other epistemic practices that span art and science include observation and representation, common to environmental field studies, computational practices such as coding and visual representations of data, and many others.

Understanding more about how programs can fully leverage these intersections is key to ensuring that informal science programs move beyond arts and crafts to expand young people's understanding of the ways that STEM fields value and integrate specific skills and interests that adolescents may otherwise associate only with non-STEM fields.

Leveraging Student Interests and Resources

Digital Youth programs such as *Bridge21* in Dublin, *WACArts* in London, or the *HIVE* in New York engage students in digital production as they investigate issues that are important to them or their community. Integrating a wide range of artistic media and forms of expression, students take up technologies to both investigate and communicate issues of interest. For example, digital media are used to communicate across interest-driven youth communities, to collect and analyze data related to community health or environmental issues, and to tell the story to others. Digital production is a context in which arts and technology skills merge, and, in an equity-oriented context, programs are careful to use digital production in ways that recognize and leverage young people's cultural resources, and honor their cultural heritage and community.

At Science Gallery Dublin, young participants have the opportunity to explore a diverse range of fields through the lens of a broad theme e.g. LIFELOGGING and SECRET through inquiry and group based learning. Their learning is mentored by undergraduate students in science and technology and a group of external artists and researchers involved in producing the flagship exhibition programmed on the same theme. Thus the context of their project development and learning is always accompanied by the aesthetic of the exhibition and Gallery space. The physical execution of their project and the tools they use are dependent on the themes, the interests as identified by the group, and mentors. These may be in the realm of digital, electronic, print-making, biomedical, mechanical, digital production, maths and statistics or a number of these simultaneously. However the process of design and development, iteration and and reiteration is consistent across themes and disciplines and introduces participants into a way of making and collaborating may not always be familiar. This self guided learning and blurring of disciplinary boundaries appears to have the effect of freeing participants from self identifying as being good or weak at a particular subject.

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Data-Driven Reflection for Equity and Inclusion

Another key dimension of inquiry for the group was how art + science programs could be strengthened through the use of non-disruptive formative assessment tools designed and adapted for particular program contexts[20]. We prototyped two types of tools: one to track student engagement and the other to track and facilitate teacher reflection.

At *Science Gallery Dublin*, the *Exploratorium*, and *826 Valencia* in San Francisco, we were interested in exploring how to monitor and track young people's deepening engagement. But program leaders did not want to disrupt the informal program culture by using lengthy interviews or surveys. Building on learning research in gaming environments[21], Bell and his team experimented with developing "exit tickets" — quick pulse-taking measures that can characterize the degree of learner engagement across a range of dimensions as they engage in project-based experiences, without disrupting the flow of activity or program.

Using a research protocol (see Appendix D), youth were quickly polled at different points over time about various dimensions of their engagement in project-based experiences. Figure 1 shows how a group of young people engaged in project work with different areas of focus. Constructs measured included focused immersion ("focus"), heightened enjoyment, temporal disassociation ("flow"), narrative engagement ("interest"), and intention to revisit ("wanting to know or do more").

On average, students' measures, were relatively high for all activities (black line), ranging from 4.1 (wanting to know more) to 4.6 (interest), where 3 was neither positive or negative, and 5 was strongly positive. As can be seen, students' focused

Averages all data

- Soldering 1
- Ideation Ws
- App Making
- Mediating
- Webcam Hack
- Seed Dating
- Soldering

immersion was consistently high (4.5 average), with only the Ideation Workshop scoring lower for other measures. This workshop was different than the other activities students engaged in since it focused on a very specific theme (agriculture) which , in a follow up in a focus group was identified by students as being something that they did not relate to.

The data were useful for both learner level and classroom level interpretation. It allowed the program leaders to identify and examine more closely what had happened in each of the sessions, e.g. with the Ideation workshop (less positive scoring) and for Soldering (very positive scoring) in particular.

Support / Assess / Generate / Debrief / Learn / Participate / Share / Enable / Develop / Reflect / Disccuss / Engage / Measure / Design / Create →

To support equitable instruction, the research-practice team also developed a formative assessment tool in the form of a debrief questionnaire. This tool was used with teen mentors (ages 16–18) who were facilitating learning for younger students in the Exploratorium's XTech program and with undergraduate mentors in the Science Gallery Dublin mentoring programme. Facilitator debriefs, 30–45 minute discussions after participants go home, allowed staff to share what they are learning about younger students ideas, and participation; they also enable the sharing of facilitation strategies, ideas and concerns. Regular debriefing is a critical part of developing a reflective and equity-focused program, and is especially important for programs with adolescent-aged facilitators or mentors. A central aim in developing this formative assessment was to formalize the debriefing discussions in a way that might also yield insights, in a systematic way over time, into student experiences.

In response to needs of the programs, the debriefs focused on issues such as noticing

- → How facilitators engaged with youth to grapple with STEM concepts and tools.
- → How facilitators supported young people's process of generating ideas and design solutions.
- → The shared disciplinary practices in the arts, sciences, and engineering, such as designing, measuring, responding to feedback, etc.

In the summer of 2015, the debrief questionnaire was piloted with XTech's 2 lead teachers and 6 high school facilitators during a two-week program for a beginner cohort of 18 middle schoolers. Initial analysis revealed how individual writing prompts and questionnaire successfully engaged facilitators in reflective discussions. For example, youth facilitators noticed and discussed how, on the second day of the program as children were learning to use a wide variety of tools, there was a need to "slow down" as a matter of safety. In discussing how and why to help children slow down, facilitators came to reflect on the learning benefits for children. Throughout the 2 week program, the idea of "slowing down" was applied to a wide range of teaching and learning practices, such as modeling curiosity, observing, and explaining new understanding.

The tool was also adapted and piloted at *826 Valencia*, a writing program supporting youth ages 6 to 18. Leaders of the program wanted to collect and collate the staff reflections, to keep a running history of their observations of young people as well as staff's thoughts on equity-focused teaching strategies. To this end, the program created an online portal they called the AST Voyagers Log where educators entered their reflections on their interactions with students. The online debrief addressed programmatic time constraints which did not allow for immediate debrief discussions; facilitators reflected and recorded their observations at home, when they had more time.

AST Voyagers Log

The log includes logistical data, the learning goals of each student, and a list of 7 free-response questions:

- → Pick a short, memorable quote from today that speaks to the learning goals.
- → What surprised you?
- → Name a moment of courage.
- → Quote a time the voyager advocated for a need.
- → Name a moment of reflection.
- → Name a moment of collaborative learning.
- → Describe an instance when you shifted your approach.

Moving forward, the XTech program is exploring the possibility of creating an online portal for the debrief questionnaire. Meanwhile, 826 Valencia may also adapt the Engagement Survey for their short-term in-school programs. Science Gallery Dublin has built this debrief into the daily practice of their mentors for their mentoring programme.

Needs and Recommendations

There are many powerful examples of programs that integrate the arts and sciences to broaden youth participation in STEM learning. There is also a research and evaluation base that demonstrates ways in which these programs expand student interest and participation in the programs themselves. However, programs, and the constructs explored in the research, are widely divergent and therefore, while there are strong implications that emerge from looking at what we know about learning in and through the arts and what we know about broadening participation, there is less solid evidence about what it looks like when the arts, equity, and science come together. To this end, collectively the group generated a framework organized around three key dimensions: Youth engagement, equity-oriented facilitation, and reflective practice.

1. Engagement. In what ways do art + science programs effectively....

→ Engage young people with questions and conditions that matter to them?
→ Entail creative production, including digital, visual, and computational?
→ Position youth as meaningful contributors to art + science investigations?
→ Leverage shared epistemic practices such as observation, modeling/ representations, and meaning-making in those investigations?

2. Facilitation. In what ways do equity-oriented art + science programs effectively ...

→ Recognize and leverage skills, interests, and experiences youth bring to programs?
→ Provide opportunities for peer mentoring and leadership?
→ Broker opportunities for young people to deepen their engagement, learning, and leadership across a range of learning environments and opportunities?

3. Professional Development. What forms of support are needed for ISE educators to ...

→ Adopt culturally expansive teaching strategies including active efforts to leverage and broker learning opportunities across the STEM learning ecology?
→ Engage in data-driven reflection and professional development?
→ Adapt and effectively use formative assessment tools to support ongoing program improvement?

See Appendix C for a more detailed research framework.

To begin to answer these questions there is a need to more fully develop, across a wide range of settings, a number of different lines of inquiry, that can both advance the evidence base and enhance expert facilitation as well as young people's learning opportunities. Such an agenda would include:

- → **Developing the evidence base** for how productive art + science programs expand young people's STEM engagement by conducting cross-setting and longitudinal studies of youth learning trajectories.
- → **Expanding accounts** of how equity-oriented program design and facilitation broadens participation in STEM learning within the program and beyond through case study development of a range of different strategies referencing a common framework to allow cross-case comparisons.
- → **Supporting ISE field engagement** with evidence related to broadening participation, the potential of art and science integration, and the need for more culturally responsive approaches.

In conclusion, the project suggests that there is a strong potential for art+science to support interest-driven, learner-directed activities in STEM. More concerted and connected work in this area can begin to develop the evidence base upon which future policy and practice can be formed.

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Project Partners

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— Further Information

For more information about this project or related programmes please contact Jane Chadwick

Science Gallery Dublin
Trinity College Dublin 2
Ireland
T: 00353 896 2361