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Special Section: Leonardo STEAM Initiative on Education

# *The Main Course Was Mealworms: The Epistemics of Art and Science in Public Engagement*

Bronwyn Bevan (learning scientist), University of Washington, College of Education, U.S.A. Email: bronwynb@uw.edu. ORCID 0000-0002-9417-3361.

Sam Mejias (sociologist), London School of Economics and Political Science, Department of Media and Communications, U.K. Email: s.mejias@lse.ac.uk. ORCID: 0000-0003-3462-3815.

Mark Rosin (science communicator, mathematician) Pratt Institute, Department of Math & Science, U.S.A, Email: mark@guerillascience.org. ORCID: 0000-0002-8921-4683.

Jen Wong (science communicator, curator) Science Gallery London, King's College London, U.K. Email: jen@guerillascience.org. ORCID: 0000-0002-7993-4812.


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**Abstract**
In this paper we share an emerging analytical approach to designing and studying STEAM programs that focuses on how programs integrate the respective epistemic practices—the ways in which knowledge is constructed—of science and art. We share the rationale for moving beyond surface features of STEAM programs (e.g., putting textiles and electronics on the same table) to the disciplinary-specific ways in which participants are engaged in creative inquiry and production. We share a brief example from a public STEAM event to demonstrate the ways in which this approach can foster reflection and intentionality in the design and implementation of STEAM programs.

There is a long history of art and science integration in education, particularly in out-of-school learning programs such as summer camps, afterschool, and public engagement events. Today, these programs often rebrand themselves as STEAM. Some programs integrate art and science in surface ways---e.g., decorating bridges engineered from paper straws or listening to min-lectures about color mixing in a painting class. Others adopt deeper approaches, often towards some greater trans-disciplinary purpose, such as creating museum exhibitions or conducting community journalism.

Out-of-school learning programs can range from year-long to week-long, to more ephemeral (hour- or even minutes-long) "public engagement" activities occurring at street corners or science festivals (Fig. 1). Because they are designed to appeal to people who may not already identify as productive STEM learners, STEAM programs are argued to have particular salience for communities contending with significant systemic barriers to STEM learning [1] ---e.g.,

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under-resourced schools, limited access to high quality out-of-school programs, and strong cultural messaging. Highly collaborative, learner-directed, with performative or "audiencing" dimensions, research has demonstrated that STEAM programs can engage young people in exploring ideas, developing competencies, and finding personal direction [2, 3, 4, 5]. But, the evidence remains thin on if and how they deepen learners' long-term engagement and understanding in the disciplines. Driven by STEM funders, many STEAM programs contort themselves to demonstrate impact in areas such as test scores, enrollment in STEM academic majors, or even interest in or pursuit of STEM careers.

**Figure 1. The mathematics of tic-tac-toe, National Math Festival, Washington DC. (© Guerilla Science. Photo by Victoria Louise.)**

We define STEAM as the integration of disciplines from the arts and design with the STEM disciplines. We leave undiscussed here our views on the extent to which the history of this term belies its political versus its pedagogical origins. We note that the term STEM similarly had political origins before evolving into a field of pedagogical activity; it today experiences similar contestation in terms of if and how it is a disciplinary phenomenon versus an expedience. Nevertheless, to strengthen rather than subvert STEAM programs that are happening in the world, we posit a need to delve beneath the surface dimensions of art and science (e.g., the materials used, the terminology provided) to attend to the integration of the epistemic, or knowledge-building, practices of the respective disciplines [6].

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**<1> Epistemics**

In 2012, the US National Academy of Sciences issued a framework for K-12 science education that identified eight epistemic practices of science, later parsed into three clusters of activity: investigating, sense-making, and critiquing practices [7, 8]. At about the same time, two learning scientists described seven arts practices, clustered into technical/critical, creative, and ethical practices [9]. (See supplementary documents for brief discussion about the practice turn in science and science education.) In our study, we build on these frameworks (see Table 1) to explore what epistemic practices look like in public engagement events styled as STEAM. A leading question we explore is whether there are truly integrated epistemic practices of STEAM, or if STEAM programs are more likely to interweave specific artistic or scientific practices a different times and for different reasons [10].

| | STEM PRACTICES | CONJECTURED STEAM PRACTICES | ARTS PRACTICES |
|---|---|---|---|
| **Exploring** | Asking questions/defining problems<br>Planning and carrying out investigations<br>Using mathematical and computational thinking | Noticing and questioning<br>Exploring materiality<br>Defining the problem space | Deep noticing<br>Deconstructing component elements and their respective meanings |
| **Meaning-Making** | Developing and using models<br>Analyzing and interpreting data<br>Constructing explanations/designing solutions | Producing tentative representations<br>Conducting principled iterations/revisions<br>Engaging multiple modalities<br>Finding relevance | Applying artistic principles to augment meaning<br>Designing interrelations within and across multiple sign systems<br>Referencing or combining existing works and ideas |
| **Critiquing** | Arguing from evidence/peer review<br>Evaluating and communicating findings | Critical historicity; Hacking the ideas of others<br>Cultivating dissent<br>Holding commitments to standards of the field<br>Sharing results/"Audiencing" | Critical historicity; negotiating what constitutes a "good" project<br>Given a particular artistic goal, evaluating how successfully this goal has been met |

**Table 1. Framework for Epistemic Practices in STEAM**

We begin with an understanding that, when done well, arts-and-science integrated programs can spark delight, curiosity, anxiety, and other intertwined forms of emotion and cognition that heighten attention and engagement with ideas and questions (Fig. 2). Such approaches are often missing from classroom science, and may or may not be present in school or out-of-school STEAM programs.

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**Figure 2. Surprise and delight at Sweet Shoppe in Brooklyn. (© Hunter Canning)**

We see two main benefits of adopting an epistemic approach to studying STEAM programs: First, we posit that learning in STEAM programs can be strengthened. For example, the arts practice of critical historicity, if better incorporated into STEAM programs, can make the usually invisible (to the non-scientist) process of peer review more visible to learners, helping the public better understand how scientific knowledge is constructed. Likewise, better integrating the science practice of evidence-based reasoning could enrich learning in STEAM programs. Second, an epistemic approach to STEAM can allow more proximal documentation of program impacts, reducing pressure on programs to resort to test scores and other measures developed for different purposes.

**<1>Example**

To illustrate, we share early data from our study of Guerilla Science, a program based in London and New York that designs immersive storyworlds in which scientists engage the public [11]. Programs are staged at music festivals, county fairs, nightclubs and other settings where young people are not actively seeking out science engagement, but rather stumble across it and choose to participate (Fig. 3). (See supplementary materials for more detail.)

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**Figure 3. Enticing new audiences, National Math Festival, Washington DC. (© Guerilla Science. Photo by Victoria Louise.)**

Our study documents how the epistemic practices central to participation in Guerilla Science storyworlds (Fig. 4)---e.g., practices engaged during blindfolded sensory speed-dating (neuroscience), eating at an insect diner (environmental sustainability), or booking a vacation to the moons of Jupiter (physics and space science)---lead to new questions and understandings. We share an example from the Dutchess County Fair, 100 miles north of New York City. Over six days 400,000 visitors walk through barns filled with chickens, cows, and goats; admire the products of local quilters and bakers; and take rides on ferris wheels and carousels. They line up at food stands serving deep-fried onions, hamburgers, and cotton candy. The fair is attended by local communities from all walks of life including migrant agricultural workers, tradespeople, local professionals, and vacationing families.

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**Figure 4. Exploring love and neuroscience, 2017 Oregon Eclipse Festival. (© Guerilla Science. Photo by Skyler Greene.)**

In August 2018, Guerilla Science installed a retro diner in one of the barns. The *Entomophatron* was staffed by actors, scientists, and artists of multiple gender identities dressed in pink polka-dotted dresses and steeped in information about insects and the future of food (Fig. 5). County fair goers who stumbled upon this unlikely sight, approached the diner counter curiously, if tentatively, enticed by free bags of popcorn seasoned with agave worm salt. Once seated at a counter stool, "customers" were handed a menu and invited to take a blind taste test, comparing a bean nacho chip to a cricket nacho chip. Next, they were invited to eat roasted crickets, then mealworms, then "ants on a log" (dried ants sprinkled over celery and peanut butter), and finally a handful of roasted ants with no chaser (Fig. 6).

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**Figure 5. The Entomophatron. (© Guerilla Science. Photo by Cassandra Flores.)**


**Figure 6. Entomophotron menu. (© Marina McClure)**

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Over four days we recorded 51 interactions involving 140 participants. Laughter, curiosity, or disgust (feigned or not) were starting points for most of the participants. "Interactions" ranged between 1 and 33 minutes, with an average of about 10. While they ate, participants engaged in dialogue with the actors/waitresses who both maintained the storyworld of the diner experience, and also wove in information about insects as food. Much of this process was performative on the part of the participants themselves as they engaged in the activities in front of their friends or family members, some of whom snacked along with them, others of whom watched in horror (Fig. 7).

**Figure 7. Daring diner at the Entomophotron. (© Marina McClure)**

In the following transcript, an adult male "customer" (C), who has been observing four school girls interact with the female actress/waitress (W) at the counter, leans in and points to the "ants on a log":

| | | | |
|---|---|---|---|
| 1 | C | I'll try this. It looks good. *[Reaches over and picks up a piece of ant covered celery]* | *Makes initial positive contact* |
| 2 | W | They're good! | *Double-voicing; affirming his observation* |
| 3 | C | A protein source. | *Indicates prior knowledge* |

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| | | | |
|---|---|---|---|
| 4 | W | Great protein source! | *Double-voicing; recognizes his knowledge* |
| 5 | C | Yeah. *[Nods and swallows the celery]* What else do you have here? | *Suggests willingness to participate* |
| 6 | W | Join us! I'd be happy to go over the menu with you! | *Re-asserts the storyworld via waitress role* |
| 7 | C | Okay | *Enters the storyworld by sitting down at the counter* |
| 8 | W | Since you started out with this, we could just let that go… *[Points to dish with ants on a log]*… We have roasted mealworms and roasted crickets. If it was me…. These *[Points to mealworms]* have a pumpkin flavor… and these *[Points to crickets]* have more of a nutty flavor. Which would you like to ... | *Marks differences between the insects. Analogues to everyday experiences (pumpkin and nut flavors)* |
| 9 | C | I'll try one of each. | |
| 10 | W | Awesome. Here you are. *[Drops mealworm into his palm]* | |
| 11 | C | Mmmm. *[Tosses mealworm into his mouth, nods in affirmation.]* | |
| 12 | W | These *[points at mealworms]* are much better – I should be giving you – | *Recognizes she has deviated from the storyworld's meny sequence* |
| 13 | C | --Delicious *[Interrupts]* | |
| 14 | W | --the cricket first because these *[mealworms]* are better. So I can give you more mealworms if you like after. | |
| 15 | C | That's good too. *[Referring to cricket]* A little bitter. Those are really good. *[Points to mealworms]* | *Communicates his discernment of difference* |
| 16 | W | Yeah, these are really good. Would you like some more? | |
| 17 | C | Okay. So they're roasted? *[Extends his palm]* | *Rubs mealworms to explore texture* |
| 18 | W | Roasted, lightly seasoned. | |
| 19 | C | This is great. I gotta get a picture of this. *[Puts one into his mouth. Takes out camera]* | *Documents experience* |
| 20 | W | I also have a regular bag of agave popcorn. | |
| 21 | C | I have it already. | |
| 22 | W | Oh, perfect. | |
| 23 | C | That's how you got me in here, the popcorn. | |
| 24 | W | Would you like to try the ants on their own because the peanut butter overpowers it? | |

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| | | | |
|---|---|---|---|
| 25 | C | Okay. So these are just natural you didn't flavor them? *[Pops a fistful of ants into his mouth]* | *Communicates his discernment of difference* |
| 26 | W | No, roasted ants: that's their own flavor. I'll show you the container. They release an acid that they use as a self defense mechanism that's what makes it tastes like… | *Explains the science* |
| 27 | C | Pretty good. *[Nods]* | |
| 28 | W | [Unintelligible]. | |
| 29 | C | Thank you. Let me get a picture of this. These are great. *[Takes a picture]* I saw a show where in the future, when there's going to be food shortages, they're gonna harvest insects like from the Amazon. Giant beetles and things and then you can eat them too. | *Responds to her scientific fact by indicating awareness of other science, including its social relevance. Continues to document.* |
| 30 | W | Well, that's what we're talking about. Like crickets. They turn feed into protein 12 times more efficiently than cattle. | *Moves from qualitative to quantitative facts* |
| 31 | C | Uh huh. Wow. *[Photos the jars]* | *Appreciates factual information* |
| 32 | W | Yeah | |
| 33 | C | I'll get you in the picture too. *[Takes more pictures]* Thank you. *[Smiles at waitress and departs]* | *Displays emotional affect by commemorating experience with a photo.* |

This example was selected due to its representative nature as well as its short duration, which facilitates its inclusion here. In longer term (e.g., week-long, semester-long) STEAM programs, where program leaders might have pre-determined learning goals or experiences planned for participants, we would expect to see more fully developed epistemic practices. But studying shorter term engagements, where learning goals and activities are more emergent, can shed light on the different guises that epistemic practices can take, and, importantly, provide insights into how such an analytical framework can illuminate the contributions of shorter term arts-integrated public engagement events to the public's relationship with science, without having to use obtrusive tools such as pre/post surveys.

We found that, with some exceptions, "customers" at the counter tended to make short utterances, largely reacting to the prospect or the experience of eating an insect. Explanations provided by the waitresses were also short and generally met with expressions of interest, but with little probing or counter-argument. About one-third of the time participants expressed some familiarity with the phenomenon of human consumption of insects. About half of the time (53%) we documented back-and-forth questioning about the science intrinsic to the event. Thus, in this short excerpt, as in most, we find the presence of epistemic practices from Table 1's investigating and meaning-making categories, but, notably, not the critiquing category.

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For example, here, as in much of our data, the participant observed others at the counter for some time before deciding to join in. This **careful noticing** enabled him to monitor the emotional affect of those already eating the insects. The physical "theatre" of the diner created a venue for observation---observers were able to watch other customers squirm, laugh, and egg each other on. The physical theatre also serves as a tool for the actress/waitress who used it to beckon new customers to take a seat and look at a menu.

We see the customer **engaging with the materiality or sensory dimensions** of the different insects (Fig. 8)---contrasting the textures and tastes of the different critters (lines 9--19 and 25--27).

**Figure 8. Mealworms with goat cheese, sun-dried tomato, and fresh herbs. (© Marina McClure)**

In lines 3--4, the double-voiced dialogue shows that the customer is **articulating the problem space**---that insects represent an important protein source---which the waitress echoes, affirming and acknowledging his existing understanding. Later, in line 29, the customer will make it explicit that he understands the significance of the science.

In lines 26--31 the dialogue shifts to more **meaning-making practices**, where both customer and waitress begin to share explanations with one another, **representing their understanding** of the concepts and contexts being explored. In their brief back-and-forth they **frame the relevance** of insect protein in a changing world. The performative aspects of this interaction might constitute a

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**creative production**, an imaginary world of waitress and customer talking about what's on the menu. The participant's use of his camera to document the experience (lines 19, 29, 31, and 33) may indicate an intention of further meaning-making, beyond the scope of the event itself, whether through posting and sharing via social media, or through reflection at a later time.

We also see what is not here. The waitress asks few questions about what the customer might know or wonder about. There is no **critical discussion** about insects as a food source (for example, if and how it intersects with vegetarianism). There is no discussion of how and why scientists have constructed knowledge about human protein consumption, nutrition, population growth, and environmental sustainability. There is no **systematic comparison** of the different insects consumed. We conjecture that shorter term engagements, both for temporal and relationship/trust reasons, may not as readily afford critiquing practices (though they may be preparing participants for future critical engagement).

Early analysis of the data collected at the Dutchess County Fair demonstrate the many ways in which the carnival aspects of the Guerilla Science event created the invitation for participants to relate their personal histories to event's science focus. Initial disgust almost uniformly gave way to the exchange of ideas and questions. About one-third of participants shared personal perspectives, ranging from wry comments about wishing consuming the ants invading their kitchen, to memories of beetles that had been a delicacy in their youth in Mexico. These types of personal exchanges correlate with interactions that are about 30% longer in time than average, perhaps creating more time and opportunity for participants' learning and meaning-making.

**<1>Conclusion**

The purpose of taking an epistemic view of STEAM programs is to understand if and how they can engage the public more deeply in the questions, processes, and epistemologies of science in ways that are relevant to their lives. We posit that the theatrical aspects of the experience described above created a more inclusive, embodied, and therefore personal, invitation to engage in epistemic practices of investigation and sense-making. The dialogic nature of the experience helps us see how these practices lead to the exchange of ideas, histories, and information.

Our research seeks to map existing and new practices in the STEAM programs we design and study, and to determine if there are epistemic practices that are specific to STEAM. As we refine Table 1, we hope to develop tools that can help STEAM program leaders reflect on and be intentional about how their programs engage their audiences in epistemic practices. For example, the analysis presented here illuminated a paucity of critiquing practices in this particular event. In response, Guerilla Science leaders are developing new training approaches to prepare science communicators to more systematically engage audience members in critiquing practices such as arguing from evidence, cultivating dissent, and sharing results (with fellow diners). It is this sort

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of reflective practice—on the what, when, and how of science and art integration—that this study seeks to provoke and support to advance our understanding how STEAM can promote more inclusive learning opportunities in both art and science.

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**Biographic Information**

Bronwyn Bevan is a Senior Research Scientist at the University of Washington.

Sam Mejias is a Research Fellow at the London School of Economics.

Mark Rosin is Director of Guerilla Science US, and faculty at the Pratt Institute.

Jen Wong is Director of Guerilla Science UK.