frontiers in Computer Science

ORIGINAL RESEARCH
published: 17 March 2022
doi: 10.3389/fcomp.2022.830959

Raaz: A Transdisciplinary Exploration at the Intersection of Bioart, HCI, and Community Engagement

Lydia Stamato[1], *Erin Higgins*[1], *Hasan Mahmud Prottoy*[1], *S. Nisa Asgarali-Hoffman*[2], *Lisa Scheifele*[3,4], *Linda Dusman*[5], *Tagide deCarvalho*[6], *Teresa Ascencao*[7] *and Foad Hamidi*[1]*

[1] *Department of Information Systems, University of Maryland, Baltimore County (UMBC), Baltimore, MD, United States,* [2] *Information School, University of Maryland, College Park, MD, United States,* [3] *Baltimore Underground Science Space (BUGSS), Baltimore, MD, United States,* [4] *Department of Biology, Loyola University Maryland, Baltimore, MD, United States,* [5] *Department of Music, University of Maryland, Baltimore County (UMBC), Baltimore, MD, United States,* [6] *Keith Porter Imaging Facility, University of Maryland, Baltimore County (UMBC), Baltimore, MD, United States,* [7] *Arts Unfold, Toronto, ON, Canada*

Living organisms and their biological properties, including the capacity for transformation and representation of information, offer exciting and inspiring opportunities for transdisciplinary art and design explorations. While an emerging body of work is increasingly investigating the possibilities at the intersection of interactive computing, biology, and art, more work is needed to investigate the potential of these approaches for supporting community and public engagement and participation in art, science, and technology. In this project, we describe a multimedia transdisciplinary bioart installation and hands-on agar art activity that we presented to members of the public in a community biology lab setting. Using short interviews, observations, and questionaries, we investigated attendees' reactions and impressions of the experience and found that the event generated transdisciplinary reflections, invited participants to bring their previous knowledge and experience to bear in engaging with different aspects of the work, and that the audience benefited from contextualization by artists.

Keywords: human-computer interaction, living media interfaces, poetry, bioart, DNA

OPEN ACCESS

Edited by:
Raphael Kim,
Queen Mary University of London, United Kingdom

Reviewed by:
Phillip Gough,
The University of Sydney, Australia
Seung Ah Lee,
Yonsei University, South Korea

***Correspondence:**
Foad Hamidi
foadhamidi@umbc.edu

Specialty section:
This article was submitted to Human-Media Interaction, a section of the journal Frontiers in Computer Science

Received: *07 December 2021*
Accepted: *14 February 2022*
Published: *17 March 2022*

Citation:
Stamato L, Higgins E, Prottoy HM, Asgarali-Hoffman SN, Scheifele L, Dusman L, deCarvalho T, Ascencao T and Hamidi F (2022) Raaz: A Transdisciplinary Exploration at the Intersection of Bioart, HCI, and Community Engagement. Front. Comput. Sci. 4:830959. doi: 10.3389/fcomp.2022.830959

INTRODUCTION

Interactive living media interfaces (LMIs) that combine living organisms, such as bacteria and fungi, and digital computational components create engaging, informative, and innovative systems for learning, therapy, ecological- and self-exploration, and community science (Merritt et al., 2020). LMIs provide unique ways for users to interact with designed artifacts and systems and experience computing beyond a computer, making them particularly suitable for broadening participation in science and technology. However, the design and evaluation of these systems often require expensive equipment and expertise, creating barriers to their widespread and equitable uptake and development. Furthermore, as emerging computational systems, hybrid digital-living media systems have the potential to promote ethical introspection and discussion and to produce culture, a capacity foregrounded in the adjacent field of bioart (Menezes, 2015; Vaage, 2016; Asgarali-Hoffman and Hamidi, 2021).

However, this potential is underexplored in the field of human-computer interaction (HCI). In this case study, we explore the technical, cultural, ethical, and aesthetic implications of combining synthetic biology, poetry, audio design, imaging, and information theory to create a multimedia bioart installation and present it to members of the public in a participatory community setting: the community biology lab where the artwork was primarily developed.

Raaz (Farsi: راز) is a multimedia bioart installation (**Figure 1**) that creates a meditative space focused on embodied representations of a canonical poem by fourteenth-century Persian Sufi poet Khajeh Mohammad Hafiz Shirazi. The biologically-embodied text is a meditation on timelessness through transformative love. The text is encoded using Morse code, translated into viable genetic code, fabricated, and inserted into the genome of living yeast cells used to make wine. The tomb of the poet in Shiraz, Iran inspires the space layout of the installation. At the center, a bottle of poetry-infused wine is surrounded by large-format photographic prints of the microscopic yeast. Ambient audio surrounds the wine with a reading of the Hafiz poem, which is transformed into timelessness over 12 min using the resonant frequencies of a room similar to the tomb of Hafiz. The Morse code translation combines with an original bass flute melody tuned to the poetry reading. The melodies fragment and transform as they sound via speakers installed surrounding the space. Through multiple representations, the poem resonates both literally and metaphorically through the meditative space.

In this paper, we build on our previous research investigating the possibilities and limitations of working creatively with living organisms through the design and evaluation of interactive interfaces (Hamidi et al., 2021) by collaboratively developing a multimedia bioart installation and using it together with a hands-on agar art activity (**Figure 2**), to engage community members in a Do-it-Yourself Biology (DIYbio) context. *Agar art* refers to paintings or drawings made with living microorganisms (e.g., bacteria or yeast cells) whose color and texture change over time (Adkins et al., 2018). This paper extends our previous research with bioartists, biodesigners, and community lab leaders by implementing and exemplifying earlier findings that identified the opportunity to investigate transdisciplinary modes of collaboration, cultural and embodied aspects of living media, and the need to negotiate access to tools, skills, and knowledge (Hamidi et al., 2021). The main contribution of this case study is a detailed description of how contemporary methods

Figure 1 | The *Raaz* installation with bottle of transgenic wine in the center surrounded by microscopic images of yeast on the walls.

Figure 2 | Two participants creating living drawings (i.e., Agar Art) using bacteria and yeast.

in HCI, synthetic biology, microscopy and imaging, audio design, and exhibition design can come together in the creation of a public-facing project to engage community members in transdisciplinary reflection, raising questions and concerns, and developing ideas that go beyond disciplinary bounds. In this way, our approach exemplifies a transdisciplinary orientation that "focuses on a broader goal, transcending disciplinarity and using collections of methods and their associated domains of expertise on an as-needed basis as required by the pursuit of this target broader goal" (Blevis and Stolterman, 2009).

This article is an extended version of a paper originally presented at the 2021 ACM SIGCHI Conference on Human Factors in Computing Systems (CHI'21) (Hamidi et al., 2021). The original conference paper presented an interview study with bioartists and an initial description of the *Raaz* project that focused on the poetry-infused wine and the biological processes used to develop it. In this journal article, we extend the conference paper by exploring the presentation of *Raaz* as a multimedia installation with visual and audio components, and present findings from this public-facing community-engaged exhibition.

RELATED WORK: LIVING MEDIA INTERFACES AS A SITE FOR RESEARCH AND INNOVATION

There is a growing body of HCI research that investigates the possibilities of incorporating living organisms into the design of interactive artifacts (e.g., Lee S. A. et al., 2015; Yao et al., 2015; Hamidi and Melanie, 2017; Gome et al., 2019), the creation of tools and processes to create novel hybrid systems (Yao et al., 2015; Gome et al., 2019), and studies with DIYbio communities (Kuznetsov et al., 2012, 2015, 2018; Lin et al., 2019). In a recent review of LMIs, Merritt et al. used four lenses, biological, ethical, artistic, and HCI, to analyze a series of exemplar interactive projects that combine living organisms and digital components (Merritt et al., 2020). They identified projects that incorporate a range of living organisms in almost every biological kingdom, including plants (e.g., Holstius et al., 2004; Fernando et al., 2009), animals (e.g., Robinson et al., 2015), fungi (Hamidi and Melanie, 2017), eubacteria (i.e., *E. coli*) (Cheok et al., 2011), and protists (e.g., *Euglena gracilis*) (Lee M. E. et al., 2015). They also identified a range of control mechanisms (e.g., light exposure or water and nutrients intake) and methods of manipulation (e.g.,

environmental factors, embedded actuators) used to implement interaction with different organisms (Merritt et al., 2020).

Within HCI, LMIs have been used in a range of applications, including learning (Kafai et al., 2017; Walker and Kafai, 2021), environmental awareness (Holstius et al., 2004), ambient data visualization (e.g., Kuribayashi et al., 2007), behavior change (e.g., Holstius et al., 2004), artistic expression (e.g., Alistar and Pevere, 2020), and entertainment (e.g., Poupyrev et al., 2012). Many of these applications are built on the premise that interacting with living organisms is engaging and motivating for users (Hamidi and Melanie, 2017), can lead to valuable and long-lasting learning outcomes (Kafai et al., 2017), and that living media are especially suited for the representation and communication of environmental and ecological data (Holstius et al., 2004). Other HCI research adjacent to work on LMIs (since they do not use living organisms) have used tangibles and tabletop interaction techniques to increase biology and biodesign learning in the context of interactive exhibits (e.g., Manshaei et al., 2016; Loparev et al., 2017).

Interest in this area is growing with several ongoing efforts calling for more research on questions of ethics and equity in the space. For example, the Animal-Computer Interaction (ACI) research community is focused on designing interactive systems for, with, and by animals (Mancini, 2011). A central theme within this space is how to account for animal agency and include them in a participatory manner in the design process (e.g., Robinson et al., 2014), a call that is not uncontroversial (Lawson et al., 2015). Other efforts view microorganisms as interactive materials that, due to being alive, are situated at the intersection of design, biology, and ecology. For example, Pataranutaporn et al. proposed that microbes could be viewed as "programmable biological interfaces" (Pataranutaporn et al., 2020) with unique affordances for HCI applications. These include microbes' ability to store (i.e., embody) and communicate information and respond to bio-fabrication processes, among others (Pataranutaporn et al., 2020). However, they also pointed out that technical, ethical, societal, and environmental challenges remain in this space, and drew on new understandings in bioethics (New Directions, 2012) that call for prioritizing public beneficence, democratic deliberation, and justice and fairness, among other actions (Pataranutaporn et al., 2020).

Other studies of DIYbio initiatives have identified parallels between these communities and DIY and maker initiatives. For example, Kuznetsov et al. found that like hackers and makers, community lab members often operate at intersections across an array of stakeholders, resources, and interests (Kuznetsov et al., 2012). Using a set of functional prototypes, such as an interactive device for viewing bioluminescent algae, the researchers illustrated several areas of future exploration at the intersection of HCI and DIYbio, including developing tools for transdisciplinary collaboration, mechanisms for external communication, and hybrid bio-electronic assemblies.

More recently, we interviewed expert bioartists, biodesigners, and community lab organizers in order to learn about their motivations, practices, and ways in which they experience and engage information and interaction in their work with living organisms and other biological components, such as hormones, proteins, or DNA (Asgarali-Hoffman and Hamidi, 2021; Hamidi et al., 2021). In our analysis focused on bioart in practice, we described three overarching themes that describe (1) ways in which the work of bioart generates "transdisciplinary fluency," which enables individuals to think, work, and collaborate using a variety of epistemologies, values, and skills; (2) the "familiar" qualities of living media that, by virtue of their relation to humans as living organisms, evoke a fundamental shift in perspective and values through interaction; and (3) the necessity of sufficient access to knowledge, expertise, materials, and tools, which artists and their collaborators negotiate and create by appealing to their positions and relationships (Hamidi et al., 2021). Broadening our investigation of bioart to include perspectives of community lab organizers and researchers and designers with diverse professional backgrounds, we developed a perspective on bioart that highlighted the possibilities bioart creates for public awareness, education, and engagement and the cultural and social role of bioartists defined by politics at the intersection of biology and identity (Asgarali-Hoffman and Hamidi, 2021).

This project builds on and complements previous research in this area by presenting a detailed example of how creative practices that draw on biology, poetry, and audio and visual composition, can benefit from multiple techniques and epistemologies. The project develops multimedia experiences into a contemplative space for engaging community members in transdisciplinary reflection on emerging technologies, the meanings of the poetry and music, and ultimately themselves as the completion of the installation experience. Furthermore, we describe our process for navigating academic, creative, and community spaces when developing and presenting the project and evaluating its impact on audience members in a community setting.

MATERIALS AND METHODS

Raaz: A Multimedia Bioart Installation

Raaz (Farsi: **راز**) is a multimedia installation that consists of a poetry-infused bottle of transgenic wine surrounded by large-print microscopic images of genetically modified yeast cells that include an encoding of a poem by the fourteenth-century Persian Sufi poet Hafiz. The layout is inspired by the poet's tomb in Shiraz, Iran, and is accompanied by audio that combines the poem's recitation, its Morse code representation, and original bass flute music. *Raaz*' use of multiple representations of the poem is a meditation on its themes of transformation and timelessness. Furthermore, the installation explores themes of transformation; the cultural significance of wine in Sufi poetry; and the relationship between biology, poetry, and information.

A Bottle of Poetry-Infused Wine

The poetry-infused wine at the center of the installation was fermented using *Saccharomyces cerevisiae* yeast cells whose DNA was genetically modified using DIYbio synthetic biology methods to include an encoded fourteenth-century Persian poem by the Sufi poet Khajeh Mohammad Hafiz Shirazi (Farsi: **خواجه شمس‌الدن محمد حافظ ش‌راز**) who used the pen name Hafiz (**حافظ**) (aka Hafez and Hafiz of Shiraz).

The poem is a famous line from a longer ghazal, a classic Persian poetic form, and has been translated many times into English and other European languages since the late eighteenth-century. It was first translated into English in 1771 by William Jones, and later into German by Joseph von Hammer-Purgstall in 1812 (Meisami, 2000). The following is a classic translation by William Clark from 1891:

"Never dieth that one, whose heart is alive with love:
On the world's record, is written the everlasting existence of ours." (Hafez, 1974).

A contemporary translation of the poem by the last author follows:

"One whose heart is vitalized by Love never dies:
Our continuity is written on the face of time."

Hafiz was born in Shiraz (Farsi: : شراز), a desert city in Southern Iran known for its poetry and wine, in 1,315 (Meisami, 2000). Hafez's poetry collection, known as the Divan of Hafiz, is one of the most popular poetry books in present-day Iran. The poems are regularly memorized in Iran and recited at significant events such as weddings and new year celebrations.

Wine (Farsi:: شراب) and fermentation have a long history as powerful and controversial metaphors in Sufi poetry (Saeidi and Unwin, 2004; Pourjavady, 2012). One common interpretation is for fermentation to stand as a metaphor for spiritual transformation that turns grapes (human potential) into wine (transcendent spirituality). Other interpretations have likened inebriation due to drinking wine to becoming intoxicated by divine love. Another layer of complexity surrounds these metaphors since drinking alcohol and wine is prohibited in Islam (and currently illegal in Iran). Therefore, drinking or making wine also symbolizes forbidden and subversive acts of transcendence that deviate from conservative interpretations of religion. The difficulty of capturing these cultural complexities in translations of Sufi poetry has been noted previously (Davis, 2004; Loloi, 2004; Seyed-Gohrab, 2014). In this context, the tension present in fermenting wine or writing mystical poetry as a creative act is reminiscent of the notoriety that sometimes surrounds the work of bioartists who often interrogate prevalent social and cultural norms in working with genetically modified organisms (Mitchell, 2015). Incidentally, the Western cultural aspects of wine have recently received some attention in HCI (Paay et al., 2019).

Raaz means "secret" or "mystery" in Farsi and we use it to refer simultaneously to the invisibility of the poem encoded in the yeast cell's DNA sequence and to the ambiguity of the metaphor of wine as both a spiritual and a material concept both sacred and taboo. The word also has further significance in Farsi in that if the central letter, "a" (Farsi:), is dropped the word becomes Raz (Farsi: رز) which is another word for wine. Therefore, in the Farsi interpretation, the word "wine" is hidden in the word "secret."

The current project references *Genesis* (Kac, 1999) a canonical bioart installation that used synthetic biology processes to encode an English translation of a line from the biblical Book of Genesis describing humanity's supposedly divinely-appointed dominion over nature into the DNA sequence of living bacteria (Kac, 1999). The artist (Eduardo Kac) then displayed the bacteria in an interactive installation that could be accessed and manipulated remotely over the Internet or in person. Kac has described the project as an exploration of the "manifold relations between biology, belief systems, information technology, dialogical interaction, ethics and the Internet" (Kac, 1999). More recently, in their collaborative bioart project *Baitul Ma'mur:* Khan and Davis, 2021, Sarah Khan and Joe Davis stored 2.417 quintillion copies of an encoding of the Arabic phrase "سبحان الله" (English: glory to God) in a 1 mm layer of DNA placed on the head of a straight pin. Through this work, Khan and Davis draw parallels between efficient encoding techniques storing multiple copies of the sacred phrase and the intricate and repetitive patterning used in traditional Islamic architecture. They described the project as "an exercise in bridge building, between art, mathematics, science, and spirituality across multiple expressions" (Khan and Davis, 2021). In *Raaz*, we contribute to this exploration "across multiple expressions" by paying homage to the resilient spirit of Persian mystic poets who used the power of metaphors and linguistic transmutations to capture vivid experiences of personal and spiritual transformation and ensure that their poetry survived oppressive orthodox religious and political doctrines and agendas.

Raaz differs from the earlier projects in that it engages with an additional ethical dimension: as described above, wine (and the process of producing it) is taboo in Islamic traditions, which is precisely why it is used in Sufi poetry as a poetic metaphor for a dangerous but necessary spiritual transformation. By turning the key metaphorical concept of wine from the Sufi tradition into material reality, *Raaz*' engagement with the process of winemaking parallels the ethically ambiguous practice of genetically modifying living organisms (Vaage, 2016). *Raaz* further contributes to diversifying the bioart field by bringing in a non-Western perspective to a space dominated by Western artistic and scientific perspectives (Heather et al., 2020). In addition to these distinctions, *Raaz* differs from *Genesis* with respect to the living media and biological processes employed, thereby extending the scope of materials used in the HCI-bioart space. In another project, *The Last Supper* (2018), artist Karolina Zyniewicz genetically modified yeast to include a gene from Zyniewicz' own genome, which was then used to ferment beer and make bread that were ritually consumed by the artist and her colleagues (Zyniewicz, 2018). Despite similarities in drawing on religious symbolism and genetically modified food, this project differs from *Raaz* in its approach to the source and symbolism of transcendent spirituality, as it is informed by the artists' engagement with the Christian tradition.

Synthetic Biology Processes Used to Create the Transgenic Wine

The steps needed to move from the original poem to the fermenting wine can be broken down into the following stages: (1) converting the poem into a viable DNA sequence, (2) having the DNA sequence synthesized and inserting it into a plasmid (a circular DNA capable of carrying the inserted DNA into cells), (3) transforming living yeast cells using the plasmid and verifying that the yeast cell DNA has incorporated the correct code, and (4) growing the transgenic yeast and using it to ferment grape

juice into wine. We next provide an overview of these steps (for a partial overview, see **Figure 3**). For more details, please see our previous paper describing these steps in detail (Hamidi et al., 2021).

Drawing on the concepts of encoding and mapping from Information Theory (Pierce, 2012) and in a process similar to Kac's in *Genesis* (Kac, 2008), we first translated the Persian poem into Morse code, a binary code that maps each letter of the alphabet to a sequence of dots and dashes. While the Morse code encoding was originally designed by Samuel Morse in the 1830s for translating the English alphabet to signals that could be transmitted using electrical pulses and silences between them using early telegraph systems (Editors of the Encyclopedia Britannica, 2019), it is widely used with other scripts, including the Persian (or Farsi) alphabet of the original Hafiz poem. We used the common Morse encoding for the Persian alphabet to translate the poem into a series of Morse dots and dashes (**Figure 3**).

Next, we encoded the Morse code sequence into a sequence of letters representing the four nucleotides that make up DNA sequences, again referencing a convention utilized by Kac in the *Genesis* project by replacing dots by the genetic base Cytosine (C), dashes with Thymine (T), spaces between letters with Guanine (G), and word spaces with Adenine (A). This process resulted in a linear sequence consisting of the four nucleotide letters, which through their order encode the information of the poem (**Figure 3**). We next added additional nucleotides that would allow an enzyme (the *BsaI* restriction enzyme) to recognize and cut the DNA so that it could be joined to the complementary plasmid DNA, a process called molecular cloning. We made these changes so that it would be possible to integrate the DNA segment into a plasmid backbone, pYTK096, that was cut with the same enzyme. We chose this plasmid because it can be used for integration into the yeast chromosome through homologous recombination as well as a functional *URA3* gene to serve as the selection marker (Lee M. E. et al., 2015). Having a selection marker is important because it allows for the selection and growth of only those yeast cells that successfully maintain the customized DNA sequence.

Once the design of the DNA sequence was completed, we sent it to a supplier of custom nucleic acids (Integrated DNA Technologies–IDT) to be chemically synthesized. Once fabricated, we then performed a Golden Gate reaction to join together the custom DNA and the pYTK096 plasmid backbone (Engler and Marillonnet, 2014; Lee S. A. et al., 2015). While the DNA would eventually be integrated into yeast cells, the steps of selecting the plasmid with the newly inserted DNA are first performed in bacteria, where the process is more efficient. The product of the reaction was then used to transform bacterial strain *E. coli* DH5 α. Some of the bacteria pick up the plasmid DNA into which the custom sequence has been inserted, and we then amplified the synthesized DNA by growing the bacteria in the LB media liquid culture with kanamycin as the selection agent that ensured that only bacterial cells that have picked up plasmid DNA can survive. This process resulted in bacterial cells that could multiply, resulting in numerous living cells containing our desired genetic segment. With the addition of 15% glycerol, bacterial cells are also amenable to freezing at −80°C, allowing us to "bank" our DNA in the bacterial cells for long-term storage. Next, we conducted a miniprep to extract the plasmid containing the DNA sequence from bacteria cells using Promega's Wizard SV miniprep kit. We then performed an enzyme digest that used the

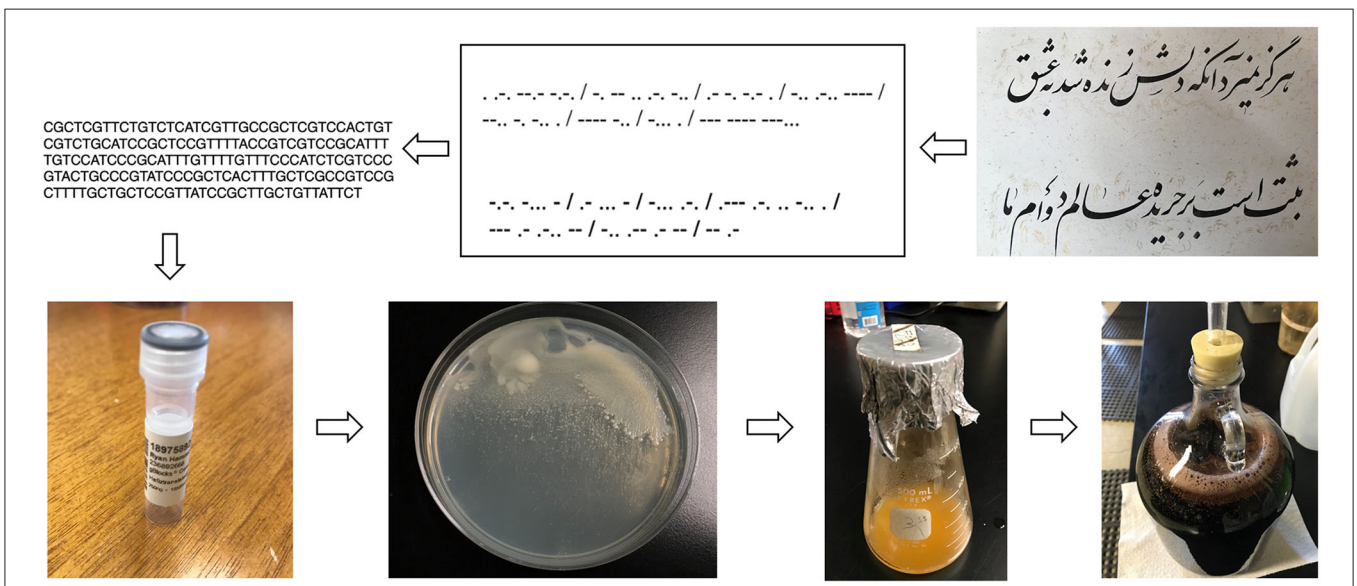

Figure 3 | A partial overview of the processes used to infuse wine with the Farsi poem (counter clockwise from top right): the poem in Farsi calligraphy; poem translated into Morse code; poem mapped into CGTA with additional letters added to make it viable; synthesized DNA molecules; bacteria with modified DNA including the poem; yeast sample with the modified DNA; wine created with the genetically-modified yeast.

BsmBI enzyme to cut a sample of the extracted plasmid into two fragments to verify that the ligation of the DNA into the plasmid took place correctly by examining the length of the fragments.

We next linearized the plasmid by adding *NotI* restriction enzymes so that the DNA segment, including the poem, could be integrated into the genome of yeast cells. Finally, we transformed yeast cells with the linearized fragment and selected for yeast colonies that successfully integrated the Hafiz gene into their genome using a process known as homologous recombination: We used a strain of yeast (BY4741) with an interrupted *URA3* gene rendering it unable to produce uracil. We chose this strain because it will not survive if grown on uracil-deficient nutrient media unless it has integrated the linear DNA fragment that in addition to the poem contains a functional *URA3* gene (which in our original design we had added to our customized DNA molecule). We re-plated any surviving yeast onto new plates lacking uracil to eliminate any background cells that did not pick up the DNA. At the end of this process, we had a colony of yeast cells with integrated DNA sequence containing Hafiz's poem.

Once the transgenic yeast was created, we grew it over several days in rich media (YPD; yeast extract-peptone-dextrose) to create enough cells to ferment a gallon of wine. We then harvested the cells by centrifugation, washed them twice with water to remove residual media, and combined the yeast with red grape juice in a sterilized container which we incubated at room temperature. After a period of 2 weeks, we collected and bottled the transgenic wine.

Description of Audio

Raaz' audio consists of three components, (1) a recitation of the original Persian poem to which a reductive filtering transformation (first created by the composer Alvin Lucier in his composition *I am sitting in a room*) has been applied, fading into a sine tone-like melody over a period of 19 min, (2) a digitally produced and tuned Morse code encoding of the poem in Farsi, and (3) a meditative solo bass flute composition tuned to the other two audio components. The recitation and transformation of the poem along with the flute solo move slowly through the installation space, enveloping the audience in a slow and meditative sonic process immersing the large-scale microscopic photographs of the yeast cells in sound. Around the wine bottle, empty wine glasses mounted on pedestals throughout the space resonate with the tuned Morse code of the poem via speakers attached to their pedestals. In the installation at BUGSS (described below), we decided not to use the glasses due to time limitations, but we verified that the audio works well with empty glasses attached to speakers and we plan to use them in the future. The use of empty glasses is significant because it represents another Sufi metaphor: the human soul as an empty spiritual vessel. The Morse code provides an active counterpoint to the meditative surround audio of the poetry and the flute that, through the use of convolution reverb, sounds in the replicated sonic space of a large tomb.

Description of Images and Video

Finally, the installation included six large format images surrounding the wine, including one image of the poem in Persian calligraphy and five photomicrographs of yeast cells (see **Figure 4** for an example). During the oral presentation piece, we also showed a video of moving yeast cells. The images were printed on matte paper and mounted on black foam core. One of the images was printed on silk cloth and used to surround the wine bottle.

To produce these images, a mixture of live transgenic yeast and wine sediment was stained with three fluorescent dyes: acridine orange, calcofluor white, and congo red. Photomicrographs and video were acquired with a Zeiss LSM 900 confocal microscope using 405 and 488 nm lasers and 3 collection windows (blue, green and red wavelengths) and were processed using Huygens (SVI) deconvolution software and Imaris (Oxford Instruments) cell imaging software.

Description of Exhibition Design

In our original exhibition design, the *Raaz* installation was situated in a quiet room of $\sim 16' \times 16'$ (feet). Eight pedestals [each $\sim 40''$ (inches) tall] were assembled into a wide circular pattern, creating a visual circumference within the space. On each of the pedestals sat an empty wine glass containing a transducer for augmenting the soundtrack through its hallow opening. An additional identical pedestal was placed in the middle of the space—this one holding a wine bottle with the poetry-infused wine. Centered in between each of the pedestals within the circle, were five high-resolution, large-scale ($66'' \times 66''$) prints of the yeast photographed by microscope and another equal-sized plate inscribed with the poem in Persian calligraphy. The installation layout was inspired by the poet's tomb in Shiraz, Iran, which is of similar dimensions, surrounded by eight columns, and the grave at its center.

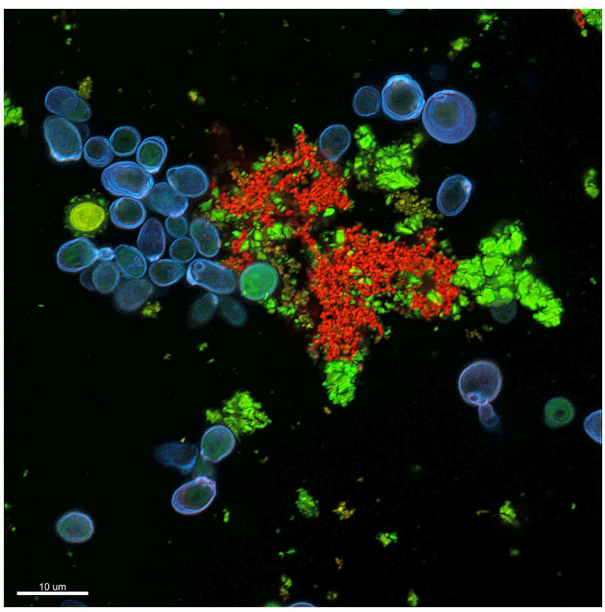

Figure 4 | A microscopic image of yeast cells with grape juice sediment that was displayed at the installation.

In subsequent iterations, we simplified several elements of the exhibition design to make the installation easier to setup in diverse settings. Specifically, we decreased the number of pedestals to three—one for the wine bottle and two for empty glasses—and replaced transducers with speakers to improve audio quality and resonance. While these changes made the layout different from the poet's tomb, they made the work more adaptable to diverse (often smaller) installation spaces.

Collaborative Team and Project Context

Our art and research team consisted of five HCI researchers, including the academic/bioartist who is an expert in the design and evaluation of LMIs (Hamidi), four PhD students (Stamato, Higgins, Prottoy, Asgarali-Hoffman), a composer and educator (Dusman), a biologist with expertise in imaging and microscopy (deCarvalho), a synthetic biology researcher and educator who is also the director of the community lab in which the research took place (Scheifele), a performance and visual artist with expertise in exhibition design (Ascencao), a recording engineer and sound designer (Wonneberger), and an independent bioartist (Hammond).

The initial part of the project, developing the creative concept and materials, largely took place during the 2020 and 2021 COVID-19 pandemic. Therefore, the creative activities that resulted in the project's audio component (Section Description of Audio), visual component (Section Description of Images and Video), and exhibition design (Section Description of Exhibition Design) were conducted using a combination of synchronous and asynchronous activities. The synchronous activities consisted of remote meetings over video, as well as a small number of socially distanced in-person meetings. The in-person meetings were necessary in cases where a physical sample needed to be exchanged to be photographed or an audio sample needed to be collected from one of the artists. The asynchronous activities consisted of email communications and sharing of digital files, including the exchange of audio and visual samples and exhibition design drafts for feedback.

The steps needed to create the audio and visual components of the installation took place at our university campus. The synthetic biology procedures necessary for the project (Section A Bottle of Poetry-Infused Wine) took place at a local DIYbio lab. The Baltimore Underground Science Space (BUGSS) is a BSL-1 facility that offers affordable courses, seminars, workshops and biology lab space to members of the public (Scheifele and Burkett, 2016). BUGSS is located in the city of Baltimore, Maryland and serves more than 450 members and visitors each year. Courses at BUGSS offer hands-on immersion in biotechnology. In past courses, participants have analyzed the content of probiotic pills, tested their own DNA for genetic variants related to stress resilience, and tested foods for the presence of genetic modification. Seminars often focus on the intersection of science and society, including the efficacy of commercial cannabidiol products, changes to the Chesapeake Bay environment, and the effects of racial disparities in health care. Workshops at BUGSS are distinct for their interdisciplinary nature, frequently incorporating bioinformatics or bioart themes such as bioluminescence. Like most DIY-biology spaces, BUGSS facilitates independent and community projects. Examples include Barcoding the Harbor, which uses DNA analysis to catalog organisms living in Baltimore's harbor; Open Source Gendercodes, which engineers plant cells to produce steroid hormones that could be used for gender transition; and Open Insulin, which is developing infrastructure for community-based manufacturing of insulin for diabetics.

Community-Engaged Event Description

As interdisciplinary researchers concerned with ethical HCI, we are interested public perception and co-creation of emerging biotechnology. To better understand the reactions and reflections that experiencing *Raaz* may engender in members of the public, we decided to present the project at a public-facing event at BUGSS. Presenting the installation at the community lab allowed us to share it in the context in which its biological components were developed and to evaluate its ability to engage members of the public in a community context. There are several aspects of BUGSS that likely impacted participants' engagement with the exhibit. First, BUGSS classes, seminars, and activities focus on cutting-edge science such that participants expect to hear about fields and technologies that are rapidly developing and inherently interdisciplinary. Given this focus on modern techniques and concepts, the core of BUGSS' audience is adults and high school students, and intergenerational dialogue and collaboration is common. Third, BUGSS is an urban space, located in downtown Baltimore city, but draws members from throughout the surrounding counties and Mid-Atlantic region, generating a community that is ethnically, culturally, and linguistically diverse. Finally, BUGSS is a membership organization that also encourages participation of non-members at individual events; we therefore expected the audience to include those who were regulars at the space, were fluent with modern biotechnology, and had preexisting relationships with each other and the space, as well as individuals for whom this would be their first exploration of science, bioart, and living media.

We designed the event to comprise of three components. First, three artists who had worked on *Raaz*, (Hamidi, Dusman, Wonneberger) gave a combined 30-min artist talk about their process, motivation, and context of the work. Handouts with information about *Raaz* were printed on standard letter size ($8.5'' \times 11''$) paper and folded in half widthwise to form a booklet. Handouts were placed on audience chairs before the start of the event. The handout included the DNA synthesis protocol, a Farsi to Morse code to nucleotide translation diagram, lines of the poem in Farsi and English translation, and contact information. Second, audience members had the option to visit the *Raaz* installation in a room adjacent to the one where the talk was given. This space was intended to be quieter, allowing participants to immerse themselves in the multisensory experience and engage in reflection. The artists remained at the periphery to engage in discussions and answer questions as people moved in and out of the exhibit space.

Third, we wanted to give participants additional time to deliberate and make meaning collectively by discussing their experience. We encouraged this practice by offering an opportunity to engage in a communal agar art activity that

requires 10–15 min of dedicated time (**Figure 2**) in the adjoining wet lab area. While this is a time-intensive activity, the mechanics of performing agar art can be mastered quickly, such that participants have ample time and cognitive space to engage with each other and the artists. We further hoped that transitioning from passively listening to the artist talk or experiencing *Raaz* to actively producing their own elementary work of bioart would encourage additional insights about working with living media. *Agar art* (aka *microbial* or *bacterial art*) refers to living paintings or drawings made with living microorganisms (e.g., bacteria or yeast cells) whose color and texture change over time on a growth medium, usually in a petri dish, solidified by agar (Adkins et al., 2018). Creating agar art that involves the hands-on use of living organisms to create free-form patterns or figures has emerged as a popular, participatory, and low-cost method to introduce people of diverse ages and skill levels to bioart, especially through initiatives such as the annual art contest sponsored by the American Society for Microbiology (ASM) (Chan-Laddaran, 2015; American Society Microbiology, 2017). Recent work that combined agar art into the introductory biology course work of undergraduate university students has provided preliminary evidence that engaging in agar art can increase student engagement, science self-identification and self-efficacy, and inspire open-ended science investigation (Adkins et al., 2018). We decided to include the agar art activity because it provides several points of contrast with *Raaz* in how participants experience bioart. First, it is participatory in that audience members could create their own designs using the living organisms. Second, it is hands-on and provides an opportunity to touch and even smell the living media which is not currently the case with *Raaz*. Finally, it allows participants to empathize with biologists and bioartists, since it needs to take place in sterile conditions and under supervision, since working with microorganisms may be unintuitive or unfamiliar to participants. Additionally, the activity shares many qualities with experiencing *Raaz*: it creatively combines microbiology and art; involves working directly with living microorganisms; the majority of the execution occurs in a wet lab; and, it involves multiple senses.

The event primarily took place in three of the five distinct spaces that comprise BUGSS: a lab lobby ($\sim 22' \times 21'$) where the opening talk took place and there were seats and refreshments available for the participants; a more enclosed room ($\sim 16' \times 10'$) next to the lobby, usually used as a lounge, where *Raaz* was installed; and a large wet lab ($\sim 35' \times 21'$) also connected to the lobby where the majority of the hands-on biology activities at BUGSS take place. Refreshments offered included wine, cookies, and dates. Participants were able to move between the three spaces at BUGSS freely during the event. They also had access to a restroom and outdoor space that was not used because of inclement weather. See **Figure 5** for an illustration of the layout of these spaces. The interior walls separating the space where *Raaz* was installed from the storage room, and the lobby from the wet lab, are lightweight, rising about 8′ from the floor with about 6′ between the wall and the ceiling with exposed wooden rafters. The exterior walls are exposed brick; large, uncovered windows on the front of the building let in natural light during the day.

We coordinated and publicized the event using both the community lab and our university department's communication channels, including mailing lists, social network posts (i.e., Facebook, Instagram, and Twitter), and personal email communication. Additionally, we posted information about the event on a local arts community calendar. Registration was by donation for use toward the community lab's public education programs.

Since the event was in-person and during the COVID-19 pandemic, we worked with the community lab leadership and advisory board to ensure we followed safety procedures, which included a limit on attendee capacity and requiring everyone to wear a mask. The event took place over 2 h on a weekend evening. Members of our team arrived at the site ∼3 h before the start time to prepare the exhibition space and set up the installation.

Participants

A total of 22 adults were present at the event, including 13 audience attendees and eight members of the research team (including artists, researchers, and the community lab leader). Of the audience attendees, 11 completed a questionnaire and nine were interviewed. Participants interviewed ranged in age from late twenties to middle sixties (mean = 41; median = 39); four described themselves as female, five as male; one as Black and eight as white. One interview participant reported beginner to intermediate Persian language competence (a native speaker, who completed a questionnaire, was not interviewed). A handful of high school students who had been working in the lab before the event participated in agar art making and the talk before leaving early (presumably being picked up by parents/guardians). While several attendees knew the researchers in a personal capacity, none had seen *Raaz* before. A few attendees described finding out about the event independently. All interview participants reported being local to the Baltimore area. All but one audience attendee who completed a questionnaire used a personal automobile to get to the event (one used a taxi/ride app). One attendee, who completed a questionnaire and was interviewed, had been to BUGSS before, but was not a member.

Data Collection and Analysis Methods

To evaluate how participants engage and make meaning in a bioart installation in a community lab setting, we used ethnographic methods including observation and interviews. Researchers' presence and planned data collection activities were introduced at the beginning of the artist talk. Data collection included photography, field notes, focused semi-structured interviews, and a questionnaire. These techniques are among installation and exhibit evaluation methods described by Hornecker and Ciolfi in their work on HCI in museums (Hornecker and Ciolfi, 2019). These broad and flexible techniques were found to be feasible given our research context. They also served to triangulate the experience space, allowed researchers to engage as participant observers, and allowed audience experience to take priority.

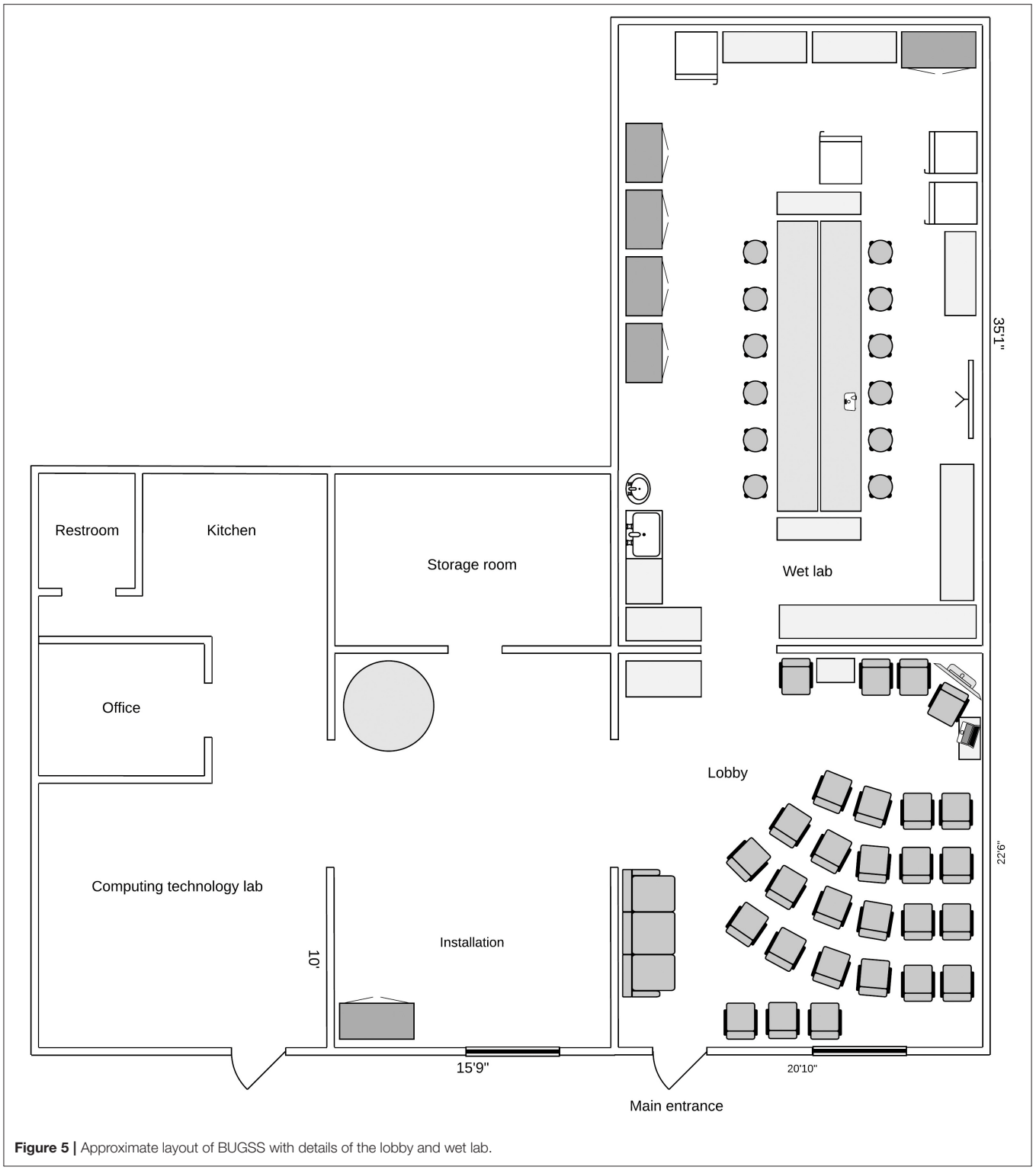

Figure 5 | Approximate layout of BUGSS with details of the lobby and wet lab.

The interview guide was designed to engage participants as event attendees while also surfacing information about participants' background and experience at the event. The average interview length was about 7 min (ranging from about 4–10 min). Most interviews were conducted individually; one was conducted with two participants who attended the event together. Seven interviews were conducted in the wet lab while participants made agar art and two were conducted in the

lobby. Informed verbal consent was obtained for these interviews. We used a field notes guide for each of the four discrete aspects of the event: the artists talk, the agar art activity, the *Raaz* installation, and the reception. The guide provided probes for aspects of the event, including who was present; how people moved around, interacted with one another, and used personal technology; how people engaged with objects in the lab, with the art installation, and with the agar art activity; who spoke, when, and about what; and the affective tone of each time/space. Approximately 14 unstructured, informal interviews were conducted during observation and documented in field notes, and about 100 photographs and two short videos were taken. Shortly after the event, the authors who were present completed long-form observation documentation capturing their view of objective information as well as their personal reflection. The questionnaire, which was printed and included in the handout, gathered demographic information and information about prior experience with community labs, art events, science events, and reactions to the event. Our research protocol was approved by the University of Maryland, Baltimore County Internal Review Board (IRB).

Data were analyzed using a combination of inductive and theoretical thematic analysis (Braun and Clarke, 2006). Interview transcripts were explored by beginning with high-level codes identified in prior research (e.g., Asgarali-Hoffman and Hamidi, 2021; Hamidi et al., 2021; Walker et al., 2022) and during the event. Five researchers worked independently to explore these codes, and then discussed them together, leading to their refinement. Observations and questionnaire data contributed to code and theme construction. Themes were refined collaboratively, and those salient to understanding audience reception of and interaction with *Raaz* in a community lab setting are presented.

FINDINGS

Reflections on Publicly Presenting *Raaz*

Following the event, as the principal bioartists, I (Hamidi) noted that I could have included more details and examples about the information theory aspects of the project to ensure this was clear to audience members, since a number of participants asked me for more details after the talk. I also observed how the team was able to quickly transform a space in the community lab that was previously used to store unused equipment and posters of previous projects into a space resembling a Do-It-Yourself (DIY) art gallery. While it was difficult to move some of the storage units with lab equipment in them, after the event I reflected that having these items in the same space as the installation was helpful in contextualizing the art and helping with emphasizing the notions of transformation and adapting to the surrounding environment present in the artwork. Additionally, I observed that during the event I could see the space as simultaneously a biology lab, an art gallery, and a community meeting space. Furthermore, I wondered if, in the future, an artist talk that literally walks audience members through different stages of transformation and multisensory immersive experience (i.e., reading the poem, seeing/smelling the bacteria and yeast, and drinking the wine) in conjunction with the other elements of the installation could result in deeper engagement. Finally, with respect to the two components of the event (i.e., the *Raaz* installation and agar art activity), I found that they engaged audience members in different and potentially complementary ways. While the installation primarily engaged auditory and visual senses and was not interactive, the agar art activity required the hands-on use of basic wet lab equipment and material (i.e., agar plates, agar, living bacteria/yeast, etc.). Following the event, I wondered if the format could be modified in the future to include more background explicitly on agar art in the artist talk to better contextualize it and integrate the two activities.

Presenting *Raaz* in a public science space caused me (Dusman) as the composer to reflect on the sonic portion of the installation, particularly on its meaning for the audience. Considerations of audience expectations in a science environment are, of course, different than audience expectations in a gallery or museum, and the "high art" approach taken to crafting the audio experience did not seem as appropriate in an environment where the audience expected to learn. That said, the acoustical environment of an old factory with high ceiling and brick walls created an excellent immersive effect for the surround audio, and the audience seemed appreciative of the conceptual approach to the sonic design.

As the community lab leader, I (Scheifele) observed that a diverse group of people (compared to other events at the lab) had attended the event and most of them (all but one) participated in the agar art activity. I also observed a lot of discussion between participants, and noted that participants were careful with using the tools and drawing delicately on the plates such that participants seemed to quickly adopt the techniques needed for work with microbes.

Findings From the Community-Engaged Event

Our data analysis resulted in several themes that describe important aspects of audience experience and interaction with bioart in a community lab setting, which we will present in detail next. Overall, our exploration shows that the experience with *Raaz* as an artwork that incorporates biology and multiple forms of media in a community science space, was shaped by the process explanation, conversation with the artists and others, the physical and social space, the opportunity to participate in a hands-on bioart activity (which is related to the art making process of *Raaz* itself), and past personal and professional experience. Despite not being exhibited in typical art installation space, various elements came together to create a meaningful opportunity to reflect on and debate the messages conveyed through *Raaz*.

Providing Context, Explaining Process

The opening talk presented at the beginning of the event was described by participants as essential to their understanding of *Raaz*, bioart, and the event more broadly. The event was scheduled from 5:00 to 7:00 P.M. on a Saturday evening. It had been drizzling outside since the beginning of the day. Researchers' notes captured that audience turnout at the beginning was a bit low but gradually increased, and reflected

that attendance was more than expected on a day like this, and just the right amount for this kind of event. It seemed from the observation notes, interviews, and interactions that most attendees had some idea about BUGSS or had some familiarity with the artist or collaborators, although *Raaz* as an artwork appeared to them as a fresh and new kind of experience.

The talk was designed in the tradition of an artist talk combined with the visual and spoken language of a scientific presentation. It described the technical, artistic, and collaborative process of the making of *Raaz* in detail without going into too many technicalities. It also introduced the research team so that the audience could get an idea about the data collection process. Speakers also introduced BUGSS and encouraged attendees to participate in the agar art workshop, but did not provide much detail on other lab activities as the talk mostly focused on *Raaz*. The audience seemed to listen attentively, which the question-and-answer session following the talk reflected. There were questions about the technical, artistic, and procedural aspects of *Raaz*.

When we asked people about their experience of various aspects of *Raaz*, such as spatial, audio, and visual components, they referenced the importance of the talk and other descriptive artifacts on their appreciation of the artwork. For example, P6 emphasized the role of description, saying, "I liked how all the artists and people described what we were experiencing. Because otherwise, I think, I would not have really gotten the experience." P3, who showed appreciation especially for the audio aspects of the work, mentioned the importance of hearing about the audio design process. After checking with the interviewer whether the encoded lines of poetry were printed in the handout, P3 said, "I feel like that is what I need to do, is like go read the poem again and come back. Because that will really, like, help it sink in." P1 described familiarity with this aspect of art appreciation, saying, "I used to introduce people to fractal art, and they had no idea what they were looking at until you explained it, and then it was a profound experience for a lot of people."

Bringing Prior Knowledge and Experience to Bear

We asked attendees via questionnaire about their prior experience with art and science events to better understand the expectations and experience participants might bring to this kind of event and to better interpret the data. Among interview participants, two described attending arts events monthly, five a few times a year, and two once a year or less. Experience with science events appears rather different, with two participants reporting attending science events a few times a year and seven attending them once a year or less.

The questionnaire asked participants to describe their occupation or profession to help us better understand who attended the event and how their backgrounds may impact their reactions to the event. We found that everyone in attendance had a different occupation, including glass worker, English to Speakers of Other Language (ESOL) instructor, marketing analyst, client engagement manager at a legal firm, acupuncturist, nurse, project manager, software engineer, and web and interactive media professional. One person listed themselves as self-employed and another as retired.

We found in our interviews that participants uniformly drew on their personal and professional experience and expertise to describe their experience at the event. For several, profession was a key resource. P8 explained how his background helped him find interest in the artistic process and empathize with the artists, "I have a computer science background so hearing how the poem is translated into a binary format which is then translated into a different medium- it feels very familiar to computer science problems. That was super interesting and clearly it involved a lot of trial and error to get there." Other occupations referenced in interviews included illustration, marketing, and public health nursing, among others. Others made connections with personal hobbies and passions, such as home brewing, drawing, and arts and cultural events (e.g., Burning Man), among others.

Several participants mentioned family roles and connections. For example, P3 brought a topic from an earlier conversation into the interview, when the interviewer asked what had drawn them to the agar art activity: "I was just saying, my dad's a chemist." The participant's own history with science was difficult ("I hated the lab"), but in productive conversation with the experience of the event, "[The wet lab] feels very- like a welcoming place and a very nice place. It just also brings you back to sophomore year of college and all those poor decisions, you know." Asked to reflect on the meaning of DNA in light of the event, P9 explained, "I am, like, a mom. I have children, right? And I see that some things are, like, learned behaviors from me and from their environment and other things I am like that- that is just in you." We observed a diversity of knowledge and beliefs about the meaning and potential of DNA among interview participants, and that these views seemed loosely held due to lack of confidence ["I do not have a great science background" (P2)].

When asked about how the event related to prior art experiences, participants described a range of interest in, experience with, and expectations or hopes for art. Some described their experience with *Raaz* in relation to other immersive experiences, such as a sculpture garden, which was "the one analogy I am coming back to" for P8 and sound baths (P7). "Before Covid," P6 described attending art exhibitions in Washington, D.C., as well as immersive theater events in Baltimore. P3 described an art exhibition that "expounded topics and things that I am going to be struggling with throughout the day, and week, and like, life." Overall, individuals felt most comfortable discussing bioart through the lens of their own personal experiences. Many gravitated toward topics they had a background in (e.g., professionally or through prior personal experiences or interest) and were somewhat reluctant discussing technical aspects of bioart, such as the role of DNA. Despite this potential anchoring in one's existing knowledge and experiences, participants talked about a wide range of topics related to the event.

Bioart Generating Immediate Questions and Concerns

A predictable yet exciting observation is the way in which our community-based and -engaged multi-sensory bioart installation and workshop generated immediate questions and concerns. These were whispered cautiously and shouted enthusiastically

between and among practically all combinations of participants including audience members, researchers, and artists. One of the sentiments raised at end of the artist talk, and repeated through the evening, paraphrased, "Let's taste the wine!" serves as a starting point. Other similar questions and concerns included: Is it safe to drink the wine? How does using the genetically modified yeast change the wine's taste and quality? Is the wine available to buy? And, should it be available to own or consume?

To begin to speculate why this question and many others were raised by participants, we describe the physical setting of the *Raaz* installation and how attendees engaged with it as a whole, with each of the components, and with each other, as well as the setting and interactions supported by the agar art workshop. We suggest a correlation between the immediacy of experience with bioart experiencing and making and the immediacy of the questions and concerns bioart generates.

The installation of *Raaz* was in a room next to the lobby where the artist talk took place (**Figure 5**). The doorway to the installation space was visible from the audience position but not any part of the art itself. After the talk, most of the audience members approached the *Raaz* installation space; very few went to the agar art space at first. Researchers observed that people concentrated on the photos first, then gradually moved to the bottle of wine placed in the middle of the installation room. Being a community lab space, BUGSS differs from typical art installation sites (e.g., galleries, museums, etc.), which was identified by the attendees, researchers, and artists alike. This was thought especially to be true of the audio component. However, participants also talked about how this kind of space gave them a different kind of interaction experience with the art and with other people. The bright light, high noise level, and small space allowed participants to engage in lively discussions with the artists, collaborators, and others compared with a setting that might encourage interacting with the art individually.

The unique features of the space seem to have influenced attendees' experience of the bioart installation and the agar art workshop. From the attendees' perspective, P4 observed, "The space is obviously small and intimate." P3 suggested that darker lighting would help them "get in the zone with it more." Experience of the audio component of *Raaz* varied. P5 remarked that "visually, everything was great," but asked the artists for a copy of the audio track to listen to at home. Considering the audio track together with the space, P3 described it as "Very ambient, I guess." For P6, the audio "really tied everything together." P2, who came to the event with additional context having lived in Iran previously, described the difference between the artist talk and seeing *Raaz*:

> "I think that it hadn't hit me until I was actually in there and I was looking at the images- about this idea that they had been manipulated. And I did not expect- I found that to be completely harmless when I was first thinking about it, I thought it was mostly interesting, I was pretty cerebral about it. And then when I saw it and heard it, I thought, whoa, like [laughing] this is something [laughing]. It's been manipulated! And I don't know why it created a feeling of, somewhat, of fear, in me. I don't really know why."

Almost all attendees participated in the agar art workshop, including all but one interviewee, P1, who reported not being "terribly interested in drawing anything." In subtle contrast with the more introspective experience that *Raaz* sought to elicit, participants cultivated an open attitude during the agar art workshop. Participants interacted with each other and with researchers, inquired about what each other's art would look like, and asked more technical questions of the workshop facilitator (Scheifele) readily. P6 described making agar art as "really cool and kind of relaxing," and P5 as "fun and interactive." Participants acknowledged consequences of interacting with microorganisms discovered during the activity; as P9 described, "You have limited control because it is going to grow into something, you know? [. . .] you do not have control of that, you know, so it is interesting." P2 commented on how making agar art added another level of complexity to her understanding of *Raaz* and the questions it raised, "I thought it was also kind of funny, like, here I was kind of perturbed, you know, with the initial installation. And then I was all for, you know, taking this [pigmented] bacteria, and I was like 'Yes!' So, like, zero qualms as I was doing that." This participant expressed a very different experience engaging with bioart as a viewer compared with interacting directly with it and with microorganisms.

The question of whether and why to taste the wine was first raised at the end of the artist talk by P1. In an interview, P1 explained, "There is a science part that pops into my head and you compare it to the regular yeast to- had it been made side-by-side, for example, and see if there is a difference or different qualities to it. I am interested in the yeast part. I like brewing beer and that sort of stuff, so. The yeast part is fascinating and hopefully they recover the yeast and they can keep it viable." The experimental possibilities of gene editing captured the imagination of other participants, as well. While others wondered how it affected the quality of the yeast and wine, P7 asked, "If I encoded, like, a rock song [into DNA], would it be more destructive or something?" While superficially amusing, the question provokes ethical concerns. When asked how they felt about seeing the bottle of wine, P4 remarked, "Oh, I wanted to taste it!" and P5 responded, "Yeah! Absolutely." (Later asked by another researcher who they thought should taste the wine, P4 exclaimed, "Everyone!") P8 reflected on the meaning of the possibility of tasting the wine: "Having the bottle of wine in front of you makes you realize that the process ended with this physical thing in front of you. You can see it, you can taste it if you wanted to." Taken together, P6 described *Raaz* as making something seemingly distant—centuries-old lines of a poet buried in Shiraz—"living and here and material."

While participants uniformly recognized the artist talk as an important aspect of the event, we also observed and learned from participants how direct interaction with *Raaz* and/or with pigmented yeast or bacteria on agar had separate, sometimes interacting, effects on understanding. We also acknowledge the experience of one participant (P7) who missed the talk and used other explanatory material (the handout) and delighted in not having much contextual information: "As I was in there [in the room where *Raaz* was installed] I was reading through the pamphlet a little bit more to understand what it was, and so,

starting to understand this idea of the DNA being encoded with this Morse code and stuff like that. So started-it was kind of cool to, like, walk into it and kind of be exploring it on my own without much context."

We asked attendees a few open-ended questions about their experience with *Raaz* and bioart on the questionnaire, including what aspects of the event they might continue to think about in the coming days. Six respondents indicated what they will continue to think about. Of these, five referred to sensory aspects of the work, including the images, the sound, and the taste of the wine; one indicated the power of the poetry in addition to sensory aspects, while another wrote simply, "the connection of DNA and the self." This suggests that participants connect sensory aspects of the work with their enduring connection with it. In response to a questionnaire about whether participants would participate in a bioart project in the future, only one participant out of six respondents proposed a project topic (related to their occupation) and others expressed hesitant interest (e.g., "Yes, but I do not know how to contribute.").

DISCUSSION

Our case study demonstrates how a combined bioart installation and participatory activity attracted and engaged a diverse audience in an informal community setting. Our findings (Sections Bringing Prior Knowledge and Experience to Bear and Bioart Generating Immediate Questions and Concerns) show that people with a range of previous interests and experiences that intersected with art, biology, poetry, and computing were attracted to the activities, and that they both drew on their previous experiences and knowledge for meaning-making, and also (cautiously) ventured into new areas of exploration, including initial ethical inquiry into what it means to manipulate living organisms and cultural artifacts (Mitchell, 2015; Vaage, 2016). The transdisciplinarity of the event and multimedia presentation of the project required participants to draw on multiple points of reference (Section Bringing Prior Knowledge and Experience to Bear) in their process of meaning-making. Furthermore, while participants were asked about and referred to prior knowledge and experience, the event seems to have encouraged a process of creative exploration of ideas and questions that go beyond disciplinary bounds. For example, the question of whether to drink the wine can be explored from a variety of perspectives including biosafety, spirituality, law, performance art, and oenology, among others. In this way, our findings open a space for transdisciplinary reflection and provide evidence that hybrid, transdisciplinary, and interactive exhibits can provide a means of community-engagement at sites beyond the formal biology lab or gallery/museum (Kuznetsov et al., 2012; Mitchell, 2015; Hornecker and Ciolfi, 2019).

The combination of the multimedia bioart installation and hands-on interactive agar art activity also seems to have worked at engaging participants in different ways to create a range of sometimes contrasting reactions. Similarly, both artists and audiences recognized the importance of providing context and scaffolding for this type of art (especially the *Raaz* installation) to be easier to engage with (Sections Reflections on Publicly Presenting *Raaz* and Providing Context, Explaining Process). In this way, the artist talk and the handout can both be viewed as supporting audience members to better connect with the artwork and understand its cultural and scientific significance. The artist talk in particular may be characterized as a demonstration of transdisciplinary fluency (Hamidi et al., 2021), an attempt by the artists to both share their experience venturing into new creative territory and inviting audience members to adopt a similar approach in their exploration at the event. Previous research on studying interaction in hybrid art/science settings have shown that new experiences can pose challenges to audience members who are not sure of the norms governing behavior in those spaces (Hornecker and Ciolfi, 2019). Our findings also suggest that leveraging audience members' prior experience and interests can increase confidence needed to engage with new ideas.

Interactive installation art is a powerful art form for HCI research to explore due to the way in which it depends on the participation of the viewer for its creation (Nam and Nitsche, 2014). By studying the installation of *Raaz* at BUGSS closely, we observed a distinction between *engagement* and *interaction* with bioart. While audience members interacted with each other and with the artists/researchers, they *engaged* with the artwork, which was not changed by their involvement, but which set into motion a meaning-making process. On the other hand, we observed that participants *interacted* with the barely visible yeast or bacteria as they spread them over plates of agar knowing that they were exercising agency over the microorganisms while the organisms also expressed their own agency. Our interviews and observations also show that participants were more likely to discuss various aspects of the installation, for example which parts they understood and which parts made them fearful, in detail. However, participants were much less likely to discuss these topics when interacting with the agar art activity and most of them took part in it directly. We find this distinction helpful in reflecting on how combining these mechanisms in a single event may have shaped our participants' experiences and recommend that future creators of similar installations and events keep them in mind when considering what combination may work for them.

While *Raaz* involves cutting-edge synthetic biology practice, the work was conducted in a community lab by an artist-researcher with no prior biology experience outside the community lab's educational offerings, made possible through transdisciplinary collaboration (Hamidi et al., 2021) and mentorship (Walker and Kafai, 2021). This work builds on prior work in HCI, demonstrating possibilities for including DIYbio in design (Kuznetsov et al., 2012, 2015, 2018) by integrating DIYbio processes into a multisensory artifact for public exploration, contemplation, and interaction considered broadly (Hornbæk and Oulasvirta, 2017). Our evaluation of public engagement with this work uncovers areas of potential for public-facing living media artifacts and motivates future research delving deeper into public understanding, opinion, and co-creation of emerging hybrid and biotechnology interactive systems. Specifically, our findings suggest the importance of process explanation and of

building on personal knowledge and experience and highlight the richness of interaction with microbes for exploring issues of moral and ethical import. Participants expressed strong opinions about the implications and future of *Raaz* connected to its multisensory potentiality and observable genetically modified characteristics. These ideas were generated in dialogue with other participants and with the artists and researchers. At the same time, participants conveyed appreciation of the visual and audio elements of the *Raaz* and made suggestions for how the presentation and environment could better support these elements in future installations. Pairing *Raaz* with a hands-on agar art workshop, we are also able to draw out participants' understanding of the affordances and constraints of interaction with living organisms in a wet lab environment. Participants discussed the challenge and excitement of working with invisible microorganisms (just as the genetically modified yeast used to make the wine in *Raaz* are invisible), adding a new layer of possibility for direct interaction with microorganisms in an unstructured manner, in contrast with Ofer et al. (2021) more structured exploration of bioluminescent (hence, visible) algae. These complementary parts of the event generate four important takeaways for HCI: (1) working in a supportive, transdisciplinary environment can allow HCI researchers to design and evaluate complex, personalized artifacts for public engagement with cutting-edge biotechnology, (2) providing in-depth explanation of artifact development focused on process together with access to immersive engagement with the art installation supports critical reflection, (3) pairing intellectual and immersive experience with a hands-on and personalizable activity related to the technology in question fosters dialogue and nuanced questioning, and (4) ethnographically-informed evaluation of public engagement with non-digital technology can help artists, designers, and researchers understand the impact of their work and consider next steps accountable to participant experience.

Finally, we conducted this study at a single event that took place in the community lab over several hours, a format with clear time and space limitations. Alternative formats that spread similar events and activities over a longer period of time (e.g., workshop series) or beyond a single place (e.g., with a remote, possibly recorded component), would provide different affordances ripe for investigation by future research.

CONCLUSION AND FUTURE WORK

We have presented a case study describing our experience with creating and presenting a multimedia bioart installation and hands-on bioart experience to the members of the public in a community setting. The project, *Raaz*, brought together concepts and techniques in Sufi poetry, synthetic biology, audio composition and design, microscopic imaging, and exhibition design to create a transdisciplinary experience to engage diverse participants in reflection beyond disciplinary bounds. We found that participants appreciated being provided context about the project before experiencing it, that encountering it drew on their previous knowledge and experience in a meaning-making process, and that the experience gave rise to a number of relevant questions and concerns.

Future research can explore the affordances of presenting the project in different formats, such as workshops or hybrid online presentations, and measure their impact on participant engagement or reflection. We began to see how individuals' personal backgrounds influenced their experience of transdisciplinary art. To further explore these interactions, we plan to install the work in other spaces and study audience members' experiences of engagement, participation, and interaction. We hope to better understand the processes by which people engaging with art and design in community spaces become open to self-expression, new connections, and new questions; ways in which these are limited; and other possibilities for transdisciplinary artistic engagement. Finally, we plan to incorporate some of our current thinking about adding more multisensory elements, such as taste and smell, to the experience in a future iteration of the project.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by UMBC Institutional Review Board (IRB). The participants provided their written informed consent to participate in this study. Verbal informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

LSt led the research effort at BUGSS by designing instruments, coordinating, leading data collection and analysis, and writing the first draft of the findings and discussion. FH contributed to the conception and implementation of Raaz, coordinating the artistic efforts to realize and present the work and overseeing the writing efforts, wrote the first draft of the introduction, related works, and the description of Raaz sections. EH, HP, and NA-H contributed to data collection and analysis and the writing of the findings section. HP took all photos at the event. LD, LSc, TA, and Td wrote subsections in the methods that described their respective contributions to the Raaz implementation. All authors contributed to manuscript revision, and read, and approved the submitted version.

FUNDING

The project was partially supported by the National Science Foundation under Grant Nos. DRL-2005502 and DRL-2005484.

ACKNOWLEDGMENTS

We would like to thank Alan Wonneberger, who conducted the audio design and implementation of *Raaz*. We also thank Rian Ciela Hammond, who contributed to the initial conceptualization of *Raaz* and helped with conducting the initial steps needed to create the poetry-infused yeast.

REFERENCES

Adkins, S. J., Rock, R. K., and Morris, J. J. (2018). Interdisciplinary STEM Education Reform: Dishing out Art in a Microbiology Laboratory. *FEMS Microbiol. Lett.* 365:fnx245. doi: 10.1093/femsle/fnx245

Alistar, M., and Pevere, M. (2020). "Semina aeternitatis: using bacteria for tangible interaction with data," in *Extended Abstracts of the* 2020 C*HI Conference on Human Factors in Computing Systems* (New York, NY: ACM). doi: 10.1145/3334480.3381817

American Society Microbiology (2017). *ASM Agar Art Contest 2017, Vol. 2017.* Washington, DC: ASM.

Asgarali-Hoffman, S. N., and Hamidi, F. (2021). "Perspectives of bioartists and community lab organizers on working with living organisms," in *Proceedings of the* 2021 *CHI Conference on Human Factors in Computing Systems* (New York, NY: ACM). doi: 10.1145/3411764.3445060

Blevis, E., and Stolterman, E. (2009). "The confluence of interaction design & design: from disciplinary to transdisciplinary perspectives," in *Undisciplined! Design Research Society Conference 2008* (Sheffield: Sheffield Hallam University).

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qualit. Res. Psychol.* 3, 77–101. doi: 10.1191/1478088706qp063oa

Chan-Laddaran, K. (2015). *Scientist Paint With Bacteria to Make Art. Vol. 2017.* Atlanta, GA: CNN.

Cheok, A. D., Tan, T. K. C. R., Peiris, R. L., Fernando, O. N. N., Soon, J. T. K., Wijesena, I. J. P., et al. (2011). Metazoa ludens: mixed-reality interaction and play for small pets and humans. *IEEE Trans. Syst. Man Cybernet. Part A Syst. Hum.* 41, 876–891. doi: 10.1109/TSMCA.2011.2108998

Davis, D. (2004). On not translating hafez. *N. Engl. Rev.* 25, 310–18.

Editors of the Encyclopedia Britannica (2019). Available online at: https://www.Britannica.Com/Topic/Morse-Code

Engler, C., and Marillonnet, S. (2014). "Golden gate cloning," in *DNA Cloning and Assembly Methods: Methods in Molecular Biology* (Clifton, NJ: Humana Press). doi: 10.1007/978-1-62703-764-8_9

Fernando, O. N., Cheok, A. D., Merritt, T., Peiris, R. L., Fernando, C. L., Ranasinghe, N., et al. (2009). "Babbage cabbage: biological empathetic media," in *VRIC Laval Virtual Proceedings* (Laval), 363–366.

Gome, G., Waksberg, J., Grishko, A., Wald, I. Y., and Zuckerman, O. (2019). "OpenLH: open liquid-handling system for creative experimentation with biology," in *Proceedings of the Thirteenth International Conference on Tangible, Embedded, Embodied Interaction* (New York, NY: Association for Computing Machinery). doi: 10.1145/3294109.3295619

Hafez (1974). *The Divān.* ed W. Clarke. London: Octagon Press.

Hamidi, F., and Melanie, B. (2017). "Engaging children using a digital living media system," in *Proceedings of the* 2017 *Conference on Designing Interactive Systems.* (New York, NY: ACM). doi: 10.1145/3064663.3064708

Hamidi, F., Stamato, L., Scheifele, L., Hammond, R. C. V., and Asgarali-Hoffman, S. N. (2021). "'Turning the invisible visible': transdisciplinary bioart explorations in human-DNA interaction," in *Proceedings of the* 2021 *CHI Conference on Human Factors in Computing Systems* (New York, NY: ACM). doi: 10.1145/3411764.3445408

Heather, D., Gan, E., and Haapoja, T. (2020). "Illuminating multiplicity: against the unbearable whiteness of bioart," in *Art as We Don't Know It*, eds E. Berger, E. Mäki-Reinikka, K. O'Reilly, and S. Helena (Helsinki: Aalto Books).

Holstius, D., Kembel, J., Hurst, A., Wan, P., and Forlizzi, J. (2004). "Infotropism," in *Proceedings of the* 2004 *Conference on Designing Interactive Systems Processes, Practices, Methods, and Techniques–DIS '04* (New York, NY: ACM Press). doi: 10.1145/1013115.1013145

Hornbæk, K., and Oulasvirta, A. (2017). "What is interaction?" in *Proceedings of the* 2017 *CHI Conference on Human Factors in Computing Systems* (New York, NY: ACM). doi: 10.1145/3025453.3025765

Hornecker, E., and Ciolfi, L. (2019). Human-Computer interactions in museums. *Synth. Lect. Hum. Cent. Inform.* 12, i–153. doi: 10.2200/S00901ED1V01Y201902HCI042

Kac, E. (1999). *Genesis*. Linz: O.K. Center for Contemporary Art.

Kac, E. (2008). *The Natural History of the Engima 2008.* Available online at: https://www.ekac.org/nat.hist.enig.html.

Kafai, Y., Telhan, O., Hogan, K., Lui, D., Anderson, E., Walker, J. T., et al. (2017). "Growing designs with biomakerlab in high school classrooms," in *Proceedings of the 2017 Conference on Interaction Design and Children–IDC '17* (New York, NY: ACM Press). doi: 10.1145/3078072.3084316

Khan, S., and Davis, J. (2021). *Baitul Ma'mur: House of Angels.* Ars Electronica 2021. Available online at: https://ars.electronica.art/newdigitaldeal/en/baitul-mamur/

Kuribayashi, S., Sakamoto, Y., and Tanaka, H. (2007). "I/O plant," in *CHI '07 Extended Abstracts on Human Factors in Computing Systems–CHI '07* (New York, NY: ACM Press). doi: 10.1145/1240866.1241037

Kuznetsov, S., Barrett, C., Fernando, P., and Fowler, K. (2018). "Antibiotic-Responsive bioart: exploring DIYbio as a design studio practice," in *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems–CHI '18* (New York, NY: ACM Press). doi: 10.1145/3173574.3174037

Kuznetsov, S., Doonan, C., Wilson, N., Mohan, S., Hudson, S. E., and Paulos, E. (2015). "DIYbio things: open source biology tools as platforms for hybrid knowledge production and scientific participation," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems–CHI '15* (New York, NY: ACM Press). doi: 10.1145/2702123.2702235

Kuznetsov, S., Taylor, A. S., Regan, T., Villar, N., and Paulos, E. (2012). "At the seams: DIYbio and opportunities for HCI," in *Proceedings of the Designing Interactive Systems Conference on–DIS '12* (New York, NY: ACM Press). doi: 10.1145/2317956.2317997

Lawson, S., Kirman, B., Linehan, C., Feltwell, T., and Hopkins, L. (2015). "Problematising upstream technology through speculative design," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems–CHI '15* (New York, NY: ACM Press). doi: 10.1145/2702123.2702260

Lee, M. E., DeLoache, W. C., Cervantes, B., and Dueber, J. E. (2015). A highly characterized yeast toolkit for modular, multipart assembly. *ACS Synth. Biol.* 4, 975–986. doi: 10.1021/sb500366v

Lee, S. A., Bumbacher, E., Chung, A. M., Cira, N., Walker, B., Park, J. Y., et al. (2015). "Trap It!" in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems–CHI '15* (New York, NY: ACM Press). doi: 10.1145/2702123.2702220

Lin, C. Lindtner, S., and Wuschitz, S. (2019). "Hacking difference in Indonesia," in: *Proceedings of the 2019 on Designing Interactive Systems Conference* (New York, NY: ACM). doi: 10.1145/3322276.3322339

Loloi, P. (2004). *Hafiz, Master of Persian Poetry: A Critical Bibliography*. London: I.B. Tauris. doi: 10.5040/9780755611393

Loparev, A., Westendorf, L., Flemings, M., Cho, J., Littrell, R., Scholze, A., et al. (2017). "BacPack: exploring the role of tangibles in a museum exhibit on bio-design," in *Proceedings of the Eleventh International Conference on Tangible, Embedded, Embodied Interaction* (New York, NY: ACM). doi: 10.1145/3024969.3025000

Mancini, C. (2011). Animal-Computer interaction. *Interactions* 18, 69–73. doi: 10.1145/1978822.1978836

Manshaei, R., Baig, N., DeLong, S., Khayyer, S., East, B., and Mazalek, A. (2016). "Exploring genetic mutations on mitochondrial DNA cancer data with interactive tabletop and active tangibles," in *Proceedings of the 2016 ACM on Interactive Surfaces and Spaces–ISS '16* (New York, NY: ACM Press). doi: 10.1145/2992154.2996873

Meisami, J. (2000). "Shams al-din muhammad hafiz," in *Encyclopedia of Literary Translation into English*. London/Chicago: Routledge.

Menezes, M. (2015). Biology as a new media for art: an art research endeavour. *Tech. Arts J. Specul. Res.* 13, 115–123. doi: 10.1386/tear.13.1-2.115_1

Merritt, T., Hamidi, F., Alistar, M., and DeMenezes, M. (2020). living media interfaces: a multi-perspective analysis of biological materials for interaction. *Dig. Creat.* 31, 1–21. doi: 10.1080/14626268.2019.1707231

Mitchell, R. E. (2015). *Bioart and the Vitality of Media: In Vivo*. Seattle, WA: University of Washington Press.

Nam, H. Y., and Nitsche, M. (2014). "Interactive installations as performance," in *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction–TEI '14* (New York, NY: ACM Press). doi: 10.1145/2540930.2540976

New Directions (2012). The ethics of synthetic biology and emerging technologies. executive summary and recommendations. *Jahrbuch Fur Wissenschaft Und Ethik* 16, 557. doi: 10.1515/jfwe.2012.557

Ofer, N., Bell, F., and Alistar, M. (2021). "Designing direct interactions with bioluminescent algae," in *Designing Interactive Systems Conference 2021–DIS '21* (New York, NY: Association for Computing Machinery). doi: 10.1145/3461778.3462090

Paay, J., Engeler, B., Taylor, M., Day, K., Brereton, M., and Rogers, Y. (2019). "Wine and user experience design," in *Proceedings of the 31st Australian Conference on Human-Computer-Interaction* (New York, NY: ACM). doi: 10.1145/3369457.3369548

Pataranutaporn, P., Vujic, A., Kong, D. S., Maes, P., and Sra, M. (2020). "Living bits," in *Proceedings of the Augmented Humans International Conference* (New York, NY: ACM). doi: 10.1145/3384657.3384783

Pierce, J. R. (2012). *An Introduction to Information Theory: Symbols, Signals and Noise*. New York, NY: Dover Publications, Inc.

Poupyrev, I., Schoessler, P., Loh, J., and Sato, M. (2012). "Botanicus interacticus," in *ACM SIGGRAPH 2012 Emerging Technologies on–SIGGRAPH '12* (New York, NY: ACM Press). doi: 10.1145/2343456.2343460

Pourjavady, N. (2012). "Love and the metaphors of wine and drunkenness in persian sufi poetry," in *Metaphor and Imagery in Persian Poetry* (BRILL) (Leiden), 125–136. doi: 10.1163/9789004217645_006

Robinson, C., Mancini, C., Linden, J., Guest, C., Swanson, L., Marsden, H., et al. (2015). "Designing an emergency communication system for human and assistance dog partnerships," in *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing–UbiComp '15* (New York, NY: ACM Press). doi: 10.1145/2750858.2805849

Robinson, C. L., Mancini, C., Linden, J., Guest, C., and Harris, R. (2014). "Canine-Centered interface design," in *Proceedings of the 32nd Annual ACM Conference on Human Factors in Computing Systems–CHI '14* (New York, NY: ACM Press). doi: 10.1145/2556288.2557396

Saeidi, A., and Unwin, T. (2004). Persian wine tradition and symbolism: evidence from the medieval poetry of hafiz. *J. Wine Res.* 15, 97–114. doi: 10.1080/09571260500053541

Scheifele, L. Z., and Burkett, T. (2016). The first three years of a community lab: lessons learned and ways forward. *J. Microbiol. Biol. Educ.* 17, 81–85. doi: 10.1128/jmbe.v17i1.1013

Seyed-Gohrab, A. (2014). The rose and the wine: dispute as a literary device in classical persian literature. *Iran. Stud. Bull. Soc. Iran. Cult. Soc. Stud.* 47, 69–85. doi: 10.1080/00210862.2013.825506

Vaage, N. S. (2016). What ethics for bioart? *Nanoethics* 10, 87–104. doi: 10.1007/s11569-016-0253-6

Walker J, Stamato L, Asgarali-Hoffman N, Hamidi F, Scheifele L. (2022). "Community labs: deep root spaces for biomaking. in informal learning environment research special interest group," in *Annual Conference of the American Educational Research Association* (San Diego, CA).

Walker, J. T., and Kafai, Y. B. (2021). The biodesign studio: constructions and reflections of high school youth on making with living media. *Br. J. Educ. Technol.* 52, 1116–1129. doi: 10.1111/bjet.13081

Yao, L., Ou, J., Cheng, C., Steiner, H., Wang, W., Wang, G., et al. (2015). "BioLogic: natto cells as nanoactuators for shape changing interfaces," in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (New York, NY: ACM). doi: 10.1145/2702123.2702611

Zyniewicz, K. (2018). *The Last Supper 2018*. Available online at: http://karolinazyniewicz.com/gallery-category/living-projects/#the-last-supper

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.