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## ARTICLE

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# Very Complex Matter: Collaborations in Art and Geobiology

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## Abstract

Geobiologist Dawn Sumner, known for her research on early life in Antarctica, her contributions to the Mars Curiosity science team, and for co-founding KeckCAVES at the University of California Davis, has also spent the past decade working in collaboration with artists. This paper addresses the relevance of these art/science collaborations to her scientific practice through an analysis of four of her projects: *Collapse (suddenly falling down)* with Sideshow Physical Theater; *Dream Vortex* with Meredith Tromble; *Life Extreme* with Philip Alden Benn; and *The Vortex* with Donna Sternberg and Meredith Tromble. The experiences gained by Sumner and her collaborators show that there are many different ways in which artists and scientists can learn from each other. Echoing throughout the collaborations is the realisation that turning ideas into form yields a result that can stimulate the next cycle of creativity.

## Keywords

CAVE, collaboration, dance, geobiology, haptic creativity, interactivity, performance, virtual reality, visual art, visualization

*Una cuestión muy compleja: colaboraciones entre arte y geobiología*

## Resumen

La geobióloga Dawn Sumner, conocida por su investigación sobre las primeras formas de vida en la Antártida, sus contribuciones al equipo científico del Curiosity en Marte y cofundadora de Keck CAVES en la Universidad de California Davis, también ha trabajado en colaboración con artistas durante la pasada década. Este artículo aborda la importancia de estas colaboraciones entre arte y ciencia en su práctica científica por medio del análisis de cuatro de sus proyectos

*con artistas: Collapse (suddenly falling down), con la compañía de teatro físico Sideshow; Dream Vortex con Meredith Tromble; Life Extreme, con Philip Alden Benn; y The Vortex, con Donna Sternberg y Meredith Tromble. Las experiencias de Sumner y sus colaboradores demuestran que los artistas y los científicos pueden aprender de los unos de los otros de formas muy variadas. Hacerse eco de estas colaboraciones es ver que el paso de ideas a forma genera un resultado que estimula el siguiente ciclo de crecimiento.*

### Palabras clave

CAVE, colaboración, danza, geobiología, creatividad háptica, interactividad, performance, realidad virtual, arte visual, visualización

In 1917, D'Arcy Wentworth-Thompson wrote that, "[...] while growth is a somewhat vague word for a very complex matter [...] it deserves to be studied in relation to form..."<sup>1</sup> If Wentworth-Thompson could visit the laboratory of geobiologist Dawn Y. Sumner today, he would find that his concept of growth is no longer a vague matter, but an understanding that is articulated down to the nanoscale, and that informs the material and method of Sumner's research on the origins of life. Wentworth-Thompson, whose arresting diagrams contributed significantly to keeping his ideas in circulation throughout the past century, might also be taken with Sumner's visualization research, which includes the four artist collaborations that are the focus of this article.

These artist/scientist collaborations vary in the media used: with the artist and author of this article Meredith Tromble, Sumner refined interactive 3-D programming that was originally developed for data visualization to make the *Dream Vortex*, a poetic interactive work that references, among other things, Sumner's work on the Mars Curiosity rover. Underwater footage from Antarctic lakes was specially shot by Sumner's lab for Tromble's former student, videographer and digital artist Philip Benn, who transformed it into the lyrical short *Life Extreme*. Sumner's first experience working with an artist was with choreographer Della Davidson; she contributed an interactive 3-D visualization to the multi-media performance *Collapse (suddenly falling down)* in 2007. That partnership was cut short by Davidson's untimely death, but seven years later Sumner and Tromble began working with choreographer Donna Sternberg. Using the methodologies developed for *Dream Vortex*, they co-created a new work and performance, *The Vortex*, drawn from the true stories of people working in science while female, of colour, or gender non-conforming, and including Sumner's experiences in Antarctica.

Considering these works in counterpoint with Sumner's research over the past decade reveals an exploration of growth and form that

is at once literal (on a quantum level photosynthesis, and thus the energy of life, depends on structure), methodological (making data into interactive 3-D forms builds understanding), and philosophical (the adventurous atmosphere of working with artists forwards scientific creativity, while scientific tools provide artists with new mediums). The content of Sumner's science is conveyed impressionistically but accurately, on the same level as her exchange with the artists, rather than on the technical level of her scientific papers.

### The Seed: Lively Virtual Forms

In 2011, Dawn Y. Sumner, a geobiology professor at the University of California Davis, co-founded KeckCAVES, a 3-D visualization facility. Informally, Sumner calls it a "Holodeck for scientists," referring to the fictional virtual reality simulator in the "Star Trek" series. Formally, KeckCAVES is described "as an intellectual and computational framework for the visual exploration, manipulation, and creation of data and models".<sup>2</sup>

A CAVE is a place: a room whose walls, ceiling and floor surround a viewer with projected images, creating three-dimensional virtual environments or objects that are visible to multiple people and, thanks to high-powered computing, that respond to their movements in real time (figure 1). There are dozens of CAVE installations at universities around the United States; expensive equipment that, almost without exception, was funded for scientific research and visualization. But artists are drawn to their capabilities and several CAVEs have hosted artist projects, ranging from visual text environments by John Cayley at Brown<sup>3</sup> to chimeric bodyscapes by Patricia Olynyk at the University of Michigan<sup>4</sup> and cinematic explorations of memory by Roderick Coover at the University of Illinois, Chicago.<sup>5</sup>

1. Thompson (2014).

2. See: <<http://keckcaves.org/>>. [Accessed: 31/08/ 2017]

3. See "Lens" and other works at John Cayley's website, <<http://programmatology.shadoof.net/>>. [Accessed: 31/08/ 2017]

4. VR Cave Art, LSA Magazine, University of Michigan, Spring 2002, 54; review by staff writer. 2001.

5. See Roderick Coover's website at <<http://unknownterritories.org/>>. [Accessed: 31/08/ 2017]

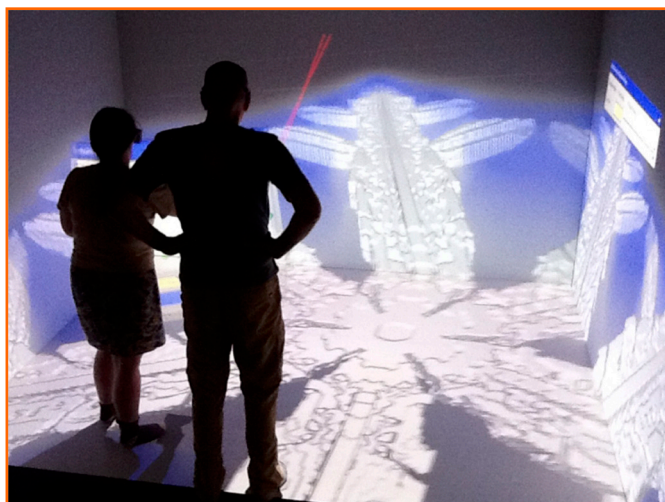


Figure 1. Dawn Sumner and mathematician Janko Gravner working with snowflake data at KeckCAVES (2011).

CAVES are not a standardized consumer technology; each one has been customized to address specific research questions, and thus each one has unique features. For example, KeckCAVES at UC Davis has a high degree of interactivity – participants can handle, move, and resize virtual objects almost as if they were using a three-dimensional iPad, while the CAVE at Villanova University is vision-centric, aiming to show 3-D scenes of the “real world”. The scientists and artists working at each site therefore have different sets of technical possibilities and aesthetic choices at their disposal, in contrast to working with standardized digital tools.

The visualization tools developed at KeckCAVES, which opened in 2010, promised insights into problems that were difficult to address using other techniques, looking at fields as diverse as veterinary science, forestry, and physics as well as geology. In it, scientists can view and handle their data as a projected 3-D object. By using a controller, the viewer has the ability to “touch”, rotate, and place the images, much like picking up physical objects and moving them around. The images can also be resized, coloured to highlight certain properties, and shared with remote viewers. Sumner’s geobiology research involves interpreting processes from patterns, mostly patterns in rocks, to understand interactions between early life and their environments. She can feed images obtained by laboriously grinding and sectioning an ancient rock sample into the CAVE and visually zoom through the sample, rotating it to understand the 3-D morphology and colouring it to highlight different aspects of its composition. The “grind” of preparing the sample is transformed

into play, enabling a fluid interaction with the visualization to find the answers to scientific questions.

The interactivity in KeckCAVES drew the attention of two science anthropologists, Natasha Myers and Joe Dumit, who conducted a close study of the way Sumner uses visualization tools to think and explore. Myers and Dumit describe their own approach as participatory, writing “We examine fieldsites where practitioners develop and use computerized visualization technologies. In the process we aim to collaborate with scientists and artists as they reflect on their practices and interpret their experiments”.<sup>6</sup>

The anthropologists note that Sumner and another scientist they studied “are constantly reworking their technologies while they develop and test their hypotheses. Both engage their technologies to get entangled kinesthetically and affectively with their data [...] they maximize their opportunity for what we are calling ‘haptic creativity’ [...] Their movements are provocations, questions that they pose inside their data-set: What if I try this? Or this? What can I see now?”<sup>7</sup>

KeckCAVES’ programming is continually developed as researchers bring in new questions about their data. Dumit proposed pushing development even further, by bringing in a group of dancers, sculptors, writers and others to explore the virtual reality environment for a project that became “Expressing the CAVES”.<sup>8</sup> Sumner, Dumit, and UCD Professor of Art Robin Hill received a grant to invite artists to experience the CAVE. Sumner was motivated by the possibility of expanding the CAVE’s tools in a way that might enhance its capabilities for science.

### The First Generative Collaboration: *Collapse (suddenly falling down)*

Sumner’s participation in an earlier collaboration, the dance theatre performance by choreographer Della Davidson titled *Collapse (suddenly fall down)*, had made her aware of the power of art to contribute to her visualization research (figure 2). In 2007, she was drawn to an art-science collaboration that participants described as, “self-assembled around a shared vision of exploring complex natural, engineered and social systems and a shared interest in using technology to address both scientific and artistic questions”.<sup>9</sup>

The performance involved a theatre-scale display of 3-D data, a requirement that is still, a decade and several iterations of 3-D technology later, a technical and often site-specific challenge. Working with her colleagues to meet this challenge was generative for Sumner over time; and it is worth quoting her at length to illustrate the indirect

6. Myers and Dumit (2011, p. 240).

7. *Ibid.*

8. Swartly (2011).

9. Neff (2010, p. 275).

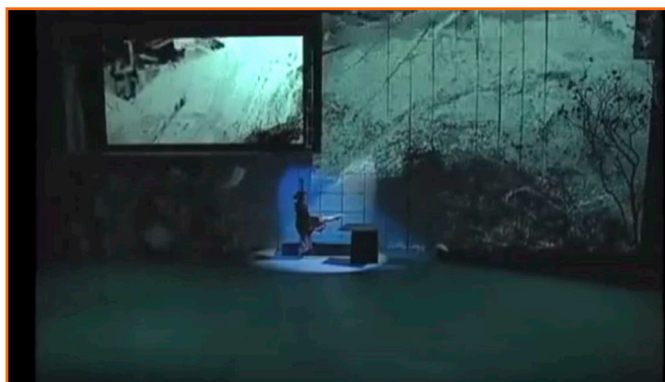


Figure 2. Sideshow Physical Theater, *Collapse (suddenly falling down)*, performance at the University of California, Davis, 2007.

benefits to her research as she understood it at the time and then again years later, after there had been more time to put the information gained from the experience directly into practice.

For a paper for the interdisciplinary journal *Leonardo* describing the collaboration, she wrote, “The *Collapse* collaboration expanded my view of my own data, even though these data were not integrated into the performance. I gained a new appreciation of the importance of viewpoint and motion for understanding spatial relationships, and of perspective and communication for personal relationships. The collaboration led to a desire to present scientific ideas in new ways and with interactions designed by artists. Integrating artistic sensibilities into scientific data interpretations and presentations provides deeper insights on many levels”.<sup>10</sup>

In 2017, she wrote, “Several things came out of *Collapse*. First was the ability to program a series of views and to jump to specific saved viewpoints. That was programmed for the performance. We have since expanded on it greatly, using it for both research and teaching. For research, you can return to a specific place reliably, which allows much more detailed comparisons and revisiting/testing prior interpretations. Second, drawing tools were developed for a specific scene during tech rehearsals. That tool allows scientists to annotate their data in the CAVE, too. [And] from our collaboration, we can now display multiple data types and manipulate data objects independently...”<sup>11</sup>

## The Second Proliferating Collaboration: *Dream Vortex*

When artist Meredith Tromble first visited KeckCAVES in 2011, as part of “Expressing the CAVES”, she was captivated by the interactive projections. She followed up with a proposal for a virtual interactive art

installation in the CAVE based on the dreams of researchers. Sumner accepted it, becoming Tromble’s main collaborating partner, leading the technical development of the work. As the project came together, physicist Jim Crutchfield, whose students had created the Mycelia software for the CAVE that Sumner and Tromble were using, offered it a home at UC Davis’ Complexity Sciences Center (CSC), which has 3-D equipment for programming development, and provided additional programming. The project became part of the regular meetings of the Macroscopic Group, an interdisciplinary group writing code and creating interfaces to improve experiences with 3-D technology. Developing new programming techniques based on the KeckCAVES software developed by Oliver Kreylos, the group met at the CSC, exploring 3-D viewing technologies such as the Razer Hydra, Leap Motion, and Oculus Rift as they became available.

From 2011-2014, Tromble and Sumner worked with their collaborators to create the content and programming structure for the piece, which was envisioned as a vortex of dream drawings that one could step into, and then select and interact with a dream image. On the content side, the work involved explaining the project and developing relationships with researchers so that they would be willing to and interested in contributing dreams. This ongoing process involved short presentations on contemporary art exhibitions to the Macroscopic Group and many informal discussions about art with the researchers more generally.

On the programming side, this required adding a range of features to an existing, relatively simple network visualization program – in her initial proposal, Tromble had envisioned interactivity with images that was possible, but which the programming did not yet permit. The contrast between her vision and the existing capabilities was almost comic: at the start of the project, Mycelia could show links and nodes that could be rotated interactively in 3-D but it had no provision for images, although it was possible to insert text (figure 3). Sumner explored how Mycelia could be developed for the piece and identified the research questions. Christopher Ellison then added the ability to show images on the nodes and adapted the base program to give allow for a wider variety of angles and range of movements for the images. In the next stage, programmer Jordan Van Aalsburg, who was developing a Python wrapper that would allow non-expert programmers to more easily program for the CAVE, transitioned the project to another CSC-developed program, Vroom. The Vroom software was intended to enhance the expression of ideas in mathematics and theoretical physics. As Crutchfield said in a video about the project, “With the Python wrapper around all the visualization routines that were written for efficiency in more constrained languages, you can more easily express certain things. One of those expressions turned out to be the *Dream Vortex*”.<sup>12</sup>

10. *Ibid.*, p. 281.

11. Personal communication to the author, 1 September 2017.

12. Tromble *et al.* (2015).

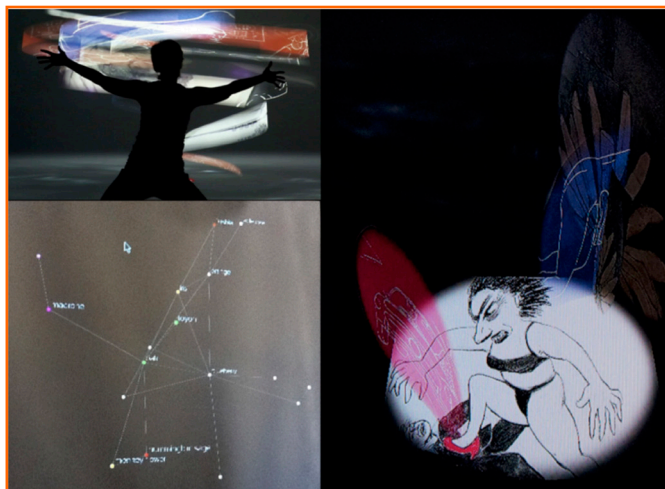


Figure 3. States of the *Dream Vortex*: Clockwise from lower left: First *Dream Vortex* prototype, 2011; Dream images from vortex arranged by viewer using Hydra Razer to interact with the vortex running on a 3-D monitor, 2014; choreographer Donna Sternberg improvising with a projection of the vortex at Mod Lab, UCD, 2015.

During this period, just as the collaboration was growing and drawing in more and more participants, the technology expanded. For two decades CAVEs had been the most effective and versatile virtual art installation environments, kinder to viewers than head-mounted displays that often caused nausea. However, due to the expensive and site-specific nature of the technology, CAVE artworks could not be exhibited or distributed through standard art channels. As a historical moment, the introduction of accessible 3-D virtual reality platforms, such as the Oculus Rift, is comparable to the advent of consumer video equipment in the 1970s, which triggered a wave of video art. Mobile virtual reality platforms now have a presence in general culture and in the art world. (For example, they sometimes appear in the work of prominent artists such as Carsten Höller, who used the Rift for an installation in his 2015 exhibition *Decision* at the Hayward Gallery in London; and they are often in the hands of young artists eager to explore new media.)

Van Aalsburg moved the *Dream Vortex* to beta versions of the Oculus Rift (OR) giving three potential platforms for the piece: CAVE, a 3-D Monitor or OR with gaming controls, demonstrating that the software originally developed for the CAVE could be available to researchers for use in mobile contexts and that the idea for the piece was adaptable to new platforms. By spring 2014, *Dream Vortex* incorporated content from more than twenty dreamers and was beginning to look like the first proposal drawing (figure 4). The artist's goal of exploring relationships between subjectivity, physicality, and objectivity, uniting a handmade visual aesthetic with digital capabilities, was becoming reality. In 2015, it was chosen as an exemplary interdisciplinary research project by a2ru, the

Association for Art in Research Universities. Sumner describes the scientific returns she has received from the on-going collaboration in terms of general creativity rather than technical advances, stating that, “[Tromble] envisions and sees things very differently than I do but it is a way that stimulates me to think about things differently”.<sup>13</sup>

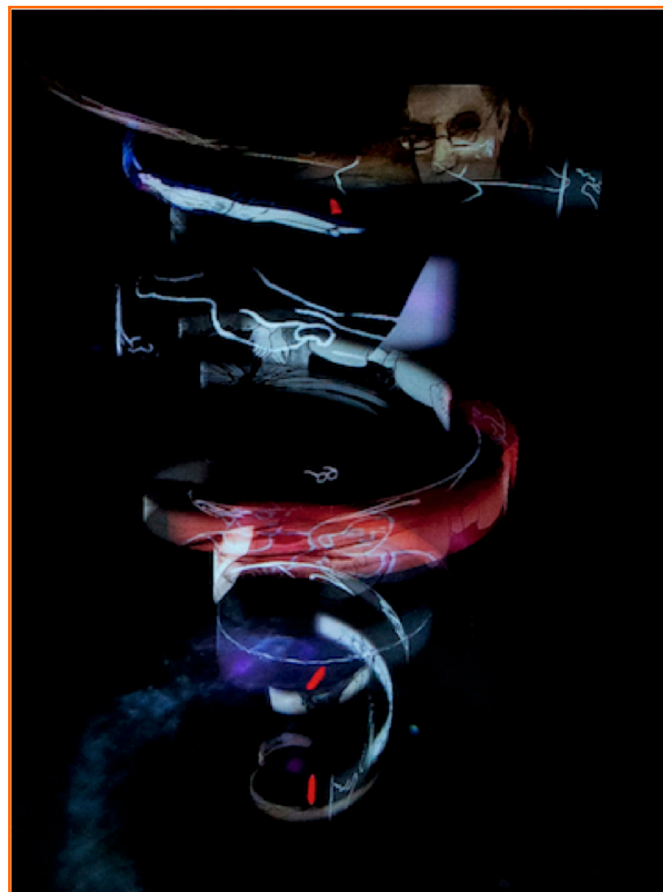


Figure 4. *Dream Vortex*, programming running on 3-D monitor, 2015.

### The Third Tangential Collaboration: *Life Extreme*

To call the video *Life Extreme*, the next artwork to emerge from the field of ideas and relationships encircling Sumner's research, “tangential” is not to diminish its value. Rather, it describes the new vector of collaboration invigorated by *Life Extreme*. Its maker, Philip Alden Benn, was already an accomplished film industry 3-D animator when he met Tromble through his MFA studies at the San Francisco Art Institute. Benn participated in a few CSC group meetings and remained in touch after his travelling for work stymied regular

13. *Ibid.*

participation. His artistic interests centre on the dialectic between nature and technology: during this period he was programming particle engines to ceaselessly recreate images of the natural world such as rocks and trees.

The dialectic between nature and technology is articulated in highly specific and practical ways in the Antarctic lake dives through which Sumner gathers data about microbial life in extreme conditions. Diving protocols are tightly regulated due to the dangers of blasting a hole in thick ice and entering cold, dark waters that have been isolated from the rest of the world for aeons. That isolation, in which single-celled organisms have existed undisturbed by multi-cellular predators, allows bacterial bodies to accumulate into humps and ridges that are visible to the human eye – forms reminiscent of fossil structures from early Earth. Sumner is among the first scientists to study them. The sober headline “Discovery of large conical stromatolites in Lake Untersee, Antarctica,” published by Sumner and her fellow researchers in the May 2011 issue of *Geobiology*,<sup>14</sup> did not deter the excitement of science news writers such as Andrea Witze, who headlined her *Wired Magazine* story, “Antarctic Lake Hides Bizarre Ecosystem”.<sup>15</sup> Explaining that the unusual shapes of the bacterial structures were informative, Sumner told Witze: “Everywhere else that we’ve looked you have a gradation between the structures... There’s something very special about this particular example that’s allowing these large conical stromatolites to form”.

Sumner’s research group returned to Antarctica in 2014 to work at another lake, resulting in another *Geobiology* paper, “Antarctic microbial mats: A modern analog for Archean lacustrine oxygen oases”.<sup>16</sup> In this paper, Sumner developed her analysis of the bacterial forms to consider the evolution of oxygenic photosynthesis. The analysis was informed and supported by detailed work in KeckCAVES measuring the underwater landscape captured on video by diver and researcher Tyler Mackey. Mackey also shot video especially intended for Benn, dispensing with the scale markers necessary for research purposes to provide Benn with an “unspoiled” view.

Benn’s dilemma as an artist was that the raw video was already mesmerizing due to the odd, filtered light and the strangeness of the bacterial “pinnacles” blanketing the lakebed. He made considered interventions to the video, focusing on speed and sound, to take viewers through the ice with the diver while enhancing the emotional impact of the experience. “In the process of editing the video”, he writes, “I slowed the footage down to subtly enhance the otherworldly effect that was inherently embedded in the raw footage. The quality of the audio recording, being muffled and watery to my ears is almost womb-like”.

In its straightforward focus on the research dive, the resulting 5:07 video,<sup>17</sup> *Life Extreme*, moves in a different direction than the other artworks Sumner has worked on. It is simultaneously more “about” her science and more removed from her direct action than the other collaborations. In Benn’s 2016 solo show at San Francisco’s Pacific Felt Factory, the work demonstrated the potential of imagery filled with scientific information to also convey artistic meaning.

## The Fourth Centrifugal Collaboration: *The Vortex*

Sumner’s investigation of life on early Earth had earned her a spot on the Mars Curiosity rover team. From 2012 onwards she worked on questions such as where to land and drive the rover, alongside her other ongoing research. Her intense workload meant that progress on her visualization research and collaborations with artists continued in fits and starts; when Tromble and Sumner were offered a spot on the first month-long art and science session at the Djerassi Resident Artist Program in the summer of 2014, they took it. As they worked on *Dream Vortex*, fellow resident and choreographer Donna Sternberg saw the interactive vortex and thought it would be an exciting movement environment. Simultaneously, ongoing discussions of creativity among the trio and other residents, including cognitive scientist Pireeni Sundaralingam and immunologist Devavani Chatterjea, revealed a number of stories about practicing science and encountering bias due to gender or race.

From those conversations a new project emerged, a dance performance simply titled *The Vortex*. It used the methodologies developed for *Dream Vortex* – stories and drawings feeding into a dynamic interactive vortex – augmented with sound, music, and choreography to tell true stories from the intersection of science and culture. The drawings captured iconic moments in stories from the historical record, such as those of biologist E.E. Just, physicist Lise Meitner, and mathematician Alan Turing, mixed with contemporary material collected with the consent and active support of the scientists involved. The experiences compressed in the imagery varied widely – for example, they might involve social invisibility, such as when researchers of South Asian heritage were repeatedly confused for each other, or when a distinguished astronomer was taken for a janitor, or hypervisibility, such as when the staff at an Antarctic base repeatedly called a female researcher “Princess” over the loudspeaker. The work gained momentum from controversies surrounding diversity in science that hit the news as the piece was developing. A tweet

14. Andersen *et al.* (2011).

15. Witze (2011). Visit: <<https://www.wired.com/2011/04/antarctica-lake-untersee/>>.

16. Sumner *et al.* (2015).

17. For a lo-res version of *Life Extreme* see: <<http://www.philipaldenbenn.com/life-extreme/>>.

from Sumner went viral during the gender controversy that erupted when California Institute of Technology professor Shrinivas Kulkarni told a National Public Radio interviewer that scientists were basically “boys with toys”.<sup>18</sup>

In the performance, which was presented publically in workshop form in 2015, and will be presented in final form by the Donna Sternberg Dancers in Los Angeles in spring, 2018, the audience sees colourful, projected fragments of story drawings arising from the floor. They swirl in a vortex towards the sky as a slightly ominous soundscape establishes the emotional tone. A dancer enters and the performance proceeds in four parts: Not Normal (being perceived as “different”), Not Right (being harassed), Ridiculous (micro-aggressions) and Breakthrough (persevering to achievement) (figure 5). At the beginning of each section, a dancer pulls a full projection of a story/drawing from the vortex to introduce the topic. The dance that interprets the theme is imaginative rather than illustrative, with pure movement and gesture conveying the emotional nuance of the drawn memory/stories. The choreographed sections are followed by an invitation to the audience to join the artists in dialogue mixed with interactive improvisation with the vortex. All the collaborators regard this discussion and interaction as an integral part of the work, an invitation to the audience to contribute, even for a few moments, to the discussions about human interaction that spiral outwards from the project.



Figure 5. Dancers, projections, and text of the audio from *The Vortex* workshop, Diavolo Theater, Los Angeles, 2016.

Although *The Vortex* contains a few direct references to both Sumner’s experiences of androcentric scientific culture and her discoveries, its relevance to her scientific practice is more general.

Even as she developed her collaborations with artists, Sumner was actively mentoring young female and nonwhite scientists and taking time from her packed schedule to talk to students in schools that are euphemistically referred to as “underserved”. Although she herself is white, in her childhood she lived on a Native American reservation and her memories are charged with vivid first-hand experiences of the negative chemistry of perceived social “difference”. Through the alchemy of ongoing creative work with artists, the focus of her collaborations moved from the initial technical exchanges and development, to appreciation for the aesthetic potential of her work, to incorporating and expanding the social concerns that she also expresses in her life as a scientist.

## Conclusion

This article presents the story of Sumner’s collaborations in sequence, demonstrating the potential of art and science teams. With the exception of *Collapse (suddenly falling down)*, at the time of writing all the works discussed continue to grow. Now that head-mounted 3-D viewers are becoming more widely available, the current form of *Dream Vortex* is being documented and the piece as a whole is being reworked for a gallery installation, freed from the site-specificity of its original technology. While *Life Extreme* is a finished work, Sumner’s collaboration with Benn continues and is currently in a “problem-seeking” state. Donna Sternberg & Dancers, with Tromble and Sumner, will work to tour *The Vortex* around research institutions and universities after its debut in Los Angeles.

In a summary evaluation of *Dream Vortex* for a2ru, computer scientist Michael Neff appraised the work as “likely to not only provide new insights, but also lead to new questions for the field to engage with”. He also wrote that, “The artistic and scientific work are in tension here, each mutually re-informing the other during an ongoing process of exploration and exchange. The work takes internal ideas – ranging from dreams to concepts of inclusion to software design – and makes them explicit and concrete so that people can interact and engage with them”.<sup>19</sup>

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Artist and writer Meredith Tromble has produced drawings, installations and performances for venues ranging from the Yerba Buena Center for the Arts and Southern Exposure in San Francisco, to the National Academy of Sciences in Washington, D.C. Her work has been presented at ISEA2015, Vancouver, at Creativity & Cognition, Glasgow School of Art, 2015, and at more than a dozen American universities ranging from Stanford University in Palo Alto to Brown University in Providence. Tromble's recent projects include an art installation created in collaboration with a neuroscientist at Gazzaley Lab, University of California San Francisco, and performance/lectures by "Madame Entropy". Her 2012 blog on contemporary art and science, "Art and Shadows", was supported by the Art Writers Initiative of the Andy Warhol Foundation. From 2000-2010 she was a core member of the artist collective Stretcher; and made flash "guerrilla" performances using a mechanism based on the research of biologist Larry Rome to generate electricity from the motion of her body.